THE CENTER FOR CLIMATE STRATEGIES

10-YEAR ENERGY ACTION PLAN MODELING

Greenhouse Gas Marginal Abatement Cost Curve Development and Macroeconomic Foundational Modeling for Oregon

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ACRONYMS AND ABBREVIATIONS

$/MWh	dollars per megawatt-hour
$/tCO$_2$e	quantify *cost effectiveness* when paired with GHG reductions
AEO	Annual Energy Outlook
AFW	agriculture, forestry and waste
AMI	advanced metering infrastructure
APTA	American Public Transportation Association
BAU	business-as-usual
Btu	British thermal unit
CCS	Center for Climate Strategies, Inc.
CEC	California Energy Commission
CFL	compact fluorescent light
CGE	computable generated equilibrium
CH_4	methane
CHP	combined heat and power
CO_2	carbon dioxide
DEQ	Department of Environmental Quality
DOE	Department of Energy
DOT	Department of Transportation
DSM	demand-side management
ECM	electronically commutated motor
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ES	Energy Supply
ETO	Energy Trust of Oregon
FCR	fixed charge rate
FOG	fats, oils and greases
GDP	gross domestic product
GHG	greenhouse gas
GIS	Geographic Information System
GPS	Global Positioning System
GWP	Global Warming Potential
ha	hectares
HDV	heavy-duty vehicle
HFC	hydrofluorocarbon
HVAC	heating, ventilation, and air conditioning systems
I&F	inventory and forecast
ILUC	Indirect Land Use Change
I-O	input-output
IPCC	Intergovernmental Panel on Climate Change
IRP	integrated resource plans
kW	kilowatt
LCFS	Low-Carbon Fuel Standard
LDV	light duty vehicle
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LFG	landfill gas
LPG	liquefied petroleum gas

ME	macroeconometric
$MMtCO_2e$	Million Metric Tons Carbon Dioxide Equivalent
MP	mathematical programming
MSW	municipal solid waste
MW	megawatt
MWa	average megawatt
MWh	megawatt-hours
N_2O	nitrous oxide
NI	nitrification inhibitors
NMOC	non-methane organic compounds
NPCC	Northwest Power and Conservation Council’s
NPV	net present value
NREL	National Renewable Energy Laboratory
NSPS	new source performance standards
O&M	operating and maintenance
ODOA	Oregon Department of Agriculture
ODOE	Oregon Department of Energy
OGWC	Oregon Global Warming Commission
PA	precision agriculture
PFC	perfluorocarbon
PGE	Portland General Electric
PI+	Policy Insight Plus
PNNL	Pacific Northwest National Laboratory
PS	Power Supply
PUD	Public Utility District
PV	photovoltaic
RCI	residential, commercial, and industrial
REMI	Regional Economic Models, Inc.
REG	recovered energy generation
RPS	renewable portfolio standard
RS	rotation schedules
RTF	regional technical forum
RZ	riparian zone
SF_6	sulfur hexafluoride
T&D	transmission and distribution
tCO_2e	metric tons
TJ	electricity and terajoules
TLU	transportation and land use
TRC	total resource cost
TriMet	Tri-County Metropolitan Transportation District of Oregon
USDOE EIA	US Department of Energy’s Energy Information Administration
USFS	United States Forest Service
VAR	volt-ampere-reactive
VAV	variable air volume
WTG	wind turbine generator
WWTP	wastewater treatment plant

CHAPTER 1. INTRODUCTION

1.1 Overview

This report summarizes the results of a project initiated by the Oregon Department of Energy (ODOE), which contracted with the Center for Climate Strategies, Inc. (CCS) to develop information and tools to assist in developing the Oregon Ten Year Energy Action Plan; this work is not an analysis of the Ten Year Energy Action Plan (in either draft or final form).

This project involved the following two primary components:

- Marginal Abatement Cost Curves for GHG Mitigation Measures: Development of a set of marginal abatement cost curves for GHG mitigation measures across all sectors, constructed using Oregon-specific data and analysis wherever possible; and
- Foundational Modeling: Using the marginal abatement cost curve results, along with other necessary components, to conduct preliminary baseline macroeconomic modeling to estimate the potential economic growth and job impacts of GHG emissions reduction measures, which will serve as a foundation for future policy analysis and potential additional modeling related to the Ten Year Energy Action Plan.

The remainder of this section provides an overview of the results of the work completed on each of these two components. Section 2 of this report provides a summary of the analytical methods, data sources, and assumptions used in preparing this analysis, as well as the limitations of the application of these measure analyses, and a presentation of the marginal abatement cost curve results themselves. Section 3 provides a summary of the analytical methods, data sources, and assumptions used, and of the limitations of, and results from the foundational macroeconomic modeling task. Appendices A through D provide brief descriptions and documentation of how the emission reductions and cost estimates were prepared for each measure or group of measures evaluated in each of the four sectors: Power Supply (PS), Residential, Commercial and Industrial (RCI), Transportation and Land Use (TLU), and Agriculture, Forestry and Waste (AFW). The GHG mitigation measures developed for each of the four sectors provide economy-wide coverage for Oregon. Appendix E provides documentation of the overarching analytical methods followed for quantifying the emission reductions and costs of measures (i.e. microeconomic analysis). Appendix F provides a summary of files delivered to ODOE for this project.

1.2 Marginal Abatement Cost Curves for GHG Mitigation Measures

The primary objective for this work component was to assemble GHG mitigation measure-level emissions reduction and cost data using a common set of metrics and analytical methods with an emphasis on using Oregon-specific data whenever possible to enable the comparison of measures. Table 1 shows the total number of measures (and in the case of RCI, groups of measures) by sector included in the analysis.

Emissions reductions were estimated based on both a “direct emissions” and a “full energy-cycle" (upstream) emissions basis incremental to Oregon’s GHG emissions forecast. For each measure, costs and emission reductions were estimated from the first year of implementation (2013 for most measures) through 2022 (in accordance with the Ten Year Energy Action Plan timeline) and from 2013 through the end point of the analysis (i.e., 2035). Costs were adjusted to 2010 dollars for both time periods.

Table 1. Number of GHG Mitigation Measures Analyzed by Sector

Sector	Number of Measures Analyzed
Power Supply (PS)*	26
Residential, Commercial, and Industrial (RCI)	136
Transportation and Land Use (TLU)	37
Agricultural, Forestry and Waste (AFW)	13
Total	**212**

* For the PS sector a total of 32 measures were analyzed. Five of the measures were advanced natural gas-fired generation which had energy-cycle emission rates that were higher than the avoided system electricity emission rate. Therefore, they were not included in the cost curve analyses. One additional measure, enhanced geothermal, was excluded from the cost curve analysis because of a lack of reliable cost and performance indicators for the measure.

In addition, emissions reduction and cost data for each measure were developed for the following three scenarios in order to evaluate the potential, when the measures are considered together within a scenario, for reducing statewide emissions toward achieving Oregon's GHG reduction goals:

- Scenario 1 (Modest Effort, Continued State and Federal Policies): Represents the continuation of state and federal policies and action at approximately current levels.
- Scenario 2 (Moderate Increase in Federal Action): Represents increased Federal action, relative to Scenario 1 (i.e., the level of state effort remains the same as in Scenario 1). This analysis uses recently proposed legislation as models to estimate the effect of new Federal policy in Oregon.
- Scenario 3 (Moderate Increase in Federal Action plus additional State Action): Represents a moderate increase in both Federal and State programs, relative to Scenario 1 and Scenario 2. The moderate state action component of this scenario represents a hypothetical collection of policy and program actions representative of historical and proposed best practice at the state energy and climate policy level. It is not necessarily a representation of the Ten Year Energy Action Plan, although because many of the proposed elements of the Plan have been vetted in other policy venues there may be similarities in some cases.

1.3 Marginal Abatement Cost Curve Uses and Limitations

The marginal abatement cost curves developed under this project and presented in Chapters 2 and 3 of this report map the GHG emissions reduction potential relative to the cost of abatement (over a specified time interval) for a range of GHG mitigation measures or policies in accordance with established economic analytical methodologies for marginal abatement cost curve development. The cost curves are constructed by plotting the cost per ton of GHG emissions reduced on the Y-axis and the amount of GHG emissions reduced on the X-axis for each mitigation measure, arranged such that the order begins with the most cost-effective measures (i.e., those measures with the lowest, or in this case, most negative, cost per metric ton of carbon dioxide equivalent emissions abated by a measure) and continues cumulatively along the X-axis ending with the least cost-effective measures (i.e., those with the highest cost-effectiveness values).

For the purpose of this project, marginal cost curves are used to organize and present "stand-alone" measure-level data for comparison purposes only. The following identifies key potential limitations on the interpretation of the cost curve results:

- The measure-level results have not been adjusted for overlaps between measures (e.g., the majority of the PS measures have interactions and overlaps with the RCI measures). The cumulative emissions reductions associated with a group of measures that included overlapping measures would be overstated.
- In some cases, measures may be mutually exclusive; meaning that implementation of one measure will exclude the implementation of another measure. This would occur, for example, if the impacts of two different wall insulation measures, one more stringent than the other (but both more stringent than baseline conditions), were to be applied in the same housing market. The CCS team has generally avoided such situations by assuming different fractions of markets were addressed in cases where two or more measures could potentially be applied in the same markets.
- The method by which a measure is implemented and financed has a significant impact on measure costs (from the perspective of the State of Oregon), and on the emissions reduction and cost effectiveness achieved. The assumptions used for the analysis of measures in this report may be quite different from how policy makers ultimately decide to implement a measure. Consequently, measures that are ranked higher than others on the cost curves should not necessarily be eliminated from consideration for further analysis.
- The cost curve does not (and cannot) reflect other measure attributes that may be very important in determining which measures are appropriate for implementation. For example, a measure may have important impacts on local air quality, other environmental benefits, or social issues (e.g., insulation of homes of low-income residents) that may not be readily captured by a strict cost-and-emissions-reduction comparison.
- The net costs shown in the cost curves are, in some cases (e.g., many RCI measures) very dependent on the balance between measure costs—including capital and operating and maintenance costs—and direct measure benefits, including reduction in electricity and gas costs, reduction in water costs, and/or enhancement of worker productivity. How these costs and benefits are evaluated, including, for example, the future trajectories of electricity and gas avoided costs, or of measure costs themselves, may have a significant impact on the cost-effectiveness shown for a given option on the curve.
- It is important to note that the development of the economy-wide cost curve does not imply that each measure/technology is completely independent of every measure/technology. For example, the effectiveness of high-efficiency air conditioning equipment is dependent on whether the building shells in which the equipment will operate are efficient.
- Technology learning was not accounted for in the analysis. That is, the cost curves assume that market conditions in Oregon are homogeneous such that the cost of deploying the first 10% of the measure/technology is the same as the cost of deploying the last 10%. This may or not be the case. For example, photovoltaic panels are benefitting from economies of scale and fabrication improvements, which may lead to future capital costs that are far lower than today's capital costs, if past experience is any guide.

- It is important to also note that the cost curves assume that new measures/technologies are perfect substitutes and that the quality of service and the risks of adopting new technologies are identical to those associated with the measure/technology that is being replaced. This may or not be the case. For example, there may be tradeoffs between electric vehicles and conventional light duty vehicles (e.g., reduced range, performance differences) which may discourage consumers other than early adopters.

1.4 Foundational Modeling

Although the primary focus of this project was on the construction of comprehensive GHG marginal abatement cost curves customized for Oregon, a secondary goal was to conduct foundational work to provide initial modeling to establish baseline macroeconomic information and illustrative scenarios of potential policy impacts using the GHG marginal abatement cost curves. The intent of this initial work is to provide a foundation for future policy analysis and additional modeling to inform the Ten Year Energy Action Plan. This work is not a macroeconomic modeling analysis of the Ten Year Energy Action Plan, in either its draft form (released in June of 2012) or the final version (which has yet to be completed).

The foundational macroeconomic modeling analysis was conducted using the Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI+) 169 Sector Model and the GHG marginal abatement cost curve data to estimate the following potential impacts of the measures included in the cost curves with respect to:

- Economic growth, or change in Gross State Product (GSP) by year
- Employment (job creation or losses)
- Personal Income
- Government revenues

The foundational macroeconomic modeling was conducted for the forecast scenarios below to estimate potential net impacts on state GDP, jobs, industry, and other key macroeconomic indicators. The two time periods used for the macroeconomic modeling were first, through the end of 2022 (in accordance with the Ten Year Energy Action Plan timeline) and, secondly, through 2035 (i.e., at the end point of the assessment) as measures of where the state will be at that point on the path toward meeting Oregon's 2050 emission reduction goals. The forecast scenarios incorporated in the macroeconomic analysis were:

- Business-as-Usual (BAU) forecast for Oregon
- Forecast of Oregon's renewable portfolio standard (RPS) (http://oregon-rps.org) as it is currently formulated, i.e., assuming no changes in policy or structure in the future.
- A least-cost forecast using the marginal abatement cost curve results each for Scenario 2 and Scenario 3. For both of these scenarios, model runs were completed for the set of measures needed to meet Oregon's 2020 GHG reduction goal and the set of measures that would reduce statewide emissions in 2035 to keep Oregon on the path to meet the state's 2050 GHG reduction goal. To determine the mitigation measures to be included for each model run, the measures were selected from the cost curve starting with the most cost-effective measures and then moving up the curve until the cumulative emission reductions from the measures met the 2020 GHG reduction goal and met the reductions needed in 2035 to stay on the

trajectory toward the 2050 GHG reduction goal. As described further below, use of obvious overlapping measures in the foundational modeling analysis of Scenario 2 and Scenario 3 were avoided; however, a complete analysis of measure interactions and overlaps was not possible given the time and resource constraints associated with this project. Thus, it important to note the uncertainty here related to the use of these cumulative emission reductions for a list of measures for which a comprehensive assessment has been completed to fully account for all interactions and overlaps.

For Scenario 2, the combined emission reductions for all of the measures did not meet the reductions needed for the 2020 goal nor the 2050 goal; therefore, one foundational modeling run was conducted for all of the measures. For Scenario 3, two model runs were completed, one for subset of measures with combined emission reductions that could reach the 2020 goal and a second run for the subset of measures with combined emission reductions that could reach the reductions needed by 2035 to stay on the path to the 2050 goal.

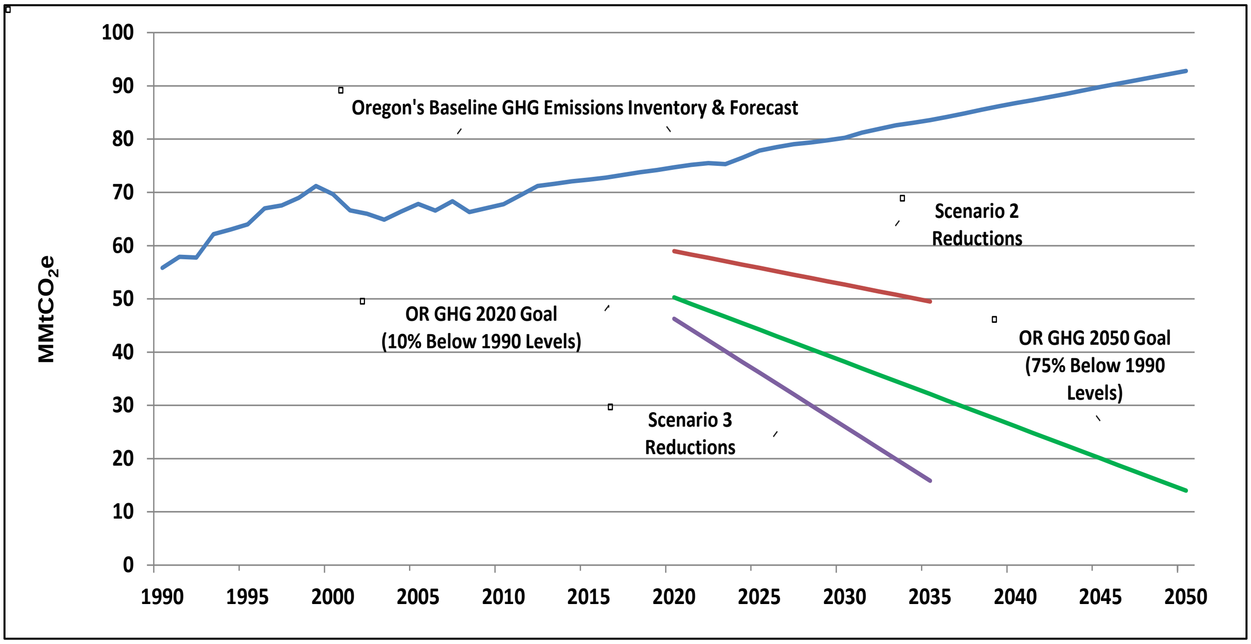
1.5 Comparison of Cost Curve Results to Oregon's GHG Reduction Goals

Oregon's conventional GHG emissions inventory and forecast is based on direct emissions. Oregon's GHG reduction goals are: 10% below 1990 levels by 2020, and 75% below 1990 levels by 2050. As previously noted, measure-level data were developed both on a "direct emissions" and a "full energy-cycle" (upstream) emissions basis. Assessing the direct emission reductions for measures enables one to compare the potential contribution of a measure or combination of measures (after adjusting for overlaps) toward achieving Oregon's GHG reduction goals in a manner consistent with past analyses of progress towards achieving the goals (e.g., Oregon Global Warming Commission reports). When comparing the emissions reductions and costs of measures; however, use of full energy-cycle emissions reductions and costs is important to incorporate the indirect (or upstream) impacts associated with the measures. Thus, full energy-cycle emissions reductions and costs were used for the marginal abatement cost curves presented in Chapter 2.

For the foundational modeling of Scenario 2 and Scenario 3, an effort was made to remove double-counting of emission reductions and costs associated with PS measures that overlap with RCI measures; as well as overlaps between AFW measures prior to conducting the modeling. However, future work should include a more thorough measure by measure evaluation of overlaps and adjustments, if needed, to avoid potential double counting of emissions reductions and costs.

The direct emissions reductions associated with these two scenarios, after adjusting for overlaps, were compared to Oregon's baseline emission inventory and forecast and to Oregon's GHG reduction goals. Figure 1 presents the preliminary results of this comparison. The preliminary results suggest that Oregon is in a position to reach its GHG reduction goals but may require the state to implement measures that go beyond a moderate increase in federal action. The reader is cautioned in that these are preliminary results and are designed to provide a starting point for policy makers to evaluate a wide range of measures for achieving Oregon's goals.

Figure 1. Comparison of Two GHG Reduction Scenarios to Oregon's Baseline Emissions Forecast and GHG Reduction Goals



CHAPTER 2. GREENHOUSE GAS MARGINAL ABATEMENT COST CURVE COMPONENTS

2.1 Introduction

This chapter provides in Section 2.2 an overview of the process and methods used to develop the cost and GHG emissions reduction results for the Oregon-specific measures included in marginal abatement cost curves prepared for the PS, RCI, TLU, and AFW sectors. Section 2.3 presents the marginal abatement cost curve results in graphical and tabular formats for each of three scenarios for all of the sectors combined, and Section 2.4 presents the marginal abatement cost curve results for each sector in graphical format for each of the three scenarios. Section 2.5 presents the marginal abatement cost curve results in graphical and tabular formats that were developed to support the foundational macroeconomic modeling of the least-cost forecasts for Scenario 2 and Scenario 3 presented in Chapter 3.

For each mitigation measure within each sector, emissions reduction and costs/savings data were developed for the following three scenarios in order to evaluate the potential of the measures, when considered together within an internally-consistent policy scenario, for reducing statewide emissions, and for making progress toward achieving Oregon's GHG reduction goals:

- Scenario 1 (Modest Effort, Continued State and Federal Policies): Represents the continuation of state and federal policies and action at approximately current levels.
- Scenario 2 (Moderate Increase in Federal Action): Represents increased Federal action, relative to Scenario 1 (i.e., the level of state effort remains the same as in Scenario 1). This analysis uses recently proposed legislation as models to estimate the effect of new Federal policy in Oregon.
- Scenario 3 (Moderate Increase in Federal Action plus additional State Action): Represents a moderate increase in both Federal and State programs, relative to Scenario 1 and Scenario 2. The moderate state action component of this scenario represents a hypothetical collection of policy and program actions representative of historical and proposed best practice at the state energy and climate policy level. It is not necessarily a representation of the Ten Year Energy Action Plan, although because many of the proposed elements of the Plan have been vetted in other policy venues there may be similarities in some cases.

For each measure, costs and emission reductions were estimated from the first year of implementation (2013 for most measures) through 2022 (in accordance with the Ten Year Energy Action Plan timeline) and from 2013 through the final year of the analysis (i.e., 2035). Costs were adjusted to 2010 dollars for both time periods.

2.2 Process and Methods

At the beginning of the project a memorandum was prepared on the "Guidelines and Common Methods & Data for Micro-Economic Analysis" to be followed in developing GHG emissions reduction measure data and processing those data to produce Oregon-adapted cost and performance estimates for all mitigation measures. The memorandum is provided as Appendix E to this report. In addition, an Excel workbook file was developed containing data (e.g., avoided fuel costs, emission factors, and demographic forecasts and other information) to be used as inputs to analyses across sectors. This information was developed in consultation with ODOE to ensure that the most recent Oregon-specific data were identified for this project effort.

The following summarizes the steps followed to identify and quantify the emission reductions and costs/savings for the mitigation measures covered in this report.

1. Identified, collected, and reviewed all key sources of data available and specific for Oregon (or, if not available for Oregon, for a region representative of Oregon), and summarized the extent, types, and forms of cost-curve related data available. This effort included collecting required input data to construct baselines for the mitigation measures such as the current inventory and forecast available for Oregon.
2. Reviewed the listing of measures compiled, with input from ODOE and other Oregon experts, as well as based on the CCS team members' experience, to identify any gaps in measure coverage. Where data gaps existed, additional data were identified as needed to support development of emission reductions and costs/savings estimates. The listing of measures was then finalized based on input from ODOE.
3. Data for each measure were collected and reviewed for completeness and organized in Excel workbook files to develop emissions reductions and costs/savings following the guidelines and principals (see Appendix E) developed for the project to adopt and adapt measure information to a consistent format (e.g., using consistent cost years, discounting protocols, emission factors, avoided fuel costs, and means of comparison of emissions reduction measures with corresponding standard practices). This information was used in deriving the inputs needed for multi-measure GHG marginal abatement cost curves, as well as other inputs needed for the macroeconomic analysis of those measures. For the RCI and TLU sectors, where appropriate, measure "bundles" including multiple measures were developed to calculate the aggregate emissions and weighted-average bundle costs/savings for use in more aggregated cost curves.
4. Prepared documentation of each measure or set of measures in a standard template that includes the following (the documentation of measures is provided in Appendices A through D):
    - Brief description of the measure (or bundle of measures);
    - Measure design specifications and data sources for each scenario (goals/level of effort and action scenarios, timing (start, phase in, end));
    - Parties involved with implementing and parties affected by implementation of the measure;
    - Data Sources and additional background information; and
    - Estimated net GHG emissions reductions and net costs/savings, (summary of analysis results, quantification methods) and key assumptions and uncertainties).
5. Prepared an Excel workbook file containing the emissions reductions, costs/savings, and cost-effectiveness inputs for preparing the marginal abatement cost-curve results and related macroeconomic modeling framework inputs using the data collected and the methods developed in earlier steps, iterating as needed in consultation with ODOE and others to assemble a comprehensive package of results for all measures. Prepared the marginal abatement cost curves in the file along with the tabular summary of data supporting each cost curve.
6. Coordinated with ODOE to identify measures for inclusion in the foundational macroeconomic modeling analysis to adjust for obvious and significant overlaps between

measures (e.g., between PS measures and RCI electricity demand impacts) to remove double-counting of emission reductions and costs/savings.

2.3 Marginal Abatement Cost Curves by Scenario

For each of the three scenarios described above, this section provides a separate marginal abatement cost curve each for each of two reporting years: 2022 and 2035. The marginal abatement cost curves presented in this section map the GHG emissions reduction potential relative to the net cost of abatement for all of the GHG mitigation measures or policies considered in this analysis in accordance with established economic analytic methodologies for marginal abatement cost curve development. The cost curves are constructed by plotting the cost per ton of GHG emissions reduced on the Y-axis, and the amount by which annual GHG emissions have been reduced by the target year (in this example, by 2022) on the X-axis, with data points for each mitigation measure arranged such that the order begins with the most cost-effective measures (those measures with the lowest, or in this case, most negative, cost per metric ton of carbon dioxide equivalent emissions abated) and continues cumulatively along the X-axis ending with the least cost-effective measures (those with the highest cost-effectiveness value). The width of the bar on the X-axis—that is, each horizontal step—corresponding to each measure represents the amount of emission reduction associated with that measure.

The emissions reductions and cost-effectiveness values used to develop the cost curves are based on full energy-cycle emissions reduction estimates, meaning that the emissions reductions reported include not only the direct GHG emissions avoided, for example, when a fuel is consumed in a vehicle or water heater, but also the emissions avoided by not producing and transporting that fuel to the end user. The values used for the X-axis represent annual emissions reductions for 2022 and 2035. The values used for the Y-axis represent the average cost-effectiveness (dollars per ton of CO_2e emissions avoided) based on cumulative costs/savings for each individual measure divided by cumulative emission reductions for each measure for the period 2013 through 2022 for the 2022 cost curves (or 2013 through 2035 for the 2035 cost curves). As previously discussed, the cost curves presented in this section have not been adjusted for overlaps between sectors so that results for measures in each sector can be compared on a consistent basis. The reader is referred to Chapter 1 for discussion on the uses and limitations to the uses of these cost curves.

2.3.1 Scenario 1 (Modest Effort, Continued State and Federal Policies)

Figures 2 and 3 provide the marginal abatement cost curves prepared as above for Scenario 1 for the years 2022 and 2035. Tables 2 and 3 provide the emissions reduction and cost-effectiveness values for the measures included in the cost curves in Figures 2 and 3. Table 4 identifies measures included in the overall cost curves analysis but not included in the marginal abatement cost curve for Scenario 1 either because there are no emissions reduction and cost data available for the measure, because the measure was assumed not to be implemented under Scenario 1 (because its implementation was not consistent with the policy assumptions driving the overall scenario), or because the measure results in an emissions increase.

A total of 187 measures are each included in the cost curves for Scenario 1 and Scenario 2, and 212 measures are include in the cost curve for Scenario 3. Because of the large number of measures included in each cost curve, the charts became too congested when labels were added to identify all of the measures on the charts. To address this issue, the measure labels included in the cost curve charts identify the five measures for each sector with the largest annual GHG emissions reductions. The tables containing the measure level data used to develop the cost curves identify the columns containing the values that correspond to the X-axis and Y-axis on the charts.

Figure 2. Marginal Abatement Cost Curve for Scenario 1, Year 2022

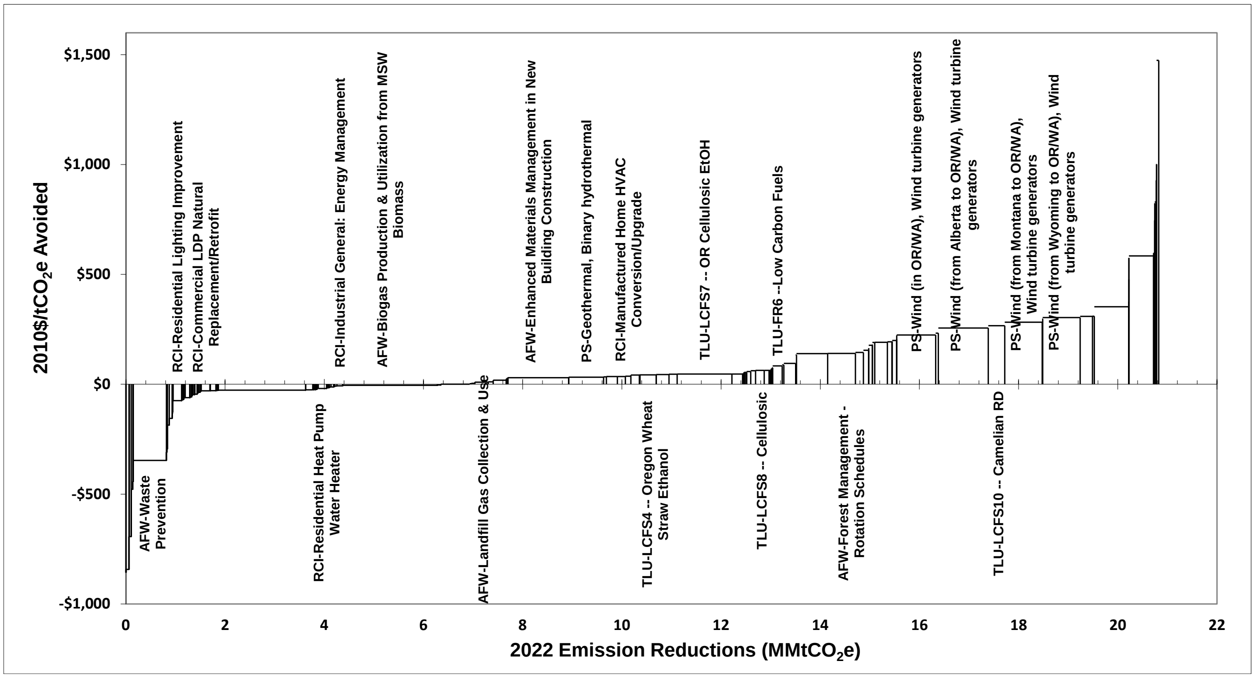


Figure 3. Marginal Abatement Cost Curve for Scenario 1, Year 2035

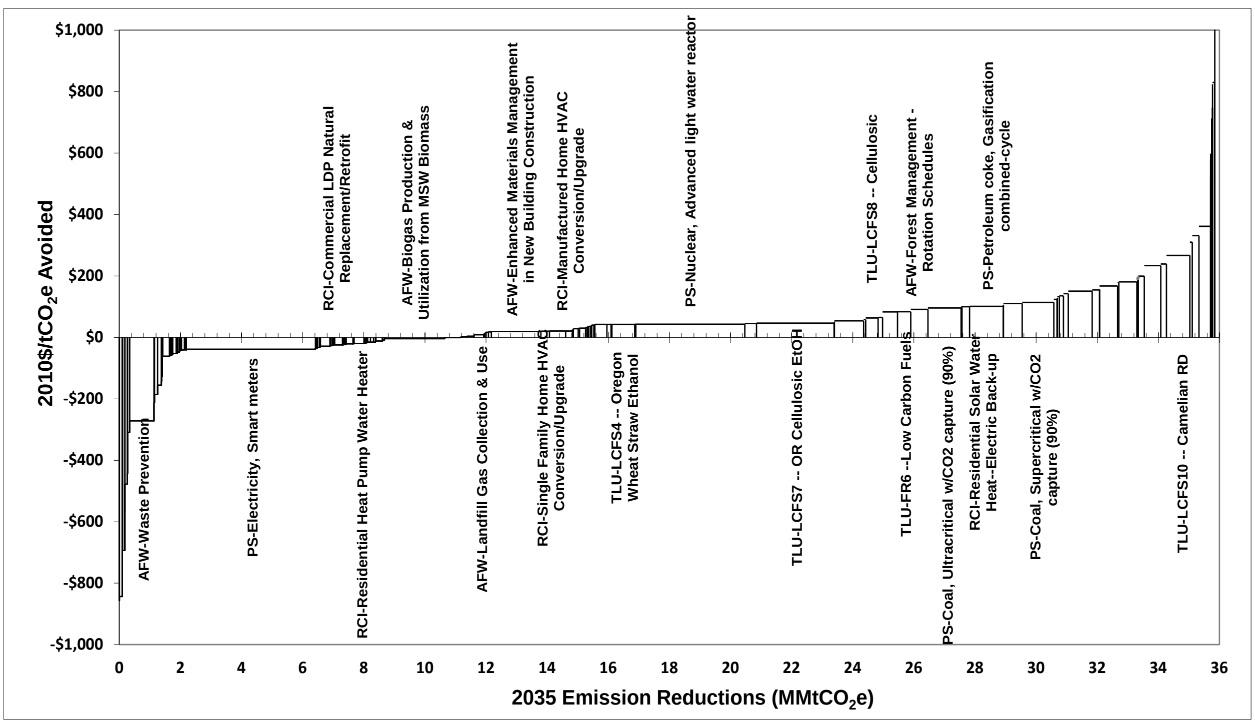


Table 2. Marginal Abatement Cost Curve Results for Scenario 1, Year 2022

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
TLU-37	LD10 -- Carsharing	0.002	0.002	0.009	-$8	-$857
TLU-31	LD4 -- PAYD	0.059	0.061	0.147	-$124	-$843
TLU-29	LD2 -- Walk/Bike Short SOV mode shift	0.008	0.069	0.031	-$22	-$693
TLU-34	LD7 -- Parking Management	0.035	0.104	0.134	-$93	-$693
TLU-25	FR4 -- More Energy Efficient Transporter Operations	0.034	0.138	0.408	-$195	-$477
TLU-32	LD5 -- TDM	0.009	0.147	0.031	-$14	-$442
AFW-10	Waste Prevention	0.669	0.816	3.512	-$1,218	-$347
TLU-35	LD8 -- Externality Taxes	0.012	0.828	0.031	-$10	-$309
RCI-73	Commercial Clothes Washer	0.008	0.836	0.036	-$11	-$294
TLU-33	LD6 -- EcoDrive	0.037	0.873	0.099	-$18	-$185
TLU-8	TL8 -- Land Use	0.056	0.929	0.670	-$104	-$156
TLU-24	FR3 -- Idle Reduction Strategies	0.003	0.933	0.041	-$6	-$143
RCI-86	Commercial Laundry Equipment--Gas	0.000	0.933	0.000	$0	-$142
TLU-22	FR1 -- Land Use Policy Changes	0.003	0.936	0.041	-$5	-$133
RCI-123	Industrial Agriculture Irrigation Improvements	0.009	0.945	0.042	-$5	-$125
RCI-66	Commercial Exit Signs	0.003	0.948	0.011	-$1	-$75
RCI-71	Commercial Ice-Maker Improvements	0.004	0.951	0.015	-$1	-$75
RCI-16	Residential Lighting Improvement	0.171	1.122	1.096	-$82	-$74
RCI-120	Industrial Lumber Conveyor Replacement	0.007	1.130	0.036	-$3	-$73
RCI-129	Industrial Weatherization Measures	0.008	1.137	0.040	-$3	-$70
RCI-128	Industrial Space Heating Measures	0.015	1.153	0.082	-$6	-$70
RCI-127	Industrial Hot Water Measures	0.008	1.161	0.044	-$3	-$69
RCI-126	Industrial Boiler Measures	0.007	1.167	0.035	-$2	-$69
TLU-23	FR2 -- Urban Traffic Congestion Relief	0.007	1.174	0.082	-$5	-$63
RCI-76	Commercial Heat Pump Water Heater	0.013	1.188	0.063	-$4	-$62
RCI-87	Commercial Cooking Equipment--Gas	0.004	1.192	0.021	-$1	-$61
RCI-38	Commercial Windows New/Integrated Design	0.001	1.192	0.002	$0	-$61
TLU-26	FR5 -- Mode Shift of Freight in Response to Higher Fees	0.095	1.287	1.143	-$70	-$61
RCI-45	Commercial Package Rooftop Measures New/Integrated Design	0.003	1.290	0.011	-$1	-$61
RCI-110	Industrial Electronics Clean Room Measures	0.001	1.291	0.003	$0	-$60
RCI-118	Industrial Kraft Pulp Measures	0.004	1.294	0.017	-$1	-$60
RCI-116	Industrial Metals Arc Furnace	0.000	1.294	0.001	$0	-$59
RCI-102	Industrial General: Lighting and	0.030	1.324	0.142	-$8	-$58

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
	Controls					
RCI-89	Commercial Insulation Measures--Gas Heat	0.005	1.329	0.026	-$1	-$53
RCI-44	Commercial Variable Speed Chiller New/Integrated Design	0.001	1.329	0.003	$0	-$52
RCI-75	Commercial Hot Water Efficiency Measures	0.001	1.330	0.004	$0	-$51
RCI-113	Industrial Fruit Storage Measures	0.008	1.338	0.037	-$2	-$51
TLU-30	LD3 -- ITS &Operations	0.003	1.341	0.008	$0	-$49
RCI-26	Residential Gas Heat Windows	0.014	1.354	0.075	-$4	-$48
RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	0.028	1.382	0.134	-$6	-$47
RCI-93	Commercial Insulation Measures--Gas	0.001	1.384	0.007	$0	-$47
RCI-24	Residential Gas Furnace Upgrade	0.009	1.392	0.047	-$2	-$46
RCI-131	Industrial Biomass-fired CHP	0.044	1.436	0.183	-$8	-$45
RCI-34	Commercial LDP New/Integrated Design	0.014	1.450	0.052	-$2	-$41
RCI-114	Industrial Food Storage Measures	0.001	1.451	0.003	$0	-$39
RCI-121	Industrial Wood Panels Hydraulic Press	0.000	1.451	0.002	$0	-$39
RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	0.002	1.453	0.008	$0	-$39
RCI-117	Industrial Mechanical Pulp Measures	0.002	1.455	0.009	$0	-$39
RCI-88	Commercial Hot Water Measures--Gas	0.004	1.459	0.020	-$1	-$37
RCI-52	Commercial Insulation Natural Replacement/Retrofit	0.029	1.488	0.129	-$5	-$37
RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	0.013	1.501	0.061	-$2	-$35
RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	0.003	1.504	0.013	$0	-$33
RCI-103	Industrial General: Motors Measures	0.004	1.508	0.018	-$1	-$31
RCI-132	Industrial Digester Gas-fired CHP	0.010	1.518	0.039	-$1	-$31
RCI-48	Commercial LDP Natural Replacement/Retrofit	0.176	1.694	0.833	-$25	-$30
RCI-112	Industrial Cold Storage Measures	0.008	1.702	0.038	-$1	-$30
AFW-3	Nutrient Management	0.111	1.813	0.609	-$18	-$29
RCI-61	Commercial Computer/Server Improvements	0.026	1.839	0.122	-$3	-$28
RCI-74	Commercial Wastewater Heat Exchanger	0.002	1.841	0.012	$0	-$28
RCI-106	Industrial General: Transformers	0.004	1.845	0.019	-$1	-$28
RCI-80	Commercial Solar Water Heat	0.007	1.853	0.035	-$1	-$28
RCI-62	Commercial Cooking/Food	0.010	1.863	0.037	-$1	-$27

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
	Service Improvements					
PS-30	Electricity, Smart meters	1.759	3.622	6.796	-$185	-$27
RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	0.001	3.623	0.003	$0	-$27
RCI-130	Industrial Gas-fired CHP	0.142	3.766	0.520	-$13	-$25
RCI-70	Commercial Refrigeration Improvements	0.014	3.780	0.057	-$1	-$25
RCI-99	Commercial Wood-fueled Space Heat Replacing Oil/LPG	0.000	3.780	0.002	-$0.05	-$25
RCI-111	Industrial Food Processing Measures	0.017	3.797	0.084	-$2	-$25
RCI-4	Manufactured Home Weatherization--Insulation	0.021	3.818	0.095	-$2	-$24
RCI-35	Schools Lighting Measures	0.011	3.829	0.052	-$1	-$24
RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	0.006	3.835	0.023	-$1	-$24
RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	0.017	3.852	0.062	-$1	-$23
RCI-83	Commercial Chiller Tower 6F Approach	0.003	3.855	0.012	$0	-$22
RCI-78	Commercial Economizer Measures	0.023	3.877	0.106	-$2	-$20
RCI-12	Residential Heat Pump Water Heater	0.169	4.046	0.735	-$14	-$19
RCI-79	Commercial Heat Reclamation Measures	0.000	4.046	0.002	$0	-$17
RCI-37	Commercial Lighting Controls New/Integrated Design	0.019	4.065	0.087	-$1	-$16
RCI-107	Industrial General: Materials Movement Measures	0.018	4.083	0.087	-$1	-$16
RCI-42	Commercial Demand Control Ventilation New/Integrated Design	0.004	4.088	0.019	$0	-$15
RCI-101	Industrial General: Air Compressor Measures	0.018	4.105	0.085	-$1	-$15
RCI-104	Industrial General: Fan Measures	0.033	4.138	0.158	-$2	-$12
RCI-11	Residential Electric Water Heat Efficiency	0.047	4.186	0.202	-$2	-$12
RCI-122	Industrial Agriculture Pump and Related Measures	0.023	4.209	0.112	-$1	-$11
RCI-33	Residential Wood-fueled Heat Replacing Oil/LPG	0.002	4.210	0.013	$0	-$10
RCI-28	Residential Multi-Measure Gas Heat	0.045	4.255	0.245	-$2	-$8
RCI-108	Industrial General: Energy Management	0.112	4.367	0.538	-$4	-$8
RCI-65	Commercial DVC Hood	0.005	4.372	0.023	$0	-$7
AFW-4a	Biogas Production & Utilization from MSW Biomass	1.905	6.277	8.010	-$37	-$5
RCI-58	Commercial Controls Commissioning HVAC Retrofit	0.072	6.349	0.357	-$1	-$4

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-39	Schools Building Envelope Measures	0.000	6.349	0.000	$0	-$2
PS-31	Electricity, Additional regulation & telecommunication services	0.004	6.353	0.000	$0	$0
PS-32	Electricity, Distribution system upgrades	0.578	6.930	0.000	$0	$0
RCI-109	Industrial Electronics Chip Fab Measures	0.003	6.934	0.017	$0	$1
RCI-105	Industrial General: Pump Measures	0.031	6.965	0.148	$0	$3
RCI-96	Commercial Gas-fired CHP	0.063	7.027	0.223	$1	$4
AFW-7b	Reforestation/Afforestation of Rangeland	0.006	7.033	0.031	$0	$6
RCI-36	Commercial Daylighting New/Integrated Design	0.003	7.036	0.012	$0	$9
AFW-5	Landfill Gas Collection & Use	0.267	7.304	2.034	$18	$9
PS-19	Waste heat, Bottoming Rankine cycle	0.103	7.407	0.807	$9	$11
AFW-2	Co-Digestion of Food Waste with Dairy Methane	0.260	7.667	1.573	$29	$18
RCI-97	Commercial Wood-fueled Space Heat Replacing Electric	0.001	7.668	0.002	$0	$20
RCI-115	Industrial Grocery Distribution Measures	0.003	7.671	0.014	$0	$21
RCI-84	Commercial Rooftop Condensing Burner	0.002	7.672	0.008	$0	$23
RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	0.002	7.674	0.006	$0	$24
RCI-32	Residential Wood-fueled Heat Replacing Electric Resistance	0.022	7.696	0.091	$2	$26
RCI-41	Schools HVAC	0.007	7.703	0.033	$1	$30
AFW-9	Enhanced Materials Management in New Building Construction	1.224	8.927	6.288	$188	$30
RCI-119	Industrial Paper Sector Measures	0.004	8.931	0.018	$1	$31
PS-8	Geothermal, Binary hydrothermal	0.699	9.630	3.699	$117	$32
RCI-9	Single Family Weatherization--Windows	0.060	9.689	0.282	$9	$34
AFW-1	Dairy Methane	0.219	9.908	1.342	$44	$35
RCI-3	Single Family Home HVAC Conversion/Upgrade	0.163	10.071	0.740	$26	$35
RCI-2	Manufactured Home HVAC Conversion/Upgrade	0.111	10.182	0.465	$17	$37
TLU-17	LCFS9 -- CNG from biogas	0.171	10.354	0.336	$14	$42
TLU-11	LCFS3 -- Imported Cellulosic Ethanol	0.012	10.365	0.012	$0	$42
TLU-12	LCFS4 -- Oregon Wheat Straw Ethanol	0.325	10.690	0.387	$16	$42
RCI-57	Commercial Premium HVAC Natural Replacement/Retro	0.001	10.691	0.003	$0	$43
PS-1	Hydropower, New projects	0.259	10.950	1.590	$70	$44

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
TLU-20	LCFS 12 -- Waste Oil	0.166	11.115	1.580	$72	$45
TLU-15	LCFS7 -- OR Cellulosic EtOH	1.104	12.219	4.555	$211	$46
PS-10	Tidal current, Water current turbines	0.214	12.433	1.184	$55	$47
RCI-59	Commercial Parking Lighting	0.019	12.452	0.068	$3	$48
RCI-23	Residential Gas Water Heat Measures	0.012	12.464	0.068	$4	$53
RCI-49	Commercial Daylighting Natural Replacement/Retrofit	0.004	12.468	0.016	$1	$53
RCI-46	Commercial Premium HVAC New/Integrated Design	0.000	12.469	0.001	$0	$53
RCI-7	Multifamily Weatherization--Windows	0.030	12.498	0.141	$8	$54
RCI-31	Residential CHP	0.020	12.518	0.074	$4	$55
RCI-8	Single Family Weatherization--Insulation	0.081	12.598	0.366	$21	$58
PS-5	Animal manure, Reciprocating engine	0.097	12.695	0.904	$56	$61
TLU-16	LCFS8 -- Cellulosic	0.175	12.871	0.175	$11	$63
PS-4	Landfill gas, Reciprocating engine	0.098	12.969	0.823	$52	$63
RCI-5	Manufactured Home Weatherization--Windows	0.021	12.990	0.097	$6	$63
RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	0.007	12.997	0.039	$2	$64
RCI-29	Residential Solar Hot Water--Gas Back-up	0.017	13.014	0.095	$6	$67
RCI-91	Commercial Heating Measures--Gas	0.011	13.025	0.061	$4	$71
RCI-95	Commercial Solar Hot Water--Gas Back-up	0.001	13.026	0.005	$0	$74
PS-3	Wastewater treatment gas, Reciprocating engines	0.015	13.042	0.143	$11	$75
TLU-27	FR6 --Low Carbon Fuels	0.190	13.232	2.285	$190	$83
RCI-17	Residential Gravity Film Heat Exchanger	0.035	13.267	0.146	$13	$88
PS-6	Woody residues, Steam-electric - brownfield	0.238	13.505	1.683	$160	$95
RCI-6	Multifamily Weatherization--Insulation	0.016	13.522	0.072	$10	$134
PS-12	Offshore Wind, Floating WTG	0.627	14.149	2.946	$412	$140
AFW-8a	Forest Management - Rotation Schedules	0.560	14.709	3.080	$431	$140
RCI-19	Residential Solar Water Heat--Electric Back-up	0.163	14.871	0.786	$114	$145
TLU-13	LCFS5 -- Brazil Sugar Cane EtOH	0.104	14.976	0.589	$91	$155
RCI-67	Commercial Signage	0.003	14.979	0.016	$2	$155
RCI-98	Commercial Wood-fueled Space Heat Replacing Gas	0.000	14.980	0.002	$0.3	$164
RCI-136	Industrial Solar PV	0.072	15.051	0.346	$61	$178
RCI-85	Commercial Ground-source Heat	0.001	15.052	0.005	$1	$181

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
	Pump					
RCI-100	Commercial Solar PV	0.045	15.097	0.217	$41	$190
PS-7	Woody residues, Steam-electric - greenfield	0.258	15.355	1.822	$348	$191
RCI-10	Residential Solar Photovoltaic	0.089	15.444	0.429	$83	$193
TLU-1	TL1 -- TriMet - Rail	0.009	15.452	0.099	$19	$195
TLU-14	LCFS6 -- Low Carbon MW Corn	0.086	15.538	0.661	$132	$199
RCI-94	Commercial Windows Measures--Gas	0.002	15.540	0.013	$3	$205
RCI-21	Residential Refrigerator Recycle	0.001	15.541	0.004	$1	$223
PS-15	Wind (in OR/WA), Wind turbine generators	0.786	16.327	3.948	$885	$224
PS-2	Hydropower, Conventional hydro upgrades in OR	0.055	16.382	0.337	$78	$232
PS-16	Wind (from Alberta to OR/WA), Wind turbine generators	1.006	17.389	5.054	$1,292	$256
TLU-18	LCFS10 -- Camelian RD	0.332	17.721	1.405	$374	$266
PS-17	Wind (from Montana to OR/WA), Wind turbine generators	0.755	18.476	3.791	$1,072	$283
RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	0.012	18.487	0.064	$19	$297
PS-18	Wind (from Wyoming to OR/WA), Wind turbine generators	0.755	19.242	3.791	$1,151	$304
PS-11	Wave, Various buoy & overtopping devices	0.248	19.490	1.527	$472	$309
TLU-19	LCFS 11 -- NW Canola	0.034	19.525	0.237	$73	$310
PS-14	Solar (Nevada), Parabolic trough	0.697	20.222	3.977	$1,403	$353
TLU-21	LCFS 13 -- MW Soybean	0.000	20.222	0.210	$79	$377
TLU-6	TL6 -- Bend Area Transit	0.001	20.223	0.007	$3	$477
TLU-4	TL4 -- Salem Area Mass Transit District	0.000	20.223	0.002	$1	$575
TLU-7	TL7 -- City of Corvallis	0.000	20.223	0.002	$1	$575
PS-13	Solar, Utility-scale Photovoltaic arrays	0.499	20.722	3.120	$1,822	$584
TLU-9	LCFS1 -- MW Corn Ethanol	0.000	20.722	-0.144	-$86	$597
TLU-10	LCFS2 -- OR Corn Ethanol	0.011	20.733	0.126	$75	$597
TLU-2	TL2 -- TriMet - Bus	0.009	20.743	0.109	$81	$746
TLU-5	TL5 -- Rogue Valley Transportation District	0.000	20.743	0.004	$3	$824
TLU-28	LD1 -- Transit Growth	0.025	20.768	0.085	$71	$830
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	0.007	20.775	0.033	$30	$927
AFW-8b	Forest Management - Riparian Zones	0.005	20.780	0.028	$28	$1,001
TLU-3	TL3 -- Lane Transit District	0.001	20.781	0.016	$16	$1,001
AFW-6	Urban Forestry	0.042	20.824	0.150	$221	$1,475
RCI-1	Residential Cooling Appliances	0.000	20.824	0.001	$6	$6,015

Table 3. Marginal Abatement Cost Curve Results for Scenario 1, Year 2035

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
TLU-37	LD10 -- Carsharing	0.003	0.003	0.035	-$30	-$857
TLU-31	LD4 -- PAYD	0.093	0.096	1.244	-$1,049	-$843
TLU-29	LD2 -- Walk/Bike Short SOV mode shift	0.014	0.110	0.152	-$106	-$693
TLU-34	LD7 -- Parking Management	0.072	0.182	0.704	-$488	-$693
TLU-36	LD9 -- Congestion Charges	0.001	0.183	-0.052	$29	-$566
TLU-25	FR4 -- More Energy Efficient Transporter Operations	0.078	0.262	0.939	-$448	-$477
TLU-32	LD5 -- TDM	0.012	0.274	0.152	-$67	-$442
TLU-35	LD8 -- Externality Taxes	0.069	0.343	0.409	-$126	-$309
AFW-10	Waste Prevention	0.795	1.138	13.081	-$3,554	-$272
RCI-73	Commercial Clothes Washer	0.015	1.153	0.188	-$40	-$212
TLU-33	LD6 -- EcoDrive	0.098	1.251	0.966	-$179	-$185
TLU-8	TL8 -- Land Use	0.123	1.375	1.541	-$240	-$156
TLU-24	FR3 -- Idle Reduction Strategies	0.008	1.383	0.094	-$13	-$143
TLU-22	FR1 -- Land Use Policy Changes	0.008	1.390	0.094	-$13	-$133
RCI-123	Industrial Agriculture Irrigation Improvements	0.008	1.398	0.142	-$18	-$127
RCI-86	Commercial Laundry Equipment--Gas	0.000	1.398	0.002	$0	-$109
PS-31	Electricity, Additional regulation & telecommunication services	0.005	1.403	0.078	-$5	-$65
TLU-23	FR2 -- Urban Traffic Congestion Relief	0.016	1.418	0.188	-$12	-$63
RCI-66	Commercial Exit Signs	0.002	1.421	0.045	-$3	-$62
TLU-26	FR5 -- Mode Shift of Freight in Response to Higher Fees	0.219	1.640	2.628	-$161	-$61
RCI-71	Commercial Ice-Maker Improvements	0.007	1.647	0.087	-$5	-$60
RCI-120	Industrial Lumber Conveyor Replacement	0.012	1.659	0.160	-$10	-$60
RCI-129	Industrial Weatherization Measures	0.018	1.677	0.211	-$12	-$57
RCI-128	Industrial Space Heating Measures	0.036	1.713	0.427	-$24	-$57
RCI-127	Industrial Hot Water Measures	0.019	1.733	0.231	-$13	-$57
RCI-126	Industrial Boiler Measures	0.015	1.748	0.183	-$10	-$56
RCI-16	Residential Lighting Improvement	0.115	1.863	2.769	-$145	-$52
RCI-87	Commercial Cooking Equipment--Gas	0.009	1.872	0.108	-$6	-$51
RCI-76	Commercial Heat Pump Water Heater	0.025	1.898	0.312	-$16	-$51
RCI-38	Commercial Windows New/Integrated Design	0.001	1.899	0.013	-$1	-$50
RCI-45	Commercial Package Rooftop Measures New/Integrated	0.006	1.904	0.064	-$3	-$50

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
	Design					
RCI-110	Industrial Electronics Clean Room Measures	0.001	1.906	0.014	-$1	-$50
RCI-118	Industrial Kraft Pulp Measures	0.007	1.913	0.085	-$4	-$50
TLU-30	LD3 -- ITS &Operations	0.002	1.914	0.032	-$2	-$49
RCI-116	Industrial Metals Arc Furnace	0.000	1.915	0.005	$0	-$49
RCI-102	Industrial General: Lighting and Controls	0.055	1.970	0.684	-$33	-$48
RCI-89	Commercial Insulation Measures--Gas Heat	0.011	1.981	0.130	-$6	-$46
RCI-44	Commercial Variable Speed Chiller New/Integrated Design	0.001	1.982	0.016	-$1	-$44
RCI-75	Commercial Hot Water Efficiency Measures	0.002	1.984	0.022	-$1	-$43
RCI-113	Industrial Fruit Storage Measures	0.016	2.000	0.188	-$8	-$43
RCI-26	Residential Gas Heat Windows	0.031	2.031	0.376	-$16	-$42
RCI-93	Commercial Insulation Measures--Gas	0.003	2.034	0.036	-$1	-$42
RCI-131	Industrial Biomass-fired CHP	0.095	2.129	1.096	-$45	-$41
RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	0.043	2.172	0.621	-$25	-$41
RCI-24	Residential Gas Furnace Upgrade	0.020	2.192	0.236	-$10	-$41
PS-30	Electricity, Smart meters	4.227	6.419	45.050	-$1,741	-$39
RCI-34	Commercial LDP New/Integrated Design	0.031	6.449	0.345	-$12	-$35
RCI-88	Commercial Hot Water Measures--Gas	0.009	6.458	0.103	-$4	-$35
RCI-121	Industrial Wood Panels Hydraulic Press	0.001	6.459	0.010	$0	-$35
RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	0.008	6.467	0.073	-$3	-$35
RCI-114	Industrial Food Storage Measures	0.001	6.468	0.014	$0	-$35
RCI-117	Industrial Mechanical Pulp Measures	0.004	6.472	0.045	-$2	-$34
RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	0.018	6.490	0.264	-$9	-$34
RCI-52	Commercial Insulation Natural Replacement/Retrofit	0.062	6.552	0.728	-$24	-$33
RCI-132	Industrial Digester Gas-fired CHP	0.019	6.571	0.230	-$7	-$32
RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	0.005	6.577	0.067	-$2	-$30
RCI-103	Industrial General: Motors Measures	0.007	6.584	0.088	-$3	-$29

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-48	Commercial LDP Natural Replacement/Retrofit	0.305	6.889	3.921	-$112	-$29
RCI-112	Industrial Cold Storage Measures	0.017	6.905	0.197	-$5	-$28
RCI-74	Commercial Wastewater Heat Exchanger	0.005	6.910	0.058	-$2	-$27
RCI-61	Commercial Computer/Server Improvements	0.051	6.961	0.617	-$16	-$27
RCI-106	Industrial General: Transformers	0.007	6.969	0.092	-$2	-$27
RCI-80	Commercial Solar Water Heat	0.014	6.983	0.172	-$5	-$26
RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	0.013	6.996	0.147	-$4	-$26
RCI-62	Commercial Cooking/Food Service Improvements	0.019	7.014	0.251	-$6	-$26
RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	0.002	7.016	0.020	$0	-$25
RCI-111	Industrial Food Processing Measures	0.032	7.048	0.399	-$10	-$24
AFW-3	Nutrient Management	0.255	7.302	3.055	-$75	-$24
RCI-35	Schools Lighting Measures	0.019	7.321	0.243	-$6	-$24
RCI-70	Commercial Refrigeration Improvements	0.028	7.349	0.328	-$8	-$24
RCI-4	Manufactured Home Weatherization--Insulation	0.036	7.385	0.476	-$11	-$23
RCI-83	Commercial Chiller Tower 6F Approach	0.005	7.390	0.060	-$1	-$22
RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	0.036	7.426	0.411	-$9	-$22
RCI-130	Industrial Gas-fired CHP	0.217	7.644	2.774	-$58	-$21
RCI-78	Commercial Economizer Measures	0.043	7.686	0.526	-$11	-$21
RCI-12	Residential Heat Pump Water Heater	0.321	8.008	3.914	-$78	-$20
RCI-42	Commercial Demand Control Ventilation New/Integrated Design	0.011	8.019	0.122	-$2	-$19
RCI-79	Commercial Heat Reclamation Measures	0.001	8.020	0.010	$0	-$19
RCI-37	Commercial Lighting Controls New/Integrated Design	0.036	8.056	0.442	-$8	-$18
RCI-107	Industrial General: Materials Movement Measures	0.034	8.090	0.419	-$7	-$18
RCI-33	Residential Wood-fueled Heat Replacing Oil/LPG	0.002	8.091	0.034	-$1	-$17
RCI-101	Industrial General: Air Compressor Measures	0.033	8.124	0.409	-$7	-$17
RCI-99	Commercial Wood-fueled Space Heat Replacing Oil/LPG	0.001	8.126	0.014	-$0.2	-$17
RCI-11	Residential Electric Water Heat Efficiency	0.093	8.218	1.112	-$17	-$15

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-28	Residential Multi-Measure Gas Heat	0.103	8.321	1.231	-$19	-$15
RCI-104	Industrial General: Fan Measures	0.061	8.382	0.760	-$12	-$15
RCI-122	Industrial Agriculture Pump and Related Measures	0.018	8.400	0.364	-$5	-$14
RCI-108	Industrial General: Energy Management	0.209	8.610	2.595	-$31	-$12
RCI-65	Commercial DVC Hood	0.004	8.614	0.084	-$1	-$11
RCI-39	Schools Building Envelope Measures	0.000	8.614	0.001	$0	-$10
RCI-58	Commercial Controls Commissioning HVAC Retrofit	0.059	8.674	1.178	-$11	-$9
RCI-109	Industrial Electronics Chip Fab Measures	0.007	8.680	0.081	$0	-$6
RCI-105	Industrial General: Pump Measures	0.058	8.738	0.714	-$3	-$4
AFW-4a	Biogas Production & Utilization from MSW Biomass	1.905	10.642	32.771	-$131	-$4
PS-32	Electricity, Distribution system upgrades	0.517	11.160	8.726	-$8	-$1
RCI-36	Commercial Daylighting New/Integrated Design	0.008	11.168	0.088	$0	$1
PS-19	Waste heat, Bottoming Rankine cycle	0.078	11.246	1.908	$5	$2
RCI-96	Commercial Gas-fired CHP	0.121	11.367	1.356	$3	$2
AFW-7b	Reforestation/Afforestation of Rangeland	0.012	11.379	0.153	$0	$3
AFW-2	Co-Digestion of Food Waste with Dairy Methane	0.225	11.604	4.619	$17	$4
RCI-97	Commercial Wood-fueled Space Heat Replacing Electric	0.001	11.605	0.012	$0	$9
AFW-5	Landfill Gas Collection & Use	0.324	11.929	5.909	$52	$9
RCI-115	Industrial Grocery Distribution Measures	0.006	11.935	0.072	$1	$9
RCI-84	Commercial Rooftop Condensing Burner	0.003	11.938	0.040	$0	$10
RCI-41	Schools HVAC	0.007	11.946	0.124	$2	$13
RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	0.004	11.950	0.046	$1	$13
RCI-32	Residential Wood-fueled Heat Replacing Electric Resistance	0.045	11.995	0.526	$7	$13
RCI-119	Industrial Paper Sector Measures	0.007	12.001	0.085	$1	$17
AFW-1	Dairy Methane	0.076	12.077	3.956	$67	$17
RCI-9	Single Family Weatherization--Windows	0.094	12.172	1.327	$24	$18
AFW-9	Enhanced Materials Management in New Building Construction	1.620	13.792	24.975	$480	$19
RCI-3	Single Family Home HVAC Conversion/Upgrade	0.284	14.076	3.722	$74	$20

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
PS-8	Geothermal, Binary hydrothermal	0.527	14.603	11.132	$232	$21
RCI-2	Manufactured Home HVAC Conversion/Upgrade	0.221	14.824	2.629	$55	$21
RCI-23	Residential Gas Water Heat Measures	0.028	14.853	0.341	$9	$26
RCI-57	Commercial Premium HVAC Natural Replacement/Retro	0.002	14.854	0.020	$1	$26
PS-10	Tidal current, Water current turbines	0.164	15.018	3.501	$100	$29
RCI-59	Commercial Parking Lighting	0.042	15.061	0.469	$14	$29
PS-1	Hydropower, New projects	0.195	15.256	4.344	$131	$30
RCI-7	Multifamily Weatherization--Windows	0.047	15.303	0.665	$22	$33
RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	0.016	15.319	0.194	$6	$33
RCI-49	Commercial Daylighting Natural Replacement/Retrofit	0.007	15.326	0.084	$3	$34
RCI-46	Commercial Premium HVAC New/Integrated Design	0.001	15.327	0.008	$0	$34
RCI-29	Residential Solar Hot Water--Gas Back-up	0.040	15.367	0.479	$17	$35
PS-4	Landfill gas, Reciprocating engine	0.060	15.427	1.738	$62	$36
RCI-91	Commercial Heating Measures--Gas	0.026	15.453	0.307	$12	$38
RCI-95	Commercial Solar Hot Water--Gas Back-up	0.002	15.455	0.027	$1	$40
PS-5	Animal manure, Reciprocating engine	0.073	15.528	1.936	$77	$40
RCI-31	Residential CHP	0.032	15.560	0.396	$17	$42
TLU-17	LCFS9 -- CNG from biogas	0.394	15.954	0.773	$33	$42
RCI-8	Single Family Weatherization--Insulation	0.139	16.093	1.833	$78	$42
TLU-11	LCFS3 -- Imported Cellulosic Ethanol	0.027	16.120	0.027	$1	$42
TLU-12	LCFS4 -- Oregon Wheat Straw Ethanol	0.748	16.867	0.891	$38	$42
RCI-5	Manufactured Home Weatherization--Windows	0.034	16.902	0.471	$20	$43
PS-28	Nuclear, Advanced light water reactor	3.566	20.467	50.710	$2,180	$43
TLU-20	LCFS 12 -- Waste Oil	0.381	20.848	3.634	$165	$45
TLU-15	LCFS7 -- OR Cellulosic EtOH	2.539	23.387	10.477	$485	$46
PS-3	Wastewater treatment gas, Reciprocating engines	0.012	23.398	0.307	$16	$51
PS-29	Nuclear, Small modular reactor	0.958	24.356	13.620	$733	$54
RCI-17	Residential Gravity Film Heat Exchanger	0.069	24.425	0.824	$48	$58
TLU-16	LCFS8 -- Cellulosic	0.403	24.828	0.403	$25	$63
PS-6	Woody residues, Steam-electric - brownfield	0.144	24.973	3.878	$252	$65

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
PS-12	Offshore Wind, Floating WTG	0.490	25.462	9.875	$820	$83
TLU-27	FR6 --Low Carbon Fuels	0.438	25.900	5.256	$438	$83
AFW-8a	Forest Management - Rotation Schedules	0.560	26.460	10.360	$945	$91
PS-21	Coal, Ultracritical w/CO2 capture (90%)	1.087	27.547	11.954	$1,142	$96
RCI-98	Commercial Wood-fueled Space Heat Replacing Gas	0.001	27.548	0.011	$1	$96
RCI-6	Multifamily Weatherization--Insulation	0.029	27.577	0.372	$37	$99
RCI-19	Residential Solar Water Heat--Electric Back-up	0.245	27.823	3.582	$358	$100
PS-22	Petroleum coke, Gasification combined-cycle	1.101	28.924	12.112	$1,220	$101
RCI-67	Commercial Signage	0.006	28.930	0.079	$8	$106
PS-15	Wind (in OR/WA), Wind turbine generators	0.614	29.544	12.632	$1,395	$110
PS-20	Coal, Supercritical w/CO2 capture (90%)	1.033	30.577	11.366	$1,291	$114
RCI-136	Industrial Solar PV	0.108	30.685	1.575	$195	$124
RCI-85	Commercial Ground-source Heat Pump	0.002	30.687	0.024	$3	$125
RCI-94	Commercial Windows Measures--Gas	0.006	30.693	0.065	$8	$128
RCI-100	Commercial Solar PV	0.068	30.760	0.991	$132	$133
RCI-10	Residential Solar Photovoltaic	0.134	30.894	1.954	$265	$136
PS-7	Woody residues, Steam-electric - greenfield	0.156	31.050	4.197	$596	$142
PS-16	Wind (from Alberta to OR/WA), Wind turbine generators	0.786	31.836	16.171	$2,437	$151
TLU-13	LCFS5 -- Brazil Sugar Cane EtOH	0.240	32.076	1.355	$210	$155
RCI-21	Residential Refrigerator Recycle	0.001	32.078	0.019	$3	$156
PS-17	Wind (from Montana to OR/WA), Wind turbine generators	0.589	32.667	12.128	$2,030	$167
PS-2	Hydropower, Conventional hydro upgrades in OR	0.041	32.708	0.920	$164	$179
PS-18	Wind (from Wyoming to OR/WA), Wind turbine generators	0.589	33.298	12.128	$2,188	$180
RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	0.027	33.324	0.321	$61	$191
TLU-1	TL1 -- TriMet - Rail	0.017	33.342	0.229	$45	$195
TLU-14	LCFS6 -- Low Carbon MW Corn	0.197	33.539	1.521	$303	$199
PS-14	Solar (Nevada), Parabolic trough	0.538	34.077	11.584	$2,703	$233
PS-11	Wave, Various buoy &	0.187	34.264	4.170	$997	$239

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
	overtopping devices					
TLU-18	LCFS10 -- Camelian RD	0.764	35.028	3.231	$861	$266
TLU-19	LCFS 11 -- NW Canola	0.079	35.107	0.545	$169	$310
AFW-6	Urban Forestry	0.219	35.326	1.815	$602	$331
PS-13	Solar, Utility-scale Photovoltaic arrays	0.385	35.711	8.562	$3,095	$362
TLU-21	LCFS 13 -- MW Soybean	0.000	35.711	0.482	$181	$377
TLU-6	TL6 -- Bend Area Transit	0.001	35.712	0.015	$7	$477
TLU-4	TL4 -- Salem Area Mass Transit District	0.000	35.713	0.004	$2	$575
TLU-7	TL7 -- City of Corvallis	0.000	35.713	0.004	$2	$575
TLU-9	LCFS1 -- MW Corn Ethanol	0.000	35.713	-0.332	-$198	$597
TLU-10	LCFS2 -- OR Corn Ethanol	0.026	35.739	0.290	$173	$597
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	0.007	35.746	0.128	$91	$712
TLU-2	TL2 -- TriMet - Bus	0.019	35.765	0.251	$187	$746
AFW-8b	Forest Management - Riparian Zones	0.005	35.770	0.093	$69	$746
TLU-5	TL5 -- Rogue Valley Transportation District	0.001	35.771	0.008	$7	$824
TLU-28	LD1 -- Transit Growth	0.074	35.844	0.575	$477	$830
TLU-3	TL3 -- Lane Transit District	0.003	35.847	0.036	$36	$1,001
RCI-1	Residential Cooling Appliances	0.000	35.847	0.004	$19	$4,379

Table 4. Measures Not Included in the Marginal Abatement Cost Curve for Scenario 1

Measure Number	Measure Group Name	Excluded from 2022	Excluded from 2035	Reason for Exclusion
AFW-7a	Reforestation/Afforestation of Cropland	Yes	Yes	No abatement potential was identified for the level of investment associated with Scenario 1
PS-20	Coal, Supercritical w/CO2 capture (90%)	Yes	No	Implemented after 2022
PS-21	Coal, Ultracritical w/CO2 capture (90%)	Yes	No	Implemented after 2022
PS-22	Petroleum coke, Gasification combined-cycle	Yes	No	Implemented after 2022
PS-28	Nuclear, Advanced light water reactor	Yes	No	Implemented after 2022
PS-29	Nuclear, Small modular reactor	Yes	No	Implemented after 2022
RCI-124	Industrial Rural Area Lighting	Yes	Yes	Implementation assumed to be zero or near-zero under this scenario
RCI-125	Industrial Traffic Signals Relamping	Yes	Yes	ditto
RCI-13	Residential Laundry Appliance Improvement	Yes	Yes	ditto
RCI-133	Industrial Cement Production Emissions Reduction	Yes	Yes	ditto
RCI-134	Industrial Electronics Industry Solvent Emissions Reduction	Yes	Yes	ditto
RCI-135	Industrial Halon Consumption Reduction	Yes	Yes	ditto

Measure Number	Measure Group Name	Excluded from 2022	Excluded from 2035	Reason for Exclusion
RCI-14	Residential Dishwasher Improvement	Yes	Yes	ditto
RCI-15	Residential Refrigerator/Freezer Improvement	Yes	Yes	ditto
RCI-18	Residential Cooking Appliance Improvement	Yes	Yes	ditto
RCI-20	Home Energy Monitor	Yes	Yes	ditto
RCI-22	Residential Electronics Improvements	Yes	Yes	ditto
RCI-25	Multifamily HVAC--Gas Heat	Yes	Yes	ditto
RCI-51	Commercial Windows Natural Replacement/Retrofit	Yes	Yes	ditto
RCI-60	Commercial Refrigeration Improvements	Yes	Yes	ditto
RCI-63	Commercial Wastewater Treatment Improvements	Yes	Yes	ditto
RCI-64	Commercial Water Supply Improvements	Yes	Yes	ditto
RCI-68	Commercial Fume Hood	Yes	Yes	ditto
RCI-69	Commercial Street Lighting	Yes	Yes	ditto
RCI-72	Commercial Vending Machines	Yes	Yes	ditto
RCI-77	Commercial Transformers	Yes	Yes	ditto
RCI-81	Commercial Heating Duct Measures	Yes	Yes	ditto
RCI-82	Commercial Energy Management Systems	Yes	Yes	ditto
RCI-90	Commercial Heat Reclamation--Gas	Yes	Yes	ditto
RCI-92	Commercial Wastewater Heat Exchanger--Gas	Yes	Yes	ditto
TLU-36	LD9 -- Congestion Charges	Yes	No	Emissions increase for 2022

2.3.2 Scenario 2 (Moderate Increase in Federal Action)

Figure 4. Marginal Abatement Cost Curve for Scenario 2, Year 2022

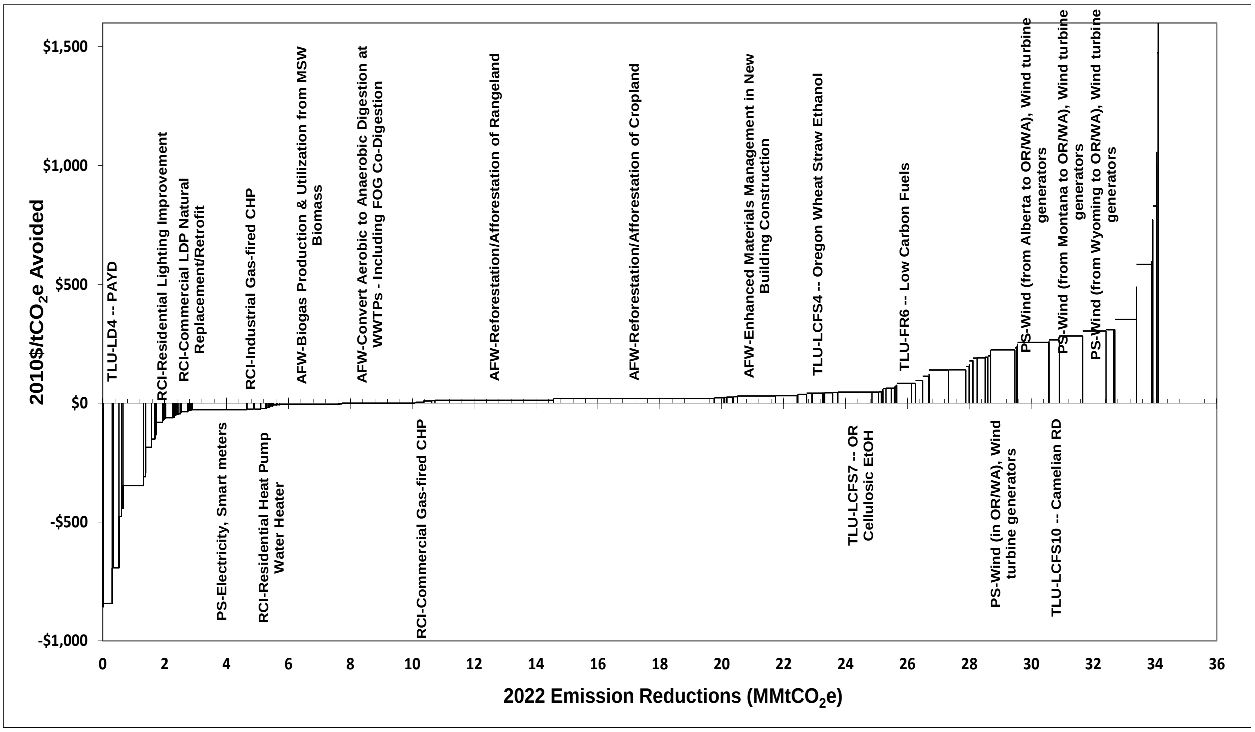


Figure 5. Marginal Abatement Cost Curve for Scenario 2, Year 2035

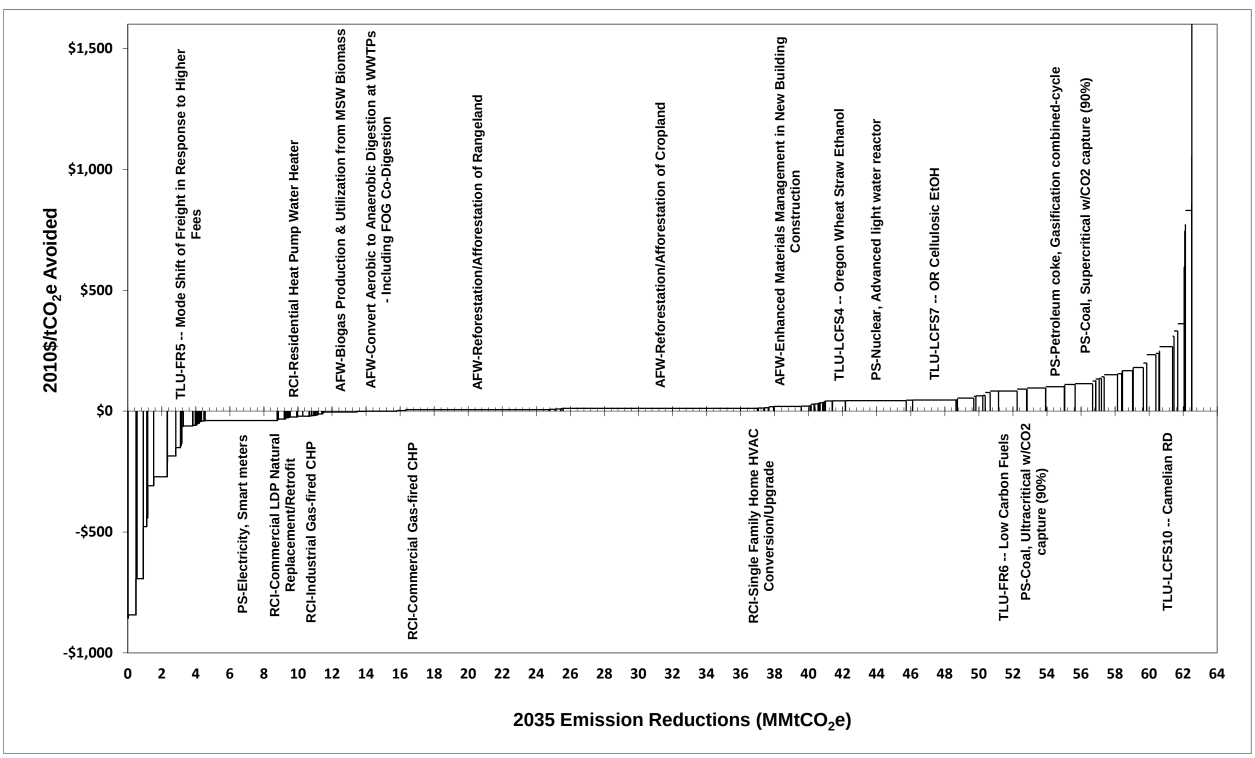


Table 5. Marginal Abatement Cost Curve for Scenario 2, Year 2022

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
TLU-37	LD10 -- Carsharing	0.012	0.012	0.046	-$40	-$857
TLU-31	LD4 -- PAYD	0.293	0.305	0.735	-$619	-$843
TLU-29	LD2 -- Walk/Bike Short SOV mode shift	0.039	0.344	0.157	-$109	-$693
TLU-34	LD7 -- Parking Management	0.177	0.521	0.671	-$465	-$693
TLU-25	FR4 -- More Energy Efficient Transporter Operations	0.085	0.606	0.468	-$223	-$477
TLU-32	LD5 -- TDM	0.046	0.652	0.154	-$68	-$442
AFW-10	Waste Prevention	0.669	1.321	3.512	-$1,218	-$347
TLU-35	LD8 -- Externality Taxes	0.059	1.380	0.155	-$48	-$309
RCI-73	Commercial Clothes Washer	0.008	1.389	0.036	-$11	-$294
TLU-33	LD6 -- EcoDrive	0.185	1.573	0.494	-$92	-$185
TLU-8	TL8 -- Land Use	0.111	1.685	0.273	-$212	-$151
TLU-24	FR3 -- Idle Reduction Strategies	0.017	1.702	0.094	-$13	-$143
RCI-86	Commercial Laundry Equipment--Gas	0.000	1.702	0.000	$0	-$142
TLU-22	FR1 -- Land Use Policy Changes	0.017	1.719	0.094	-$12	-$133
RCI-123	Industrial Agriculture Irrigation Improvements	0.009	1.727	0.042	-$5	-$125
RCI-16	Residential Lighting Improvement	0.200	1.927	1.278	-$103	-$81
RCI-71	Commercial Ice-Maker Improvements	0.004	1.931	0.015	-$1	-$75
RCI-120	Industrial Lumber Conveyor Replacement	0.007	1.938	0.036	-$3	-$73
RCI-129	Industrial Weatherization Measures	0.009	1.947	0.047	-$3	-$70
RCI-128	Industrial Space Heating Measures	0.018	1.965	0.096	-$7	-$70
RCI-127	Industrial Hot Water Measures	0.008	1.973	0.044	-$3	-$69
RCI-126	Industrial Boiler Measures	0.007	1.980	0.035	-$2	-$69
TLU-23	FR2 -- Urban Traffic Congestion Relief	0.034	2.014	0.187	-$12	-$63
RCI-76	Commercial Heat Pump Water Heater	0.013	2.027	0.063	-$4	-$62
RCI-87	Commercial Cooking Equipment--Gas	0.004	2.031	0.021	-$1	-$61
RCI-38	Commercial Windows New/Integrated Design	0.001	2.031	0.002	$0	-$61
TLU-26	FR5 -- Mode Shift of Freight in Response to Higher Fees	0.238	2.269	1.309	-$80	-$61
RCI-45	Commercial Package Rooftop Measures New/Integrated Design	0.003	2.272	0.011	-$1	-$61

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-110	Industrial Electronics Clean Room Measures	0.001	2.273	0.003	$0	-$60
RCI-102	Industrial General: Lighting and Controls	0.034	2.307	0.166	-$10	-$60
RCI-118	Industrial Kraft Pulp Measures	0.004	2.311	0.017	-$1	-$60
RCI-89	Commercial Insulation Measures--Gas Heat	0.006	2.316	0.030	-$2	-$59
RCI-116	Industrial Metals Arc Furnace	0.000	2.316	0.001	$0	-$59
RCI-93	Commercial Insulation Measures--Gas	0.001	2.318	0.008	$0	-$54
RCI-44	Commercial Variable Speed Chiller New/Integrated Design	0.001	2.319	0.003	$0	-$52
RCI-75	Commercial Hot Water Efficiency Measures	0.001	2.320	0.004	$0	-$51
RCI-113	Industrial Fruit Storage Measures	0.008	2.327	0.037	-$2	-$51
RCI-26	Residential Gas Heat Windows	0.016	2.343	0.087	-$4	-$50
TLU-30	LD3 -- ITS &Operations	0.013	2.356	0.039	-$2	-$49
RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	0.033	2.389	0.157	-$8	-$49
RCI-24	Residential Gas Furnace Upgrade	0.010	2.399	0.055	-$3	-$48
RCI-52	Commercial Insulation Natural Replacement/Retrofit	0.033	2.432	0.148	-$7	-$47
RCI-131	Industrial Biomass-fired CHP	0.066	2.497	0.274	-$12	-$45
RCI-34	Commercial LDP New/Integrated Design	0.014	2.512	0.052	-$2	-$41
RCI-15	Residential Refrigerator/Freezer Improvement	0.003	2.515	0.014	-$1	-$41
RCI-114	Industrial Food Storage Measures	0.001	2.516	0.003	$0	-$39
RCI-121	Industrial Wood Panels Hydraulic Press	0.000	2.516	0.002	$0	-$39
RCI-117	Industrial Mechanical Pulp Measures	0.002	2.518	0.009	$0	-$39
RCI-88	Commercial Hot Water Measures--Gas	0.004	2.522	0.020	-$1	-$37
RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	0.016	2.537	0.071	-$3	-$37
RCI-48	Commercial LDP Natural Replacement/Retrofit	0.206	2.743	0.972	-$35	-$36
RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	0.003	2.746	0.015	-$1	-$35
RCI-25	Multifamily HVAC--Gas Heat	0.000	2.747	0.001	$0	-$34
RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	0.006	2.753	0.029	-$1	-$33
RCI-103	Industrial General: Motors	0.004	2.756	0.018	-$1	-$31

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
	Measures					
RCI-132	Industrial Digester Gas-fired CHP	0.029	2.785	0.118	-$4	-$31
RCI-112	Industrial Cold Storage Measures	0.008	2.793	0.038	-$1	-$30
RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	0.020	2.813	0.072	-$2	-$30
RCI-35	Schools Lighting Measures	0.012	2.826	0.058	-$2	-$29
RCI-61	Commercial Computer/Server Improvements	0.026	2.852	0.122	-$3	-$28
RCI-74	Commercial Wastewater Heat Exchanger	0.002	2.854	0.012	$0	-$28
RCI-106	Industrial General: Transformers	0.004	2.858	0.019	-$1	-$28
RCI-4	Manufactured Home Weatherization--Insulation	0.023	2.881	0.105	-$3	-$28
RCI-80	Commercial Solar Water Heat	0.007	2.889	0.035	-$1	-$28
RCI-62	Commercial Cooking/Food Service Improvements	0.010	2.899	0.037	-$1	-$27
PS-30	Electricity, Smart meters	1.759	4.658	6.796	-$185	-$27
RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	0.001	4.659	0.003	$0	-$27
RCI-130	Industrial Gas-fired CHP	0.214	4.873	0.780	-$20	-$25
RCI-70	Commercial Refrigeration Improvements	0.014	4.887	0.057	-$1	-$25
RCI-99	Commercial Wood-fueled Space Heat Replacing Oil/LPG	0.000	4.887	0.002	-$0.1	-$25
RCI-111	Industrial Food Processing Measures	0.017	4.905	0.084	-$2	-$25
RCI-12	Residential Heat Pump Water Heater	0.197	5.101	0.857	-$21	-$25
RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	0.006	5.107	0.023	-$1	-$24
AFW-3	Nutrient Management	0.159	5.266	0.877	-$20	-$23
RCI-83	Commercial Chiller Tower 6F Approach	0.003	5.269	0.012	$0	-$22
RCI-78	Commercial Economizer Measures	0.023	5.291	0.106	-$2	-$20
RCI-11	Residential Electric Water Heat Efficiency	0.055	5.347	0.236	-$4	-$19
RCI-39	Schools Building Envelope Measures	0.000	5.347	0.000	$0	-$18
RCI-79	Commercial Heat Reclamation Measures	0.000	5.347	0.002	$0	-$17
RCI-37	Commercial Lighting Controls New/Integrated Design	0.019	5.366	0.087	-$1	-$16
RCI-107	Industrial General: Materials Movement Measures	0.018	5.384	0.087	-$1	-$16

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-42	Commercial Demand Control Ventilation New/Integrated Design	0.004	5.389	0.019	$0	-$15
RCI-101	Industrial General: Air Compressor Measures	0.018	5.406	0.085	-$1	-$15
RCI-28	Residential Multi-Measure Gas Heat	0.049	5.456	0.271	-$3	-$12
RCI-104	Industrial General: Fan Measures	0.033	5.488	0.158	-$2	-$12
RCI-122	Industrial Agriculture Pump and Related Measures	0.023	5.512	0.112	-$1	-$11
RCI-33	Residential Wood-fueled Heat Replacing Oil/LPG	0.002	5.513	0.013	$0	-$10
RCI-108	Industrial General: Energy Management	0.112	5.625	0.538	-$4	-$8
RCI-65	Commercial DVC Hood	0.005	5.630	0.023	$0	-$7
RCI-58	Commercial Controls Commissioning HVAC Retrofit	0.084	5.714	0.416	-$3	-$7
AFW-4a	Biogas Production & Utilization from MSW Biomass	1.905	7.619	8.010	-$37	-$5
RCI-135	Industrial Halon Consumption Reduction	0.017	7.636	0.086	$0	-$4
RCI-133	Industrial Cement Production Emissions Reduction	0.028	7.663	0.154	-$1	-$3
RCI-22	Residential Electronics Improvements	0.064	7.728	0.390	-$1	-$3
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	1.778	9.506	7.312	-$1	$0
PS-31	Electricity, Additional regulation & telecommunication services	0.004	9.509	0.000	$0	$0
PS-32	Electricity, Distribution system upgrades	0.578	10.087	0.000	$0	$0
RCI-109	Industrial Electronics Chip Fab Measures	0.003	10.091	0.017	$0	$1
RCI-105	Industrial General: Pump Measures	0.031	10.121	0.148	$0	$3
RCI-96	Commercial Gas-fired CHP	0.235	10.357	0.835	$3	$4
RCI-36	Commercial Daylighting New/Integrated Design	0.003	10.360	0.012	$0	$9
AFW-5	Landfill Gas Collection & Use	0.267	10.628	2.034	$18	$9
PS-19	Waste heat, Bottoming Rankine cycle	0.104	10.731	0.807	$9	$11
AFW-7b	Reforestation/Afforestation of Rangeland	3.833	14.564	21.081	$250	$12
AFW-7a	Reforestation/Afforestation of Cropland	5.195	19.760	28.575	$556	$19
RCI-97	Commercial Wood-fueled Space Heat Replacing Electric	0.001	19.760	0.002	$0	$20

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-115	Industrial Grocery Distribution Measures	0.003	19.763	0.014	$0	$21
RCI-84	Commercial Rooftop Condensing Burner	0.002	19.765	0.008	$0	$23
AFW-2	Co-Digestion of Food Waste with Dairy Methane	0.312	20.077	1.974	$45	$23
RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	0.002	20.079	0.006	$0	$24
RCI-9	Single Family Weatherization--Windows	0.068	20.147	0.323	$8	$24
RCI-23	Residential Gas Water Heat Measures	0.021	20.168	0.116	$3	$25
RCI-3	Single Family Home HVAC Conversion/Upgrade	0.186	20.354	0.845	$22	$26
RCI-41	Schools HVAC	0.008	20.362	0.038	$1	$26
RCI-32	Residential Wood-fueled Heat Replacing Electric Resistance	0.022	20.384	0.091	$2	$26
RCI-2	Manufactured Home HVAC Conversion/Upgrade	0.126	20.510	0.526	$14	$27
AFW-9	Enhanced Materials Management in New Building Construction	1.224	21.734	6.288	$188	$30
RCI-119	Industrial Paper Sector Measures	0.004	21.738	0.018	$1	$31
PS-8	Geothermal, Binary hydrothermal	0.699	22.436	3.699	$117	$32
RCI-29	Residential Solar Hot Water--Gas Back-up	0.020	22.457	0.111	$4	$34
RCI-49	Commercial Daylighting Natural Replacement/Retrofit	0.004	22.461	0.019	$1	$36
AFW-1	Dairy Methane	0.285	22.746	1.684	$57	$37
RCI-57	Commercial Premium HVAC Natural Replacement/Retro	0.001	22.747	0.003	$0	$38
TLU-17	LCFS9 -- CNG from biogas	0.171	22.918	0.336	$14	$42
TLU-11	LCFS3 -- Imported Cellulosic Ethanol	0.012	22.930	0.012	$0	$42
TLU-12	LCFS4 -- Oregon Wheat Straw Ethanol	0.325	23.255	0.387	$16	$42
RCI-7	Multifamily Weatherization--Windows	0.034	23.289	0.161	$7	$43
RCI-31	Residential CHP	0.039	23.328	0.149	$6	$43
PS-1	Hydropower, New projects	0.259	23.586	1.591	$70	$44
TLU-20	LCFS 12 -- Waste Oil	0.166	23.752	1.580	$72	$45
TLU-15	LCFS7 -- OR Cellulosic EtOH	1.104	24.856	4.555	$211	$46
PS-10	Tidal current, Water current turbines	0.214	25.070	1.184	$55	$47
RCI-8	Single Family Weatherization--Insulation	0.088	25.158	0.403	$19	$47

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-59	Commercial Parking Lighting	0.019	25.177	0.068	$3	$48
RCI-66	Commercial Exit Signs	0.003	25.180	0.011	$1	$49
RCI-5	Manufactured Home Weatherization--Windows	0.023	25.203	0.109	$6	$52
RCI-46	Commercial Premium HVAC New/Integrated Design	0.000	25.203	0.001	$0	$53
RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	0.007	25.211	0.041	$2	$59
PS-5	Animal manure, Reciprocating engine	0.097	25.308	0.904	$56	$61
TLU-16	LCFS8 -- Cellulosic	0.175	25.483	0.175	$11	$63
PS-4	Landfill gas, Reciprocating engine	0.098	25.581	0.823	$52	$63
RCI-91	Commercial Heating Measures--Gas	0.012	25.593	0.065	$4	$67
RCI-18	Residential Cooking Appliance Improvement	0.006	25.600	0.026	$2	$70
RCI-17	Residential Gravity Film Heat Exchanger	0.041	25.640	0.170	$12	$72
RCI-95	Commercial Solar Hot Water--Gas Back-up	0.001	25.641	0.005	$0	$74
PS-3	Wastewater treatment gas, Reciprocating engines	0.015	25.656	0.143	$11	$75
TLU-27	FR6 -- Low Carbon Fuels	0.476	26.133	2.619	$218	$83
RCI-134	Industrial Electronics Industry Solvent Emissions Reduction	0.127	26.259	0.696	$58	$83
PS-6	Woody residues, Steam-electric - brownfield	0.238	26.497	1.683	$160	$95
RCI-19	Residential Solar Water Heat--Electric Back-up	0.190	26.687	0.917	$104	$113
RCI-98	Commercial Wood-fueled Space Heat Replacing Gas	0.000	26.688	0.002	$0	$164
RCI-6	Multifamily Weatherization--Insulation	0.017	26.705	0.076	$9	$122
PS-12	Offshore Wind, Floating WTG	0.627	27.332	2.946	$412	$140
AFW-8a	Forest Management - Rotation Schedules	0.560	27.892	3.080	$431	$140
TLU-13	LCFS5 -- Brazil Sugar Cane EtOH	0.104	27.996	0.589	$91	$155
RCI-67	Commercial Signage	0.003	28.000	0.016	$2	$155
RCI-14	Residential Dishwasher Improvement	0.004	28.004	0.019	$3	$156
RCI-136	Industrial Solar PV	0.115	28.119	0.553	$98	$178
RCI-85	Commercial Ground-source Heat Pump	0.001	28.120	0.005	$1	$181
RCI-100	Commercial Solar PV	0.135	28.255	0.652	$124	$190

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
PS-7	Woody residues, Steam-electric - greenfield	0.258	28.513	1.822	$348	$191
RCI-10	Residential Solar Photovoltaic	0.089	28.601	0.429	$83	$193
TLU-14	LCFS6 -- Low Carbon MW Corn	0.086	28.687	0.661	$132	$199
RCI-94	Commercial Windows Measures--Gas	0.002	28.689	0.013	$3	$205
RCI-21	Residential Refrigerator Recycle	0.001	28.690	0.004	$1	$223
PS-15	Wind (in OR/WA), Wind turbine generators	0.786	29.476	3.948	$885	$224
PS-2	Hydropower, Conventional hydro upgrades in OR	0.055	29.531	0.337	$78	$232
RCI-13	Residential Laundry Appliance Improvement	0.011	29.542	0.049	$12	$240
TLU-1	TL1 -- TriMet - Rail	0.017	29.559	0.035	$49	$248
PS-16	Wind (from Alberta to OR/WA), Wind turbine generators	1.006	30.566	5.054	$1,292	$256
RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	0.014	30.579	0.075	$19	$260
TLU-18	LCFS10 -- Camelian RD	0.332	30.911	1.405	$374	$266
PS-17	Wind (from Montana to OR/WA), Wind turbine generators	0.755	31.666	3.791	$1,072	$283
PS-18	Wind (from Wyoming to OR/WA), Wind turbine generators	0.755	32.421	3.791	$1,151	$304
PS-11	Wave, Various buoy & overtopping devices	0.248	32.669	1.527	$472	$309
TLU-19	LCFS 11 -- NW Canola	0.034	32.704	0.237	$73	$310
PS-14	Solar (Nevada), Parabolic trough	0.698	33.401	3.977	$1,403	$353
TLU-21	LCFS 13 -- MW Soybean	0.000	33.401	0.210	$79	$377
TLU-6	TL6 -- Bend Area Transit	0.001	33.402	0.002	$6	$491
PS-13	Solar, Utility-scale Photovoltaic arrays	0.499	33.901	3.120	$1,822	$584
TLU-4	TL4 -- Salem Area Mass Transit District	0.000	33.902	0.001	$2	$593
TLU-7	TL7 -- City of Corvallis	0.000	33.902	0.001	$2	$593
TLU-9	LCFS1 -- MW Corn Ethanol	0.000	33.902	-0.144	-$86	$597
TLU-10	LCFS2 -- OR Corn Ethanol	0.011	33.913	0.126	$75	$597
TLU-2	TL2 -- TriMet - Bus	0.019	33.932	0.038	$168	$772
TLU-28	LD1 -- Transit Growth	0.123	34.055	0.427	$354	$830
TLU-5	TL5 -- Rogue Valley Transportation District	0.001	34.055	0.001	$6	$856
AFW-8b	Forest Management - Riparian Zones	0.005	34.060	0.028	$28	$1,001
TLU-3	TL3 -- Lane Transit District	0.003	34.063	0.005	$33	$1,058
AFW-6	Urban Forestry	0.042	34.105	0.150	$221	$1,475

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-20	Home Energy Monitor	0.000	34.106	0.002	$8	$3,753
RCI-1	Residential Cooling Appliances	0.000	34.106	0.001	$6	$5,491

Table 6. Marginal Abatement Cost Curve for Scenario 2, Year 2035

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
TLU-37	LD10 -- Carsharing	0.015	0.015	0.175	-$150	-$857
TLU-31	LD4 -- PAYD	0.466	0.481	6.219	-$5,243	-$843
TLU-29	LD2 -- Walk/Bike Short SOV mode shift	0.070	0.551	0.762	-$528	-$693
TLU-34	LD7 -- Parking Management	0.361	0.912	3.521	-$2,440	-$693
TLU-36	LD9 -- Congestion Charges	0.004	0.917	-0.259	$147	-$566
TLU-25	FR4 -- More Energy Efficient Transporter Operations	0.196	1.112	2.346	-$1,120	-$477
TLU-32	LD5 -- TDM	0.062	1.174	0.759	-$335	-$442
TLU-35	LD8 -- Externality Taxes	0.345	1.519	2.044	-$632	-$309
AFW-10	Waste Prevention	0.795	2.314	13.081	-$3,554	-$272
RCI-73	Commercial Clothes Washer	0.015	2.329	0.188	-$40	-$212
TLU-33	LD6 -- EcoDrive	0.492	2.822	4.831	-$896	-$185
TLU-8	TL8 -- Land Use	0.273	3.095	3.233	-$488	-$151
TLU-24	FR3 -- Idle Reduction Strategies	0.039	3.134	0.469	-$67	-$143
TLU-22	FR1 -- Land Use Policy Changes	0.039	3.173	0.469	-$63	-$133
RCI-123	Industrial Agriculture Irrigation Improvements	0.008	3.181	0.142	-$18	-$127
RCI-86	Commercial Laundry Equipment--Gas	0.000	3.181	0.002	$0	-$109
PS-31	Electricity, Additional regulation & telecommunication services	0.005	3.185	0.078	-$5	-$65
TLU-23	FR2 -- Urban Traffic Congestion Relief	0.078	3.263	0.939	-$59	-$63
TLU-26	FR5 -- Mode Shift of Freight in Response to Higher Fees	0.548	3.811	6.570	-$401	-$61
RCI-71	Commercial Ice-Maker Improvements	0.007	3.818	0.087	-$5	-$60
RCI-120	Industrial Lumber Conveyor Replacement	0.012	3.831	0.160	-$10	-$60
RCI-16	Residential Lighting Improvement	0.134	3.965	3.230	-$189	-$59
RCI-129	Industrial Weatherization Measures	0.021	3.986	0.246	-$14	-$57
RCI-128	Industrial Space Heating Measures	0.042	4.028	0.498	-$28	-$57
RCI-127	Industrial Hot Water Measures	0.019	4.047	0.231	-$13	-$57

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-126	Industrial Boiler Measures	0.015	4.063	0.183	-$10	-$56
RCI-87	Commercial Cooking Equipment--Gas	0.009	4.072	0.108	-$6	-$51
RCI-76	Commercial Heat Pump Water Heater	0.025	4.097	0.312	-$16	-$51
RCI-38	Commercial Windows New/Integrated Design	0.001	4.098	0.013	-$1	-$50
RCI-45	Commercial Package Rooftop Measures New/Integrated Design	0.006	4.104	0.064	-$3	-$50
RCI-110	Industrial Electronics Clean Room Measures	0.001	4.105	0.014	-$1	-$50
RCI-102	Industrial General: Lighting and Controls	0.064	4.169	0.798	-$40	-$50
RCI-118	Industrial Kraft Pulp Measures	0.007	4.176	0.085	-$4	-$50
RCI-89	Commercial Insulation Measures--Gas Heat	0.013	4.189	0.152	-$8	-$50
TLU-30	LD3 -- ITS &Operations	0.008	4.197	0.158	-$8	-$49
RCI-116	Industrial Metals Arc Furnace	0.000	4.198	0.005	$0	-$49
RCI-93	Commercial Insulation Measures--Gas	0.004	4.201	0.042	-$2	-$47
RCI-26	Residential Gas Heat Windows	0.036	4.237	0.436	-$19	-$44
RCI-44	Commercial Variable Speed Chiller New/Integrated Design	0.001	4.239	0.016	-$1	-$44
RCI-75	Commercial Hot Water Efficiency Measures	0.002	4.241	0.022	-$1	-$43
RCI-113	Industrial Fruit Storage Measures	0.016	4.257	0.188	-$8	-$43
RCI-24	Residential Gas Furnace Upgrade	0.023	4.280	0.276	-$12	-$42
RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	0.050	4.329	0.724	-$30	-$42
RCI-131	Industrial Biomass-fired CHP	0.142	4.472	1.644	-$67	-$41
RCI-52	Commercial Insulation Natural Replacement/Retrofit	0.072	4.543	0.837	-$34	-$40
PS-30	Electricity, Smart meters	4.227	8.770	45.050	-$1,741	-$39
RCI-15	Residential Refrigerator/Freezer Improvement	0.007	8.777	0.082	-$3	-$35
RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	0.021	8.799	0.308	-$11	-$35
RCI-34	Commercial LDP New/Integrated Design	0.031	8.829	0.345	-$12	-$35
RCI-88	Commercial Hot Water Measures--Gas	0.009	8.838	0.103	-$4	-$35
RCI-121	Industrial Wood Panels Hydraulic Press	0.001	8.839	0.010	$0	-$35
RCI-114	Industrial Food Storage Measures	0.001	8.840	0.014	$0	-$35
RCI-117	Industrial Mechanical Pulp Measures	0.004	8.844	0.045	-$2	-$34

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-48	Commercial LDP Natural Replacement/Retrofit	0.355	9.199	4.574	-$151	-$33
RCI-25	Multifamily HVAC--Gas Heat	0.001	9.200	0.007	$0	-$33
RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	0.013	9.212	0.149	-$5	-$33
RCI-132	Industrial Digester Gas-fired CHP	0.058	9.271	0.691	-$22	-$32
RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	0.006	9.277	0.079	-$2	-$31
RCI-103	Industrial General: Motors Measures	0.007	9.284	0.088	-$3	-$29
RCI-112	Industrial Cold Storage Measures	0.017	9.301	0.197	-$5	-$28
RCI-35	Schools Lighting Measures	0.020	9.321	0.267	-$7	-$27
RCI-74	Commercial Wastewater Heat Exchanger	0.005	9.326	0.058	-$2	-$27
RCI-61	Commercial Computer/Server Improvements	0.051	9.377	0.617	-$16	-$27
RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	0.042	9.420	0.479	-$13	-$27
RCI-106	Industrial General: Transformers	0.007	9.427	0.092	-$2	-$27
RCI-80	Commercial Solar Water Heat	0.014	9.441	0.172	-$5	-$26
RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	0.013	9.454	0.147	-$4	-$26
RCI-62	Commercial Cooking/Food Service Improvements	0.019	9.472	0.251	-$6	-$26
RCI-4	Manufactured Home Weatherization--Insulation	0.039	9.511	0.521	-$13	-$26
RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	0.002	9.513	0.020	$0	-$25
RCI-111	Industrial Food Processing Measures	0.032	9.545	0.399	-$10	-$24
RCI-12	Residential Heat Pump Water Heater	0.375	9.920	4.567	-$110	-$24
RCI-70	Commercial Refrigeration Improvements	0.028	9.948	0.328	-$8	-$24
RCI-83	Commercial Chiller Tower 6F Approach	0.005	9.953	0.060	-$1	-$22
RCI-39	Schools Building Envelope Measures	0.000	9.953	0.001	$0	-$21
RCI-130	Industrial Gas-fired CHP	0.326	10.279	4.161	-$87	-$21
AFW-3	Nutrient Management	0.367	10.646	4.400	-$92	-$21
RCI-78	Commercial Economizer Measures	0.043	10.688	0.526	-$11	-$21
RCI-11	Residential Electric Water Heat Efficiency	0.108	10.797	1.297	-$26	-$20
RCI-42	Commercial Demand Control Ventilation New/Integrated Design	0.011	10.808	0.122	-$2	-$19
RCI-79	Commercial Heat Reclamation Measures	0.001	10.808	0.010	$0	-$19
RCI-28	Residential Multi-Measure Gas Heat	0.113	10.922	1.359	-$25	-$18

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-37	Commercial Lighting Controls New/Integrated Design	0.036	10.958	0.442	-$8	-$18
RCI-107	Industrial General: Materials Movement Measures	0.034	10.992	0.419	-$7	-$18
RCI-33	Residential Wood-fueled Heat Replacing Oil/LPG	0.002	10.993	0.034	-$1	-$17
RCI-101	Industrial General: Air Compressor Measures	0.033	11.026	0.409	-$7	-$17
RCI-99	Commercial Wood-fueled Space Heat Replacing Oil/LPG	0.001	11.028	0.014	$0	-$17
RCI-22	Residential Electronics Improvements	0.075	11.103	1.265	-$21	-$16
RCI-104	Industrial General: Fan Measures	0.061	11.164	0.760	-$12	-$15
RCI-122	Industrial Agriculture Pump and Related Measures	0.018	11.182	0.364	-$5	-$14
RCI-108	Industrial General: Energy Management	0.209	11.392	2.595	-$31	-$12
RCI-58	Commercial Controls Commissioning HVAC Retrofit	0.069	11.461	1.375	-$15	-$11
RCI-65	Commercial DVC Hood	0.004	11.465	0.084	-$1	-$11
RCI-109	Industrial Electronics Chip Fab Measures	0.007	11.472	0.081	$0	-$6
RCI-105	Industrial General: Pump Measures	0.058	11.530	0.714	-$3	-$4
AFW-4a	Biogas Production & Utilization from MSW Biomass	1.905	13.434	32.771	-$131	-$4
RCI-135	Industrial Halon Consumption Reduction	0.021	13.455	0.332	-$1	-$3
RCI-133	Industrial Cement Production Emissions Reduction	0.028	13.483	0.518	-$1	-$2
PS-32	Electricity, Distribution system upgrades	0.517	14.000	8.726	-$8	-$1
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	1.777	15.778	30.418	-$17	-$1
RCI-36	Commercial Daylighting New/Integrated Design	0.008	15.786	0.088	$0	$1
PS-19	Waste heat, Bottoming Rankine cycle	0.078	15.864	1.908	$5	$2
RCI-96	Commercial Gas-fired CHP	0.452	16.316	5.084	$12	$2
AFW-7b	Reforestation/Afforestation of Rangeland	8.433	24.748	105.406	$679	$6
RCI-23	Residential Gas Water Heat Measures	0.048	24.797	0.581	$4	$7
AFW-2	Co-Digestion of Food Waste with Dairy Methane	0.313	25.110	6.184	$46	$7
RCI-97	Commercial Wood-fueled Space Heat Replacing Electric	0.001	25.111	0.012	$0	$9
AFW-5	Landfill Gas Collection & Use	0.324	25.435	5.909	$52	$9

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-115	Industrial Grocery Distribution Measures	0.006	25.441	0.072	$1	$9
RCI-84	Commercial Rooftop Condensing Burner	0.003	25.444	0.040	$0	$10
RCI-41	Schools HVAC	0.008	25.453	0.142	$1	$10
RCI-9	Single Family Weatherization--Windows	0.107	25.560	1.512	$17	$11
AFW-7a	Reforestation/Afforestation of Cropland	11.430	36.990	142.875	$1,651	$12
RCI-29	Residential Solar Hot Water--Gas Back-up	0.047	37.036	0.559	$7	$13
RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	0.004	37.041	0.046	$1	$13
RCI-3	Single Family Home HVAC Conversion/Upgrade	0.324	37.365	4.248	$56	$13
RCI-32	Residential Wood-fueled Heat Replacing Electric Resistance	0.045	37.409	0.526	$7	$13
RCI-2	Manufactured Home HVAC Conversion/Upgrade	0.250	37.660	2.973	$42	$14
RCI-119	Industrial Paper Sector Measures	0.007	37.666	0.085	$1	$17
AFW-1	Dairy Methane	0.271	37.937	5.297	$96	$18
AFW-9	Enhanced Materials Management in New Building Construction	1.620	39.557	24.975	$480	$19
PS-8	Geothermal, Binary hydrothermal	0.527	40.084	11.132	$232	$21
RCI-49	Commercial Daylighting Natural Replacement/Retrofit	0.008	40.092	0.098	$2	$21
RCI-57	Commercial Premium HVAC Natural Replacement/Retro	0.002	40.094	0.023	$1	$23
RCI-7	Multifamily Weatherization--Windows	0.054	40.148	0.756	$19	$25
PS-10	Tidal current, Water current turbines	0.164	40.312	3.501	$100	$29
RCI-59	Commercial Parking Lighting	0.042	40.354	0.469	$14	$29
PS-1	Hydropower, New projects	0.195	40.549	4.344	$131	$30
RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	0.017	40.566	0.205	$6	$30
RCI-66	Commercial Exit Signs	0.002	40.569	0.045	$1	$32
RCI-31	Residential CHP	0.063	40.632	0.792	$26	$33
RCI-46	Commercial Premium HVAC New/Integrated Design	0.001	40.633	0.008	$0	$34
RCI-5	Manufactured Home Weatherization--Windows	0.038	40.671	0.526	$18	$34
RCI-8	Single Family Weatherization--Insulation	0.151	40.821	2.002	$70	$35
PS-4	Landfill gas, Reciprocating engine	0.061	40.882	1.738	$62	$36
RCI-91	Commercial Heating Measures--Gas	0.027	40.909	0.326	$12	$36

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-95	Commercial Solar Hot Water--Gas Back-up	0.002	40.912	0.027	$1	$40
PS-5	Animal manure, Reciprocating engine	0.073	40.985	1.936	$77	$40
TLU-17	LCFS9 -- CNG from biogas	0.394	41.379	0.773	$33	$42
TLU-11	LCFS3 -- Imported Cellulosic Ethanol	0.027	41.405	0.027	$1	$42
TLU-12	LCFS4 -- Oregon Wheat Straw Ethanol	0.748	42.153	0.891	$38	$42
RCI-18	Residential Cooking Appliance Improvement	0.012	42.165	0.148	$6	$43
PS-28	Nuclear, Advanced light water reactor	3.566	45.731	50.710	$2,180	$43
TLU-20	LCFS 12 -- Waste Oil	0.381	46.112	3.634	$165	$45
TLU-15	LCFS7 -- OR Cellulosic EtOH	2.539	48.651	10.477	$485	$46
RCI-17	Residential Gravity Film Heat Exchanger	0.081	48.731	0.961	$45	$46
PS-3	Wastewater treatment gas, Reciprocating engines	0.012	48.743	0.307	$16	$51
PS-29	Nuclear, Small modular reactor	0.958	49.701	13.620	$733	$54
RCI-134	Industrial Electronics Industry Solvent Emissions Reduction	0.127	49.827	2.342	$143	$61
TLU-16	LCFS8 -- Cellulosic	0.403	50.230	0.403	$25	$63
PS-6	Woody residues, Steam-electric - brownfield	0.144	50.374	3.878	$252	$65
RCI-19	Residential Solar Water Heat--Electric Back-up	0.286	50.661	4.179	$321	$77
PS-12	Offshore Wind, Floating WTG	0.490	51.150	9.875	$820	$83
TLU-27	FR6 -- Low Carbon Fuels	1.095	52.245	13.141	$1,095	$83
AFW-8a	Forest Management - Rotation Schedules	0.560	52.805	10.360	$945	$91
RCI-6	Multifamily Weatherization--Insulation	0.031	52.836	0.395	$36	$91
PS-21	Coal, Ultracritical w/CO2 capture (90%)	1.087	53.923	11.954	$1,142	$96
RCI-98	Commercial Wood-fueled Space Heat Replacing Gas	0.001	53.924	0.011	$1	$96
PS-22	Petroleum coke, Gasification combined-cycle	1.101	55.025	12.112	$1,220	$101
RCI-67	Commercial Signage	0.006	55.031	0.079	$8	$106
RCI-14	Residential Dishwasher Improvement	0.008	55.039	0.099	$11	$107
PS-15	Wind (in OR/WA), Wind turbine generators	0.614	55.653	12.632	$1,395	$110
PS-20	Coal, Supercritical w/CO2 capture (90%)	1.033	56.686	11.366	$1,291	$114
RCI-136	Industrial Solar PV	0.173	56.859	2.521	$312	$124

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-85	Commercial Ground-source Heat Pump	0.002	56.861	0.024	$3	$125
RCI-94	Commercial Windows Measures--Gas	0.006	56.866	0.065	$8	$128
RCI-100	Commercial Solar PV	0.204	57.070	2.973	$395	$133
RCI-10	Residential Solar Photovoltaic	0.134	57.204	1.954	$265	$136
PS-7	Woody residues, Steam-electric - greenfield	0.156	57.360	4.197	$596	$142
PS-16	Wind (from Alberta to OR/WA), Wind turbine generators	0.786	58.146	16.171	$2,437	$151
TLU-13	LCFS5 -- Brazil Sugar Cane EtOH	0.240	58.386	1.355	$210	$155
RCI-21	Residential Refrigerator Recycle	0.001	58.388	0.019	$3	$156
RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	0.031	58.419	0.374	$62	$166
RCI-13	Residential Laundry Appliance Improvement	0.022	58.441	0.263	$44	$167
PS-17	Wind (from Montana to OR/WA), Wind turbine generators	0.589	59.030	12.128	$2,030	$167
PS-2	Hydropower, Conventional hydro upgrades in OR	0.041	59.071	0.920	$164	$179
PS-18	Wind (from Wyoming to OR/WA), Wind turbine generators	0.589	59.660	12.128	$2,188	$180
TLU-14	LCFS6 -- Low Carbon MW Corn	0.197	59.857	1.521	$303	$199
PS-14	Solar (Nevada), Parabolic trough	0.538	60.395	11.584	$2,703	$233
PS-11	Wave, Various buoy & overtopping devices	0.187	60.583	4.170	$997	$239
TLU-1	TL1 -- TriMet - Rail	0.035	60.617	0.458	$113	$248
TLU-18	LCFS10 -- Camelian RD	0.764	61.382	3.231	$861	$266
TLU-19	LCFS 11 -- NW Canola	0.079	61.460	0.545	$169	$310
AFW-6	Urban Forestry	0.219	61.679	1.815	$602	$331
PS-13	Solar, Utility-scale Photovoltaic arrays	0.385	62.064	8.563	$3,096	$362
TLU-21	LCFS 13 -- MW Soybean	0.000	62.064	0.482	$181	$377
TLU-6	TL6 -- Bend Area Transit	0.002	62.067	0.030	$15	$491
TLU-4	TL4 -- Salem Area Mass Transit District	0.001	62.067	0.007	$4	$593
TLU-7	TL7 -- City of Corvallis	0.001	62.068	0.007	$4	$593
TLU-9	LCFS1 -- MW Corn Ethanol	0.000	62.068	-0.332	-$198	$597
TLU-10	LCFS2 -- OR Corn Ethanol	0.026	62.093	0.290	$173	$597
AFW-8b	Forest Management - Riparian Zones	0.005	62.098	0.093	$69	$746
TLU-2	TL2 -- TriMet - Bus	0.038	62.136	0.501	$387	$772
TLU-28	LD1 -- Transit Growth	0.369	62.505	2.877	$2,387	$830
TLU-5	TL5 -- Rogue Valley Transportation District	0.001	62.507	0.017	$14	$856
TLU-3	TL3 -- Lane Transit District	0.005	62.512	0.071	$76	$1,058
RCI-20	Home Energy Monitor	0.001	62.513	0.010	$28	$2,809

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-1	Residential Cooling Appliances	0.000	62.513	0.005	$21	$3,997

Table 7. Measures Not Included in the Marginal Abatement Cost Curve for Scenario 2

Measure Number	Measure Group Name	Excluded from 2022	Excluded from 2035	Reason for Exclusion
PS-20	Coal, Supercritical w/CO2 capture (90%)	Yes	No	Implemented after 2022
PS-21	Coal, Ultracritical w/CO2 capture (90%)	Yes	No	Implemented after 2022
PS-22	Petroleum coke, Gasification combined-cycle	Yes	No	Implemented after 2022
PS-28	Nuclear, Advanced light water reactor	Yes	No	Implemented after 2022
PS-29	Nuclear, Small modular reactor	Yes	No	Implemented after 2022
RCI-124	Industrial Rural Area Lighting	Yes	Yes	Implementation assumed to be zero or near-zero under this scenario
RCI-125	Industrial Traffic Signals Relamping	Yes	Yes	ditto
RCI-51	Commercial Windows Natural Replacement/Retrofit	Yes	Yes	ditto
RCI-60	Commercial Refrigeration Improvements	Yes	Yes	ditto
RCI-63	Commercial Wastewater Treatment Improvements	Yes	Yes	ditto
RCI-64	Commercial Water Supply Improvements	Yes	Yes	ditto
RCI-68	Commercial Fume Hood	Yes	Yes	ditto
RCI-69	Commercial Street Lighting	Yes	Yes	ditto
RCI-72	Commercial Vending Machines	Yes	Yes	ditto
RCI-77	Commercial Transformers	Yes	Yes	ditto
RCI-81	Commercial Heating Duct Measures	Yes	Yes	ditto
RCI-82	Commercial Energy Management Systems	Yes	Yes	ditto
RCI-90	Commercial Heat Reclamation--Gas	Yes	Yes	ditto
RCI-92	Commercial Wastewater Heat Exchanger--Gas	Yes	Yes	ditto
TLU-36	LD9 -- Congestion Charges	Yes	No	Emissions increase for 2022

2.3.3 Scenario 3 (Moderate Increase in Federal Action plus additional State Action)

Figure 6. Marginal Abatement Cost Curve for Scenario 3, Year 2022

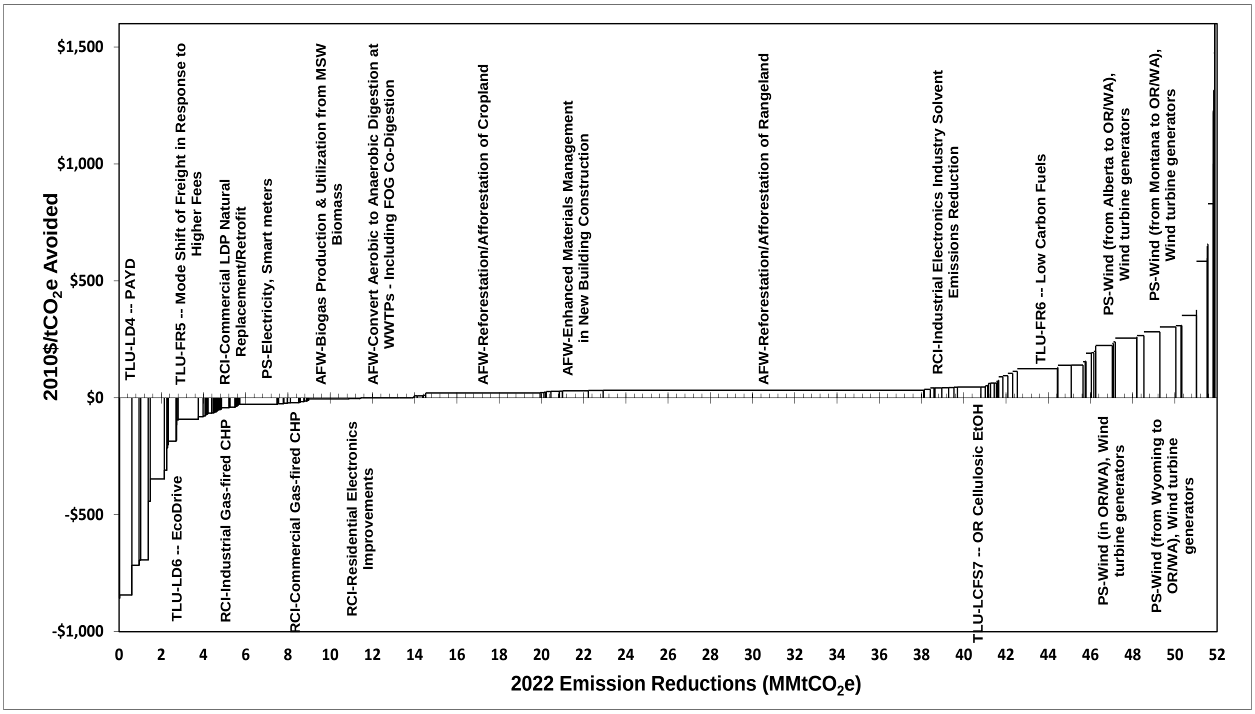


Figure 7. Marginal Abatement Cost Curve for Scenario 3, Year 2035

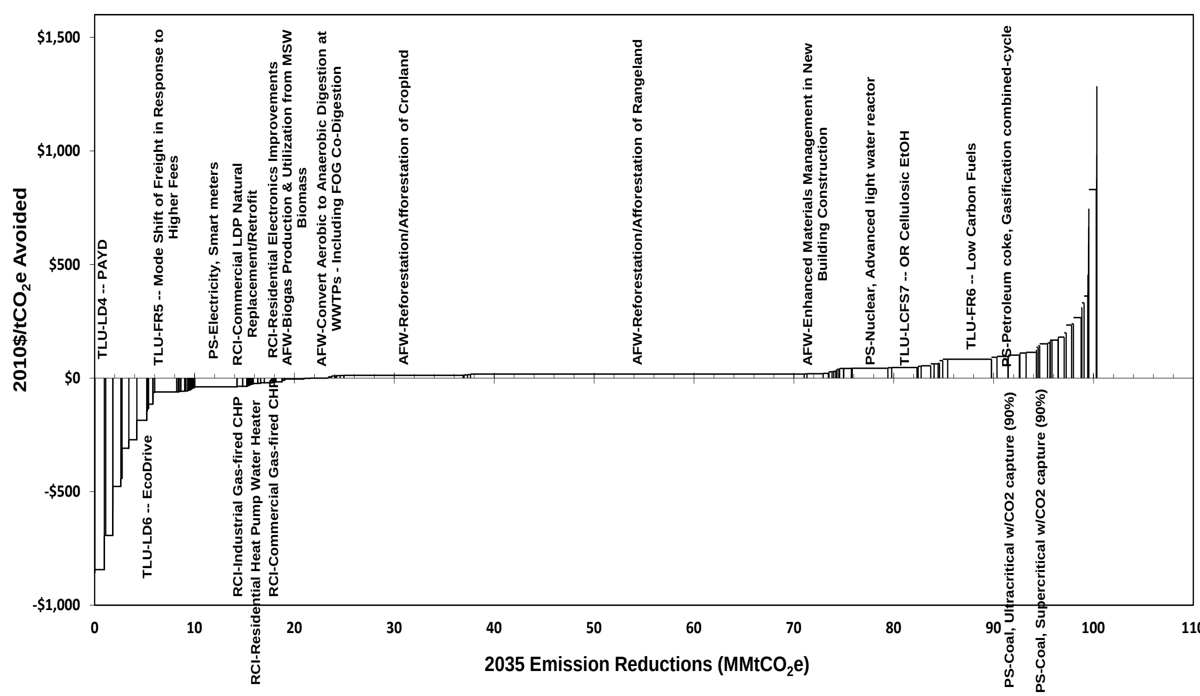


Table 8. Marginal Abatement Cost Curve for Scenario 3, Year 2022

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
TLU-37	LD10 -- Carsharing	0.024	0.024	0.093	-$79	-$857
TLU-31	LD4 -- PAYD	0.586	0.611	1.469	-$1,239	-$843
TLU-25	FR4 -- More Energy Efficient Transporter Operations	0.340	0.951	1.870	-$1,339	-$716
TLU-29	LD2 -- Walk/Bike Short SOV mode shift	0.077	1.028	0.315	-$218	-$693
TLU-34	LD7 -- Parking Management	0.355	1.383	1.343	-$931	-$693
TLU-32	LD5 -- TDM	0.091	1.474	0.307	-$136	-$442
AFW-10	Waste Prevention	0.669	2.143	3.512	-$1,218	-$347
TLU-35	LD8 -- Externality Taxes	0.119	2.262	0.310	-$96	-$309
TLU-24	FR3 -- Idle Reduction Strategies	0.034	2.296	0.187	-$40	-$214
TLU-22	FR1 -- Land Use Policy Changes	0.034	2.330	0.187	-$37	-$200
TLU-33	LD6 -- EcoDrive	0.370	2.700	0.989	-$183	-$185
RCI-73	Commercial Clothes Washer	0.017	2.717	0.080	-$14	-$182
RCI-123	Industrial Agriculture Irrigation Improvements	0.012	2.729	0.056	-$6	-$115
RCI-86	Commercial Laundry Equipment--Gas	0.000	2.729	0.001	$0	-$107
TLU-23	FR2 -- Urban Traffic Congestion Relief	0.068	2.797	0.374	-$35	-$95
TLU-26	FR5 -- Mode Shift of Freight in Response to Higher Fees	0.952	3.749	5.237	-$480	-$92
RCI-16	Residential Lighting Improvement	0.228	3.977	1.461	-$118	-$81
RCI-61	Commercial Computer/Server Improvements	0.096	4.073	0.371	-$29	-$78
RCI-71	Commercial Ice-Maker Improvements	0.005	4.078	0.020	-$2	-$75
RCI-68	Commercial Fume Hood	0.010	4.088	0.043	-$3	-$75
RCI-125	Industrial Traffic Signals Relamping	0.001	4.090	0.006	$0	-$74
RCI-120	Industrial Lumber Conveyor Replacement	0.010	4.099	0.048	-$4	-$74
RCI-77	Commercial Transformers	0.012	4.111	0.055	-$4	-$73
RCI-60	Commercial Refrigeration Improvements	0.005	4.116	0.024	-$2	-$71
RCI-129	Industrial Weatherization Measures	0.009	4.125	0.051	-$4	-$70
RCI-128	Industrial Space Heating Measures	0.019	4.145	0.103	-$7	-$70
RCI-127	Industrial Hot Water Measures	0.010	4.155	0.055	-$4	-$70
RCI-90	Commercial Heat Reclamation--Gas	0.008	4.163	0.039	-$3	-$69
RCI-63	Commercial Wastewater Treatment Improvements	0.022	4.185	0.106	-$7	-$69
RCI-126	Industrial Boiler Measures	0.008	4.193	0.044	-$3	-$69
RCI-124	Industrial Rural Area Lighting	0.000	4.193	0.000	$0	-$68
RCI-81	Commercial Heating Duct	0.001	4.194	0.005	$0	-$66

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
	Measures					
RCI-82	Commercial Energy Management Systems	0.015	4.209	0.070	-$5	-$66
RCI-75	Commercial Hot Water Efficiency Measures	0.004	4.213	0.018	-$1	-$66
RCI-131	Industrial Biomass-fired CHP	0.175	4.388	0.731	-$48	-$65
RCI-38	Commercial Windows New/Integrated Design	0.002	4.390	0.010	-$1	-$65
RCI-132	Industrial Digester Gas-fired CHP	0.077	4.467	0.314	-$20	-$64
RCI-76	Commercial Heat Pump Water Heater	0.018	4.485	0.084	-$5	-$64
RCI-110	Industrial Electronics Clean Room Measures	0.001	4.486	0.004	$0	-$63
RCI-45	Commercial Package Rooftop Measures New/Integrated Design	0.003	4.489	0.014	-$1	-$63
RCI-118	Industrial Kraft Pulp Measures	0.005	4.494	0.023	-$1	-$63
RCI-87	Commercial Cooking Equipment--Gas	0.005	4.499	0.027	-$2	-$63
RCI-92	Commercial Wastewater Heat Exchanger--Gas	0.000	4.499	0.002	$0	-$63
RCI-116	Industrial Metals Arc Furnace	0.000	4.500	0.001	$0	-$62
RCI-102	Industrial General: Lighting and Controls	0.039	4.539	0.189	-$12	-$61
RCI-89	Commercial Insulation Measures--Gas Heat	0.006	4.545	0.032	-$2	-$60
RCI-62	Commercial Cooking/Food Service Improvements	0.030	4.575	0.128	-$8	-$60
RCI-51	Commercial Windows Natural Replacement/Retrofit	0.010	4.585	0.049	-$3	-$60
RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	0.032	4.618	0.166	-$10	-$59
RCI-44	Commercial Variable Speed Chiller New/Integrated Design	0.001	4.619	0.004	$0	-$56
RCI-113	Industrial Fruit Storage Measures	0.010	4.629	0.049	-$3	-$56
RCI-93	Commercial Insulation Measures--Gas	0.002	4.631	0.009	$0	-$55
RCI-39	Schools Building Envelope Measures	0.000	4.631	0.001	$0	-$55
RCI-72	Commercial Vending Machines	0.002	4.633	0.010	-$1	-$55
RCI-69	Commercial Street Lighting	0.034	4.667	0.141	-$8	-$54
RCI-97	Commercial Wood-fueled Space Heat Replacing Electric	0.004	4.671	0.015	-$1	-$54
RCI-88	Commercial Hot Water Measures--Gas	0.009	4.680	0.050	-$3	-$53
RCI-64	Commercial Water Supply Improvements	0.010	4.690	0.046	-$2	-$52

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	0.038	4.727	0.179	-$9	-$51
RCI-74	Commercial Wastewater Heat Exchanger	0.006	4.733	0.026	-$1	-$51
RCI-52	Commercial Insulation Natural Replacement/Retrofit	0.039	4.771	0.172	-$9	-$50
TLU-30	LD3 -- ITS &Operations	0.025	4.797	0.078	-$4	-$49
RCI-26	Residential Gas Heat Windows	0.017	4.814	0.094	-$5	-$49
RCI-24	Residential Gas Furnace Upgrade	0.011	4.824	0.059	-$3	-$48
RCI-34	Commercial LDP New/Integrated Design	0.019	4.843	0.069	-$3	-$47
RCI-121	Industrial Wood Panels Hydraulic Press	0.001	4.844	0.003	$0	-$47
RCI-114	Industrial Food Storage Measures	0.001	4.845	0.004	$0	-$46
RCI-117	Industrial Mechanical Pulp Measures	0.003	4.847	0.012	-$1	-$46
RCI-130	Industrial Gas-fired CHP	0.356	5.203	1.301	-$54	-$42
RCI-15	Residential Refrigerator/Freezer Improvement	0.028	5.231	0.116	-$5	-$41
RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	0.018	5.249	0.081	-$3	-$40
RCI-103	Industrial General: Motors Measures	0.005	5.254	0.024	-$1	-$40
RCI-48	Commercial LDP Natural Replacement/Retrofit	0.235	5.489	1.110	-$45	-$40
RCI-112	Industrial Cold Storage Measures	0.011	5.500	0.051	-$2	-$39
RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	0.004	5.504	0.017	-$1	-$39
RCI-106	Industrial General: Transformers	0.005	5.509	0.025	-$1	-$38
RCI-80	Commercial Solar Water Heat	0.010	5.519	0.046	-$2	-$37
RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	0.001	5.520	0.005	$0	-$36
RCI-35	Schools Lighting Measures	0.015	5.535	0.069	-$2	-$35
RCI-111	Industrial Food Processing Measures	0.023	5.558	0.112	-$4	-$35
RCI-70	Commercial Refrigeration Improvements	0.019	5.577	0.079	-$3	-$35
RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	0.023	5.599	0.083	-$3	-$34
RCI-25	Multifamily HVAC--Gas Heat	0.002	5.601	0.010	$0	-$34
RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	0.008	5.609	0.031	-$1	-$34
RCI-83	Commercial Chiller Tower 6F Approach	0.003	5.612	0.016	-$1	-$32
RCI-78	Commercial Economizer Measures	0.030	5.642	0.141	-$4	-$31

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-79	Commercial Heat Reclamation Measures	0.001	5.643	0.003	$0	-$29
RCI-37	Commercial Lighting Controls New/Integrated Design	0.025	5.668	0.115	-$3	-$28
RCI-107	Industrial General: Materials Movement Measures	0.024	5.692	0.116	-$3	-$28
RCI-4	Manufactured Home Weatherization--Insulation	0.028	5.721	0.129	-$4	-$27
PS-30	Electricity, Smart meters	1.759	7.480	6.796	-$185	-$27
RCI-101	Industrial General: Air Compressor Measures	0.024	7.504	0.113	-$3	-$27
RCI-42	Commercial Demand Control Ventilation New/Integrated Design	0.006	7.510	0.025	-$1	-$26
RCI-104	Industrial General: Fan Measures	0.044	7.553	0.210	-$5	-$25
RCI-12	Residential Heat Pump Water Heater	0.225	7.778	0.979	-$24	-$25
RCI-122	Industrial Agriculture Pump and Related Measures	0.031	7.809	0.150	-$4	-$24
AFW-3	Nutrient Management	0.159	7.968	0.877	-$20	-$23
RCI-108	Industrial General: Energy Management	0.149	8.118	0.718	-$15	-$21
RCI-96	Commercial Gas-fired CHP	0.392	8.510	1.392	-$29	-$21
RCI-65	Commercial DVC Hood	0.006	8.517	0.030	-$1	-$21
RCI-11	Residential Electric Water Heat Efficiency	0.063	8.580	0.269	-$5	-$19
RCI-98	Commercial Wood-fueled Space Heat Replacing Gas	0.003	8.583	0.012	-$0.2	-$17
TLU-8	TL8 -- Land Use	0.178	8.760	1.072	-$17	-$16
RCI-109	Industrial Electronics Chip Fab Measures	0.005	8.765	0.022	$0	-$14
RCI-33	Residential Wood-fueled Heat Replacing Oil/LPG	0.013	8.778	0.102	-$1	-$14
RCI-58	Commercial Controls Commissioning HVAC Retrofit	0.096	8.873	0.476	-$6	-$13
RCI-105	Industrial General: Pump Measures	0.041	8.914	0.197	-$3	-$13
RCI-99	Commercial Wood-fueled Space Heat Replacing Oil/LPG	0.004	8.918	0.016	-$0.2	-$12
RCI-28	Residential Multi-Measure Gas Heat	0.056	8.974	0.307	-$3	-$11
RCI-36	Commercial Daylighting New/Integrated Design	0.005	8.979	0.016	$0	-$7
AFW-4a	Biogas Production & Utilization from MSW Biomass	1.905	10.884	8.010	-$37	-$5
RCI-22	Residential Electronics Improvements	0.516	11.400	3.120	-$9	-$3
RCI-135	Industrial Halon Consumption Reduction	0.042	11.441	0.216	$0	-$2

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-133	Industrial Cement Production Emissions Reduction	0.069	11.511	0.384	$0	$0
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	1.778	13.289	7.312	-$1	$0
PS-31	Electricity, Additional regulation & telecommunication services	0.004	13.292	0.000	$0	$0
PS-32	Electricity, Distribution system upgrades	0.578	13.870	0.000	$0	$0
RCI-23	Residential Gas Water Heat Measures	0.074	13.944	0.404	$0	$0
RCI-115	Industrial Grocery Distribution Measures	0.004	13.948	0.019	$0	$2
RCI-84	Commercial Rooftop Condensing Burner	0.002	13.950	0.011	$0	$3
RCI-91	Commercial Heating Measures--Gas	0.025	13.975	0.138	$1	$6
RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	0.002	13.978	0.008	$0	$6
RCI-31	Residential CHP	0.147	14.124	0.558	$5	$8
AFW-5	Landfill Gas Collection & Use	0.267	14.392	2.034	$18	$9
RCI-119	Industrial Paper Sector Measures	0.005	14.397	0.024	$0	$10
RCI-94	Commercial Windows Measures--Gas	0.012	14.409	0.067	$1	$11
PS-19	Waste heat, Bottoming Rankine cycle	0.104	14.513	0.807	$9	$11
RCI-41	Schools HVAC	0.009	14.522	0.044	$1	$15
AFW-7a	Reforestation/Afforestation of Cropland	5.423	19.945	29.825	$625	$21
RCI-32	Residential Wood-fueled Heat Replacing Electric Resistance	0.178	20.122	0.730	$17	$23
RCI-9	Single Family Weatherization--Windows	0.079	20.202	0.376	$9	$24
RCI-66	Commercial Exit Signs	0.004	20.205	0.015	$0	$25
RCI-59	Commercial Parking Lighting	0.025	20.230	0.091	$2	$25
RCI-49	Commercial Daylighting Natural Replacement/Retrofit	0.005	20.235	0.021	$1	$25
RCI-3	Single Family Home HVAC Conversion/Upgrade	0.218	20.453	0.986	$27	$27
AFW-2	Co-Digestion of Food Waste with Dairy Methane	0.400	20.852	2.292	$63	$28
RCI-57	Commercial Premium HVAC Natural Replacement/Retro	0.001	20.853	0.004	$0	$28
RCI-2	Manufactured Home HVAC Conversion/Upgrade	0.148	21.001	0.621	$18	$29
RCI-46	Commercial Premium HVAC New/Integrated Design	0.000	21.002	0.002	$0	$29

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
AFW-9	Enhanced Materials Management in New Building Construction	1.224	22.226	6.288	$188	$30
PS-8	Geothermal, Binary hydrothermal	0.699	22.925	3.699	$117	$32
AFW-7b	Reforestation/Afforestation of Rangeland	15.182	38.107	83.500	$2,744	$33
RCI-29	Residential Solar Hot Water--Gas Back-up	0.022	38.128	0.119	$4	$34
RCI-67	Commercial Signage	0.008	38.136	0.037	$1	$36
AFW-1	Dairy Methane	0.285	38.421	1.684	$57	$37
TLU-17	LCFS9 -- CNG from biogas	0.171	38.592	0.336	$14	$42
RCI-7	Multifamily Weatherization--Windows	0.040	38.632	0.188	$8	$42
TLU-11	LCFS3 -- Imported Cellulosic Ethanol	0.012	38.644	0.012	$0	$42
TLU-12	LCFS4 -- Oregon Wheat Straw Ethanol	0.325	38.969	0.387	$16	$42
RCI-134	Industrial Electronics Industry Solvent Emissions Reduction	0.316	39.285	1.741	$75	$43
PS-1	Hydropower, New projects	0.259	39.544	1.591	$70	$44
TLU-20	LCFS 12 -- Waste Oil	0.166	39.710	1.580	$72	$45
TLU-15	LCFS7 -- OR Cellulosic EtOH	1.104	40.813	4.555	$211	$46
PS-10	Tidal current, Water current turbines	0.214	41.028	1.184	$55	$47
RCI-95	Commercial Solar Hot Water--Gas Back-up	0.001	41.029	0.007	$0	$51
RCI-8	Single Family Weatherization--Insulation	0.110	41.139	0.499	$26	$52
RCI-5	Manufactured Home Weatherization--Windows	0.028	41.167	0.130	$7	$54
RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	0.009	41.175	0.048	$3	$61
PS-5	Animal manure, Reciprocating engine	0.097	41.272	0.904	$56	$61
TLU-16	LCFS8 -- Cellulosic	0.175	41.448	0.175	$11	$63
PS-4	Landfill gas, Reciprocating engine	0.098	41.546	0.823	$52	$63
RCI-18	Residential Cooking Appliance Improvement	0.050	41.596	0.210	$15	$70
RCI-17	Residential Gravity Film Heat Exchanger	0.046	41.642	0.194	$14	$72
PS-3	Wastewater treatment gas, Reciprocating engines	0.015	41.657	0.143	$11	$75
RCI-136	Industrial Solar PV	0.200	41.858	0.968	$87	$90
PS-6	Woody residues, Steam-electric - brownfield	0.238	42.096	1.683	$160	$95
RCI-100	Commercial Solar PV	0.225	42.321	1.087	$114	$104
RCI-19	Residential Solar Water Heat--Electric Back-up	0.217	42.538	1.048	$119	$113
TLU-27	FR6 -- Low Carbon Fuels	1.904	44.443	10.474	$1,309	$125

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
RCI-85	Commercial Ground-source Heat Pump	0.001	44.444	0.006	$1	$130
RCI-6	Multifamily Weatherization--Insulation	0.022	44.466	0.095	$12	$130
PS-12	Offshore Wind, Floating WTG	0.627	45.093	2.946	$412	$140
AFW-8a	Forest Management - Rotation Schedules	0.560	45.653	3.080	$431	$140
TLU-13	LCFS5 -- Brazil Sugar Cane EtOH	0.104	45.757	0.589	$91	$155
RCI-14	Residential Dishwasher Improvement	0.034	45.791	0.155	$24	$156
PS-7	Woody residues, Steam-electric - greenfield	0.258	46.049	1.822	$348	$191
RCI-10	Residential Solar Photovoltaic	0.118	46.168	0.572	$111	$193
TLU-14	LCFS6 -- Low Carbon MW Corn	0.086	46.253	0.661	$132	$199
RCI-21	Residential Refrigerator Recycle	0.001	46.254	0.005	$1	$223
PS-15	Wind (in OR/WA), Wind turbine generators	0.786	47.040	3.948	$885	$224
PS-2	Hydropower, Conventional hydro upgrades in OR	0.055	47.095	0.337	$78	$232
RCI-13	Residential Laundry Appliance Improvement	0.089	47.184	0.392	$94	$240
PS-16	Wind (from Alberta to OR/WA), Wind turbine generators	1.006	48.190	5.054	$1,292	$256
RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	0.015	48.205	0.080	$21	$260
TLU-18	LCFS10 -- Camelian RD	0.332	48.537	1.405	$374	$266
PS-17	Wind (from Montana to OR/WA), Wind turbine generators	0.755	49.292	3.791	$1,072	$283
PS-18	Wind (from Wyoming to OR/WA), Wind turbine generators	0.755	50.047	3.791	$1,151	$304
PS-11	Wave, Various buoy & overtopping devices	0.248	50.295	1.527	$472	$309
TLU-19	LCFS 11 -- NW Canola	0.034	50.329	0.237	$73	$310
PS-14	Solar (Nevada), Parabolic trough	0.698	51.027	3.977	$1,403	$353
TLU-21	LCFS 13 -- MW Soybean	0.000	51.027	0.210	$79	$377
PS-13	Solar, Utility-scale Photovoltaic arrays	0.499	51.526	3.120	$1,822	$584
TLU-9	LCFS1 -- MW Corn Ethanol	0.000	51.526	-0.144	-$86	$597
TLU-10	LCFS2 -- OR Corn Ethanol	0.011	51.537	0.126	$75	$597
RCI-1	Residential Cooling Appliances	0.002	51.539	0.010	$7	$648
TLU-1	TL1 -- TriMet - Rail	0.026	51.565	0.199	$130	$657
TLU-28	LD1 -- Transit Growth	0.245	51.811	0.853	$708	$830
AFW-8b	Forest Management - Riparian Zones	0.005	51.816	0.028	$28	$1,001
TLU-6	TL6 -- Bend Area Transit	0.002	51.818	0.011	$13	$1,221
TLU-7	TL7 -- City of Corvallis	0.000	51.818	0.003	$3	$1,229
TLU-2	TL2 -- TriMet - Bus	0.029	51.846	0.187	$246	$1,315

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
AFW-6	Urban Forestry	0.042	51.889	0.150	$221	$1,475
TLU-5	TL5 -- Rogue Valley Transportation District	0.001	51.890	0.006	$12	$1,977
TLU-3	TL3 -- Lane Transit District	0.004	51.894	0.026	$63	$2,380
RCI-20	Home Energy Monitor	0.005	51.898	0.021	$68	$3,206
TLU-4	TL4 -- Salem Area Mass Transit District	0.000	51.899	0.004	$18	$4,437

Table 9. Marginal Abatement Cost Curve for Scenario 3, Year 2035

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
TLU-37	LD10 -- Carsharing	0.030	0.030	0.350	-$299.91	-$856.76
TLU-31	LD4 -- PAYD	0.932	0.962	12.438	-$10,486.27	-$843.09
TLU-29	LD2 -- Walk/Bike Short SOV mode shift	0.140	1.102	1.524	-$1,056.15	-$693.23
TLU-34	LD7 -- Parking Management	0.722	1.825	7.041	-$4,880.56	-$693.13
TLU-36	LD9 -- Congestion Charges	0.008	1.833	-0.517	$293.07	-$566.47
TLU-25	FR4 -- More Energy Efficient Transporter Operations	0.782	2.616	9.386	-$4,480.21	-$477.35
TLU-32	LD5 -- TDM	0.123	2.739	1.517	-$670.69	-$442.06
TLU-35	LD8 -- Externality Taxes	0.691	3.430	4.089	-$1,263.09	-$308.93
AFW-10	Waste Prevention	0.795	4.224	13.081	-$3,553.72	-$271.66
TLU-33	LD6 -- EcoDrive	0.985	5.209	9.662	-$1,792.10	-$185.49
TLU-24	FR3 -- Idle Reduction Strategies	0.078	5.287	0.939	-$133.86	-$142.59
TLU-22	FR1 -- Land Use Policy Changes	0.078	5.366	0.939	-$125.17	-$133.33
RCI-73	Commercial Clothes Washer	0.033	5.398	0.406	-$54.11	-$133.28
TLU-8	TL8 -- Land Use	0.439	5.837	5.194	-$598.40	-$115.21
RCI-123	Industrial Agriculture Irrigation Improvements	0.010	5.847	0.189	-$21.42	-$113.25
RCI-86	Commercial Laundry Equipment--Gas	0.000	5.847	0.003	-$0.26	-$85.58
PS-31	Electricity, Additional regulation & telecommunication services	0.005	5.852	0.078	-$5.06	-$64.66
TLU-23	FR2 -- Urban Traffic Congestion Relief	0.156	6.008	1.877	-$118.29	-$63.00
TLU-26	FR5 -- Mode Shift of Freight in Response to Higher Fees	2.190	8.198	26.281	-$1,605.77	-$61.10
RCI-132	Industrial Digester Gas-fired CHP	0.156	8.354	1.842	-$112.32	-$60.96
RCI-125	Industrial Traffic Signals Relamping	0.002	8.356	0.027	-$1.62	-$60.51

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-71	Commercial Ice-Maker Improvements	0.010	8.366	0.116	-$7.02	-$60.44
RCI-68	Commercial Fume Hood	0.021	8.388	0.247	-$14.95	-$60.43
RCI-77	Commercial Transformers	0.022	8.410	0.272	-$16.40	-$60.20
RCI-120	Industrial Lumber Conveyor Replacement	0.016	8.426	0.214	-$12.85	-$60.10
RCI-60	Commercial Refrigeration Improvements	0.008	8.434	0.110	-$6.59	-$59.72
RCI-63	Commercial Wastewater Treatment Improvements	0.031	8.465	0.476	-$28.41	-$59.71
RCI-16	Residential Lighting Improvement	0.153	8.618	3.692	-$216.19	-$58.56
RCI-90	Commercial Heat Reclamation--Gas	0.016	8.634	0.192	-$11.17	-$58.18
RCI-124	Industrial Rural Area Lighting	0.000	8.634	0.002	-$0.09	-$58.12
RCI-131	Industrial Biomass-fired CHP	0.380	9.014	4.384	-$254.38	-$58.03
RCI-129	Industrial Weatherization Measures	0.022	9.036	0.263	-$15.13	-$57.48
RCI-81	Commercial Heating Duct Measures	0.002	9.038	0.024	-$1.38	-$57.47
RCI-82	Commercial Energy Management Systems	0.028	9.066	0.349	-$20.04	-$57.44
RCI-128	Industrial Space Heating Measures	0.045	9.111	0.533	-$30.55	-$57.26
RCI-127	Industrial Hot Water Measures	0.024	9.136	0.288	-$16.44	-$57.04
RCI-61	Commercial Computer/Server Improvements	0.160	9.295	2.215	-$125.91	-$56.85
RCI-126	Industrial Boiler Measures	0.019	9.315	0.229	-$12.92	-$56.54
RCI-75	Commercial Hot Water Efficiency Measures	0.007	9.322	0.089	-$4.92	-$55.28
RCI-38	Commercial Windows New/Integrated Design	0.005	9.327	0.058	-$3.23	-$55.25
RCI-92	Commercial Wastewater Heat Exchanger--Gas	0.001	9.328	0.009	-$0.50	-$54.99
RCI-51	Commercial Windows Natural Replacement/Retrofit	0.020	9.348	0.250	-$13.72	-$54.88
RCI-97	Commercial Wood-fueled Space Heat Replacing Electric	0.008	9.356	0.094	-$5.12	-$54.36
RCI-64	Commercial Water Supply Improvements	0.013	9.369	0.205	-$11.05	-$53.86
RCI-69	Commercial Street Lighting	0.065	9.434	0.782	-$41.70	-$53.32
RCI-76	Commercial Heat Pump Water Heater	0.034	9.468	0.416	-$22.12	-$53.21
RCI-72	Commercial Vending Machines	0.005	9.473	0.059	-$3.15	-$53.18
RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	0.037	9.511	0.613	-$32.35	-$52.82
RCI-87	Commercial Cooking Equipment--Gas	0.011	9.522	0.135	-$7.11	-$52.56
RCI-110	Industrial Electronics Clean Room Measures	0.002	9.524	0.019	-$1.01	-$52.52

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-45	Commercial Package Rooftop Measures New/Integrated Design	0.007	9.531	0.085	-$4.45	-$52.28
RCI-118	Industrial Kraft Pulp Measures	0.009	9.540	0.114	-$5.94	-$52.25
RCI-116	Industrial Metals Arc Furnace	0.001	9.541	0.006	-$0.33	-$51.45
RCI-102	Industrial General: Lighting and Controls	0.074	9.614	0.912	-$46.45	-$50.93
RCI-39	Schools Building Envelope Measures	0.001	9.615	0.007	-$0.38	-$50.51
RCI-89	Commercial Insulation Measures--Gas Heat	0.014	9.629	0.163	-$8.18	-$50.21
TLU-30	LD3 -- ITS &Operations	0.016	9.645	0.317	-$15.66	-$49.47
RCI-62	Commercial Cooking/Food Service Improvements	0.053	9.698	0.699	-$33.38	-$47.77
RCI-44	Commercial Variable Speed Chiller New/Integrated Design	0.002	9.700	0.022	-$1.04	-$47.60
RCI-93	Commercial Insulation Measures--Gas	0.004	9.703	0.045	-$2.11	-$47.32
RCI-88	Commercial Hot Water Measures--Gas	0.021	9.725	0.253	-$11.94	-$47.24
RCI-113	Industrial Fruit Storage Measures	0.022	9.746	0.251	-$11.78	-$46.91
RCI-74	Commercial Wastewater Heat Exchanger	0.011	9.757	0.129	-$5.74	-$44.47
RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	0.057	9.814	0.828	-$36.46	-$44.05
RCI-26	Residential Gas Heat Windows	0.039	9.853	0.471	-$20.40	-$43.34
RCI-52	Commercial Insulation Natural Replacement/Retrofit	0.083	9.936	0.970	-$41.54	-$42.81
RCI-98	Commercial Wood-fueled Space Heat Replacing Gas	0.008	9.944	0.086	-$3.68	-$42.79
RCI-24	Residential Gas Furnace Upgrade	0.025	9.968	0.295	-$12.50	-$42.30
RCI-121	Industrial Wood Panels Hydraulic Press	0.001	9.969	0.013	-$0.53	-$40.95
RCI-34	Commercial LDP New/Integrated Design	0.041	10.010	0.461	-$18.76	-$40.74
RCI-114	Industrial Food Storage Measures	0.002	10.012	0.019	-$0.78	-$40.42
RCI-117	Industrial Mechanical Pulp Measures	0.005	10.017	0.060	-$2.40	-$40.30
PS-30	Electricity, Smart meters	4.227	14.244	45.050	-$1,740.53	-$38.64
RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	0.024	14.268	0.352	-$13.40	-$38.09
RCI-130	Industrial Gas-fired CHP	0.543	14.812	6.935	-$251.50	-$36.27
RCI-103	Industrial General: Motors Measures	0.009	14.821	0.117	-$4.24	-$36.26
RCI-48	Commercial LDP Natural Replacement/Retrofit	0.406	15.227	5.228	-$189.55	-$36.26
RCI-15	Residential Refrigerator/Freezer Improvement	0.055	15.282	0.655	-$23.18	-$35.37

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-112	Industrial Cold Storage Measures	0.022	15.305	0.263	-$9.23	-$35.15
RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	0.007	15.312	0.090	-$3.11	-$34.56
RCI-106	Industrial General: Transformers	0.010	15.322	0.122	-$4.20	-$34.35
RCI-80	Commercial Solar Water Heat	0.019	15.341	0.229	-$7.81	-$34.12
RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	0.017	15.358	0.196	-$6.56	-$33.49
RCI-25	Multifamily HVAC--Gas Heat	0.004	15.362	0.052	-$1.71	-$32.93
RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	0.002	15.364	0.026	-$0.87	-$32.86
RCI-35	Schools Lighting Measures	0.025	15.390	0.324	-$10.60	-$32.74
RCI-111	Industrial Food Processing Measures	0.042	15.432	0.533	-$17.43	-$32.72
RCI-70	Commercial Refrigeration Improvements	0.039	15.470	0.450	-$14.71	-$32.66
RCI-83	Commercial Chiller Tower 6F Approach	0.006	15.477	0.079	-$2.44	-$30.70
RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	0.048	15.525	0.548	-$16.63	-$30.37
RCI-78	Commercial Economizer Measures	0.057	15.582	0.701	-$20.75	-$29.59
RCI-79	Commercial Heat Reclamation Measures	0.001	15.583	0.014	-$0.39	-$28.19
RCI-37	Commercial Lighting Controls New/Integrated Design	0.048	15.632	0.589	-$16.45	-$27.92
RCI-42	Commercial Demand Control Ventilation New/Integrated Design	0.015	15.647	0.163	-$4.47	-$27.50
RCI-107	Industrial General: Materials Movement Measures	0.045	15.692	0.558	-$15.28	-$27.37
RCI-101	Industrial General: Air Compressor Measures	0.044	15.736	0.546	-$14.69	-$26.92
RCI-104	Industrial General: Fan Measures	0.082	15.817	1.014	-$25.91	-$25.56
RCI-122	Industrial Agriculture Pump and Related Measures	0.024	15.842	0.485	-$12.27	-$25.31
RCI-4	Manufactured Home Weatherization--Insulation	0.049	15.890	0.644	-$16.07	-$24.94
RCI-12	Residential Heat Pump Water Heater	0.429	16.319	5.219	-$125.66	-$24.08
RCI-33	Residential Wood-fueled Heat Replacing Oil/LPG	0.013	16.332	0.271	-$6.38	-$23.59
RCI-108	Industrial General: Energy Management	0.279	16.611	3.460	-$78.99	-$22.83
RCI-65	Commercial DVC Hood	0.006	16.617	0.112	-$2.57	-$22.83
AFW-3	Nutrient Management	0.367	16.984	4.400	-$91.66	-$20.83
RCI-96	Commercial Gas-fired CHP	0.754	17.737	8.474	-$174.63	-$20.61
RCI-11	Residential Electric Water Heat Efficiency	0.124	17.861	1.483	-$29.59	-$19.96

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
RCI-109	Industrial Electronics Chip Fab Measures	0.009	17.870	0.108	-$1.95	-$17.97
RCI-28	Residential Multi-Measure Gas Heat	0.128	17.998	1.538	-$26.58	-$17.27
RCI-58	Commercial Controls Commissioning HVAC Retrofit	0.079	18.077	1.571	-$26.99	-$17.18
RCI-105	Industrial General: Pump Measures	0.077	18.154	0.952	-$16.19	-$17.02
RCI-22	Residential Electronics Improvements	0.601	18.754	10.118	-$166.24	-$16.43
RCI-36	Commercial Daylighting New/Integrated Design	0.011	18.765	0.118	-$1.53	-$12.96
RCI-94	Commercial Windows Measures--Gas	0.028	18.793	0.334	-$3.89	-$11.65
RCI-91	Commercial Heating Measures--Gas	0.059	18.852	0.700	-$7.00	-$10.00
RCI-23	Residential Gas Water Heat Measures	0.169	19.021	2.029	-$20.21	-$9.96
RCI-115	Industrial Grocery Distribution Measures	0.008	19.029	0.096	-$0.65	-$6.72
RCI-84	Commercial Rooftop Condensing Burner	0.004	19.034	0.053	-$0.31	-$5.78
AFW-4a	Biogas Production & Utilization from MSW Biomass	1.905	20.938	32.771	-$130.71	-$3.99
RCI-99	Commercial Wood-fueled Space Heat Replacing Oil/LPG	0.011	20.949	0.115	-$0.45	-$3.89
RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	0.006	20.955	0.061	-$0.20	-$3.21
RCI-135	Industrial Halon Consumption Reduction	0.052	21.006	0.831	-$1.01	-$1.21
PS-32	Electricity, Distribution system upgrades	0.517	21.524	8.726	-$7.62	-$0.87
RCI-119	Industrial Paper Sector Measures	0.009	21.533	0.113	-$0.10	-$0.85
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	1.777	23.310	30.418	-$16.81	-$0.55
RCI-133	Industrial Cement Production Emissions Reduction	0.070	23.381	1.296	$0.71	$0.55
RCI-41	Schools HVAC	0.010	23.390	0.165	$0.14	$0.84
PS-19	Waste heat, Bottoming Rankine cycle	0.078	23.468	1.908	$4.56	$2.39
RCI-31	Residential CHP	0.237	23.706	2.969	$15.67	$5.28
AFW-5	Landfill Gas Collection & Use	0.324	24.030	5.909	$51.82	$8.77
RCI-59	Commercial Parking Lighting	0.056	24.086	0.625	$5.98	$9.56
RCI-66	Commercial Exit Signs	0.003	24.089	0.061	$0.65	$10.65
RCI-9	Single Family Weatherization--Windows	0.126	24.215	1.770	$19.02	$10.74
RCI-32	Residential Wood-fueled Heat Replacing Electric Resistance	0.357	24.572	4.206	$45.74	$10.88

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
AFW-2	Co-Digestion of Food Waste with Dairy Methane	0.383	24.956	7.427	$84.50	$11.38
RCI-49	Commercial Daylighting Natural Replacement/Retrofit	0.009	24.965	0.113	$1.37	$12.21
AFW-7a	Reforestation/Afforestation of Cropland	11.930	36.895	149.125	$1,858.44	$12.46
RCI-67	Commercial Signage	0.015	36.910	0.189	$2.40	$12.67
RCI-29	Residential Solar Hot Water--Gas Back-up	0.050	36.960	0.599	$7.61	$12.71
RCI-46	Commercial Premium HVAC New/Integrated Design	0.001	36.961	0.010	$0.13	$12.81
RCI-57	Commercial Premium HVAC Natural Replacement/Retro	0.002	36.963	0.026	$0.36	$13.53
RCI-3	Single Family Home HVAC Conversion/Upgrade	0.379	37.342	4.963	$68.39	$13.78
RCI-2	Manufactured Home HVAC Conversion/Upgrade	0.295	37.637	3.506	$52.41	$14.95
AFW-7b	Reforestation/Afforestation of Rangeland	33.400	71.037	417.500	$7,463.07	$17.88
AFW-1	Dairy Methane	0.271	71.308	5.297	$96.47	$18.21
AFW-9	Enhanced Materials Management in New Building Construction	1.620	72.928	24.975	$479.67	$19.21
PS-8	Geothermal, Binary hydrothermal	0.527	73.455	11.132	$231.61	$20.81
RCI-95	Commercial Solar Hot Water--Gas Back-up	0.003	73.458	0.034	$0.75	$22.23
RCI-7	Multifamily Weatherization--Windows	0.063	73.521	0.886	$21.63	$24.40
RCI-134	Industrial Electronics Industry Solvent Emissions Reduction	0.316	73.838	5.855	$160.09	$27.34
PS-10	Tidal current, Water current turbines	0.164	74.002	3.501	$99.88	$28.53
PS-1	Hydropower, New projects	0.195	74.197	4.344	$130.85	$30.12
RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	0.020	74.217	0.242	$7.49	$30.96
PS-4	Landfill gas, Reciprocating engine	0.061	74.277	1.738	$62.14	$35.75
RCI-5	Manufactured Home Weatherization--Windows	0.046	74.323	0.628	$22.93	$36.52
RCI-8	Single Family Weatherization--Insulation	0.189	74.512	2.495	$95.56	$38.29
PS-5	Animal manure, Reciprocating engine	0.073	74.585	1.936	$77.08	$39.81
TLU-17	LCFS9 -- CNG from biogas	0.394	74.979	0.773	$32.59	$42.18
TLU-11	LCFS3 -- Imported Cellulosic Ethanol	0.027	75.006	0.027	$1.14	$42.46
TLU-12	LCFS4 -- Oregon Wheat Straw Ethanol	0.748	75.753	0.891	$37.81	$42.46
RCI-18	Residential Cooking Appliance Improvement	0.099	75.853	1.180	$50.65	$42.92

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
PS-28	Nuclear, Advanced light water reactor	3.566	79.418	50.710	$2,179.80	$42.99
TLU-20	LCFS 12 -- Waste Oil	0.381	79.799	3.634	$165.02	$45.41
TLU-15	LCFS7 -- OR Cellulosic EtOH	2.539	82.338	10.477	$484.82	$46.27
RCI-17	Residential Gravity Film Heat Exchanger	0.092	82.430	1.098	$50.86	$46.32
PS-3	Wastewater treatment gas, Reciprocating engines	0.012	82.442	0.307	$15.55	$50.60
RCI-136	Industrial Solar PV	0.302	82.744	4.411	$229.02	$51.92
PS-29	Nuclear, Small modular reactor	0.958	83.702	13.620	$732.57	$53.79
RCI-100	Commercial Solar PV	0.339	84.041	4.955	$309.46	$62.46
TLU-16	LCFS8 -- Cellulosic	0.403	84.444	0.403	$25.39	$63.03
PS-6	Woody residues, Steam-electric - brownfield	0.144	84.588	3.878	$252.35	$65.07
RCI-19	Residential Solar Water Heat--Electric Back-up	0.327	84.915	4.776	$367.12	$76.87
PS-12	Offshore Wind, Floating WTG	0.490	85.405	9.875	$820.36	$83.08
TLU-27	FR6 -- Low Carbon Fuels	4.380	89.785	52.562	$4,380.17	$83.33
RCI-85	Commercial Ground-source Heat Pump	0.003	89.788	0.032	$2.63	$83.48
AFW-8a	Forest Management - Rotation Schedules	0.560	90.348	10.360	$944.70	$91.19
PS-21	Coal, Ultracritical w/CO2 capture (90%)	1.087	91.435	11.954	$1,142.07	$95.54
RCI-6	Multifamily Weatherization--Insulation	0.039	91.474	0.497	$48.29	$97.25
PS-22	Petroleum coke, Gasification combined-cycle	1.101	92.575	12.112	$1,220.32	$100.75
RCI-14	Residential Dishwasher Improvement	0.064	92.638	0.789	$84.69	$107.32
PS-15	Wind (in OR/WA), Wind turbine generators	0.614	93.252	12.632	$1,394.97	$110.43
PS-20	Coal, Supercritical w/CO2 capture (90%)	1.033	94.285	11.366	$1,291.06	$113.59
RCI-10	Residential Solar Photovoltaic	0.178	94.464	2.605	$353.11	$135.56
PS-7	Woody residues, Steam-electric - greenfield	0.156	94.620	4.197	$596.16	$142.03
PS-16	Wind (from Alberta to OR/WA), Wind turbine generators	0.786	95.406	16.171	$2,436.54	$150.67
TLU-13	LCFS5 -- Brazil Sugar Cane EtOH	0.240	95.646	1.355	$209.67	$154.68
RCI-21	Residential Refrigerator Recycle	0.002	95.648	0.025	$3.89	$156.28
RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	0.033	95.681	0.401	$66.58	$165.96
RCI-13	Residential Laundry Appliance Improvement	0.174	95.855	2.104	$351.20	$166.89
PS-17	Wind (from Montana to OR/WA), Wind turbine generators	0.589	96.445	12.128	$2,030.25	$167.40

Measure Number	Measure Group Name	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
PS-2	Hydropower, Conventional hydro upgrades in OR	0.041	96.486	0.920	$164.40	$178.61
PS-18	Wind (from Wyoming to OR/WA), Wind turbine generators	0.589	97.075	12.128	$2,188.02	$180.40
TLU-14	LCFS6 -- Low Carbon MW Corn	0.197	97.272	1.521	$302.58	$198.99
PS-14	Solar (Nevada), Parabolic trough	0.538	97.810	11.584	$2,703.47	$233.38
PS-11	Wave, Various buoy & overtopping devices	0.187	97.998	4.170	$996.89	$239.07
TLU-18	LCFS10 -- Camelian RD	0.764	98.762	3.231	$861.12	$266.48
TLU-19	LCFS 11 -- NW Canola	0.079	98.841	0.545	$168.90	$309.65
AFW-6	Urban Forestry	0.219	99.060	1.815	$601.52	$331.34
PS-13	Solar, Utility-scale Photovoltaic arrays	0.385	99.445	8.563	$3,095.50	$361.52
TLU-21	LCFS 13 -- MW Soybean	0.000	99.445	0.482	$181.45	$376.56
RCI-1	Residential Cooling Appliances	0.004	99.448	0.049	$22.08	$454.62
TLU-1	TL1 -- TriMet - Rail	0.052	99.501	0.693	$319.57	$460.89
TLU-6	TL6 -- Bend Area Transit	0.003	99.504	0.046	$24.86	$545.02
TLU-9	LCFS1 -- MW Corn Ethanol	0.000	99.504	-0.332	-$198.17	$597.27
TLU-10	LCFS2 -- OR Corn Ethanol	0.026	99.530	0.290	$173.28	$597.27
TLU-7	TL7 -- City of Corvallis	0.001	99.531	0.011	$7.13	$664.93
TLU-4	TL4 -- Salem Area Mass Transit District	0.001	99.532	0.011	$7.13	$664.93
AFW-8b	Forest Management - Riparian Zones	0.005	99.537	0.093	$69.02	$746.17
TLU-28	LD1 -- Transit Growth	0.738	100.275	5.753	$4,774.39	$829.86
TLU-2	TL2 -- TriMet - Bus	0.057	100.332	0.760	$665.21	$875.51
TLU-5	TL5 -- Rogue Valley Transportation District	0.002	100.334	0.026	$25.14	$982.13
TLU-3	TL3 -- Lane Transit District	0.008	100.342	0.108	$139.02	$1,285.20
RCI-20	Home Energy Monitor	0.007	100.350	0.096	$229.48	$2,388.43

Table 10. Measures Not Included in the Marginal Abatement Cost Curve for Scenario 3

Measure Number	Measure Group Name	Excluded from 2022	Excluded from 2035	Reason for Exclusion
PS-20	Coal, Supercritical w/CO2 capture (90%)	Yes	No	Implemented after 2022
PS-21	Coal, Ultracritical w/CO2 capture (90%)	Yes	No	Implemented after 2022
PS-22	Petroleum coke, Gasification combined-cycle	Yes	No	Implemented after 2022
PS-28	Nuclear, Advanced light water reactor	Yes	No	Implemented after 2022
PS-29	Nuclear, Small modular reactor	Yes	No	Implemented after 2022
TLU-36	LD9 -- Congestion Charges	Yes	No	Emissions increase for 2022

2.4 Sector-Level Marginal Abatement Cost Curve Components for Scenario 3

This section presents marginal abatement cost curves for Scenario 3 for 2022 and 2035. The measure-level data presented here has not been adjusted for overlaps and interactions between measures.

Figure 8. Power Supply Sector - Marginal Abatement Cost Curve for Scenario 3, Year 2022

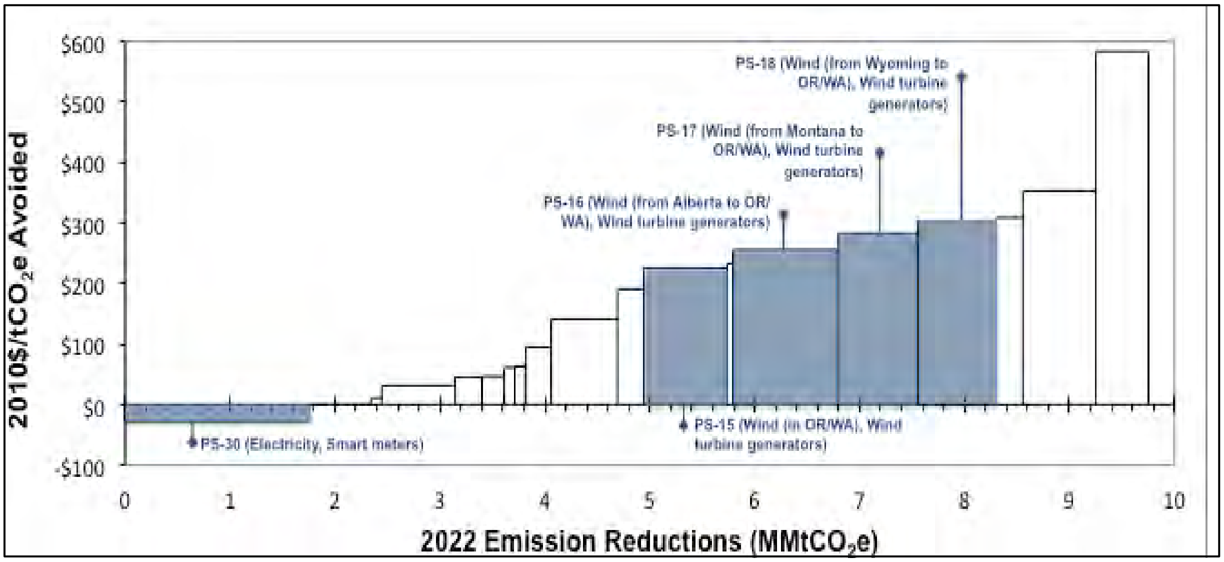


Figure 9. Power Supply Sector - Marginal Abatement Cost Curve for Scenario 3, Year 2035

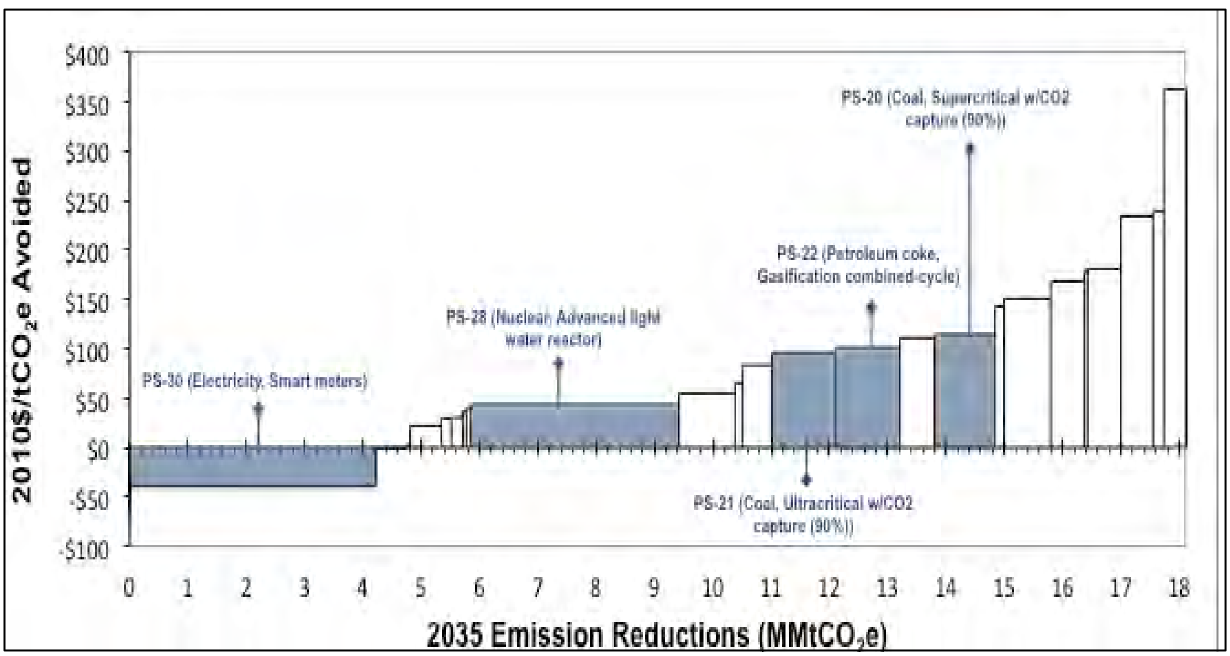
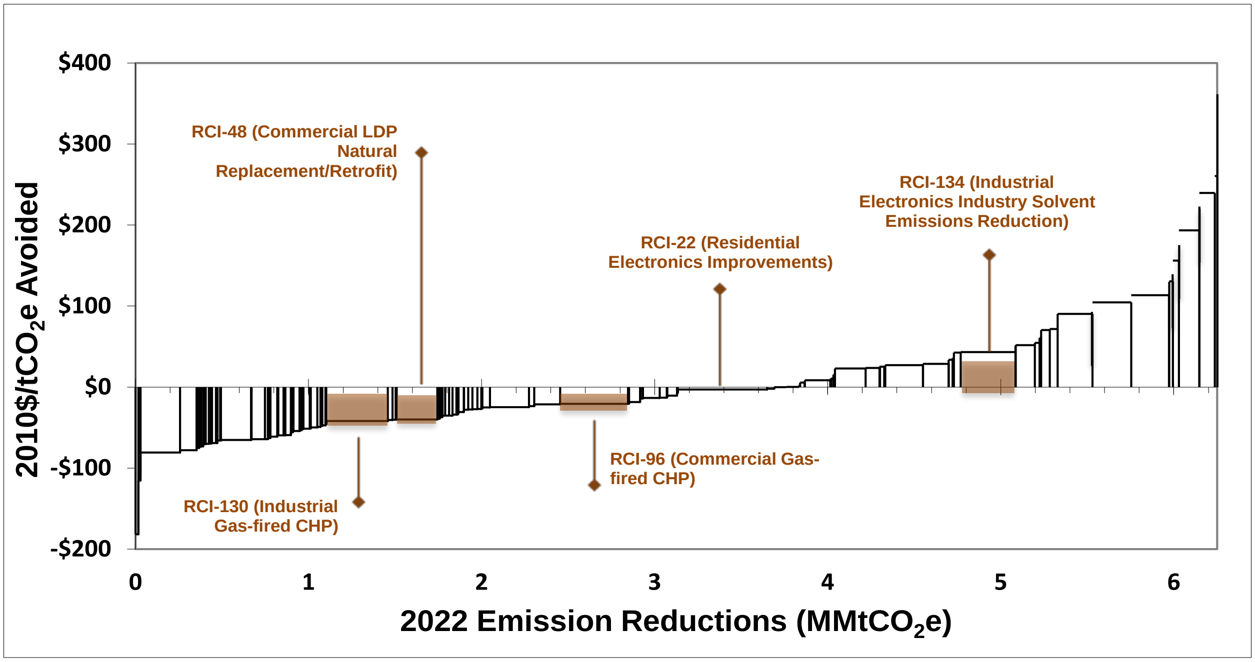
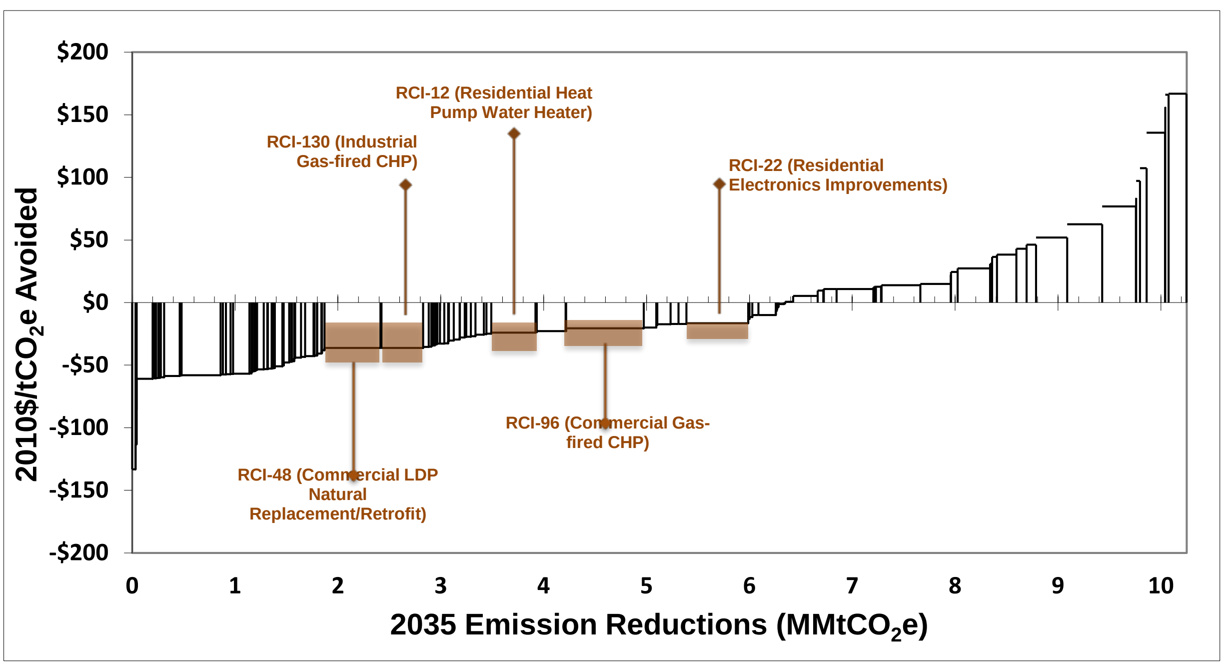


Figure 10. Residential, Commercial, and Industrial Sectors - Marginal Abatement Cost Curve for Scenario 3, Year 2022



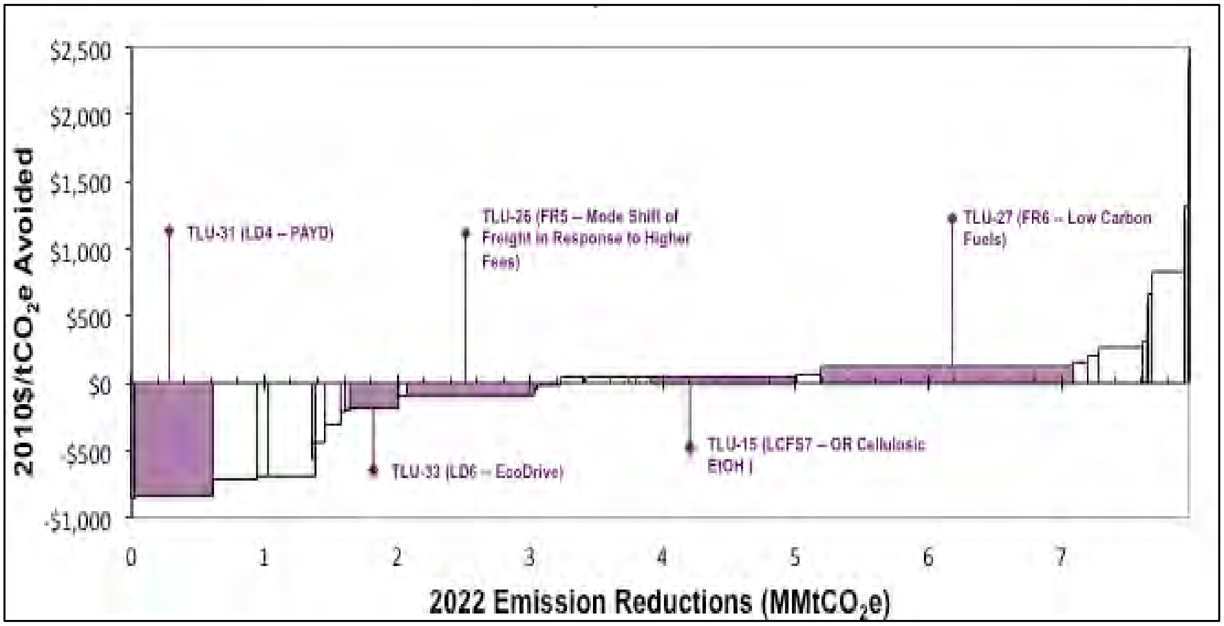
Note: RCI-1 (Residential Cooling Appliances) has a cost-effectiveness value of \$648/MMtCO$_2$e and RCI-20 (Home Energy Monitor) has a cost-effectiveness value of \$3,206/MMtCO$_2$e. These measures are not included in the chart due to the effects of the large cost-effectiveness values on the Y-axis scale.

Figure 11. Residential, Commercial, and Industrial Sectors - Marginal Abatement Cost Curve for Scenario 3, Year 2035



Note: RCI-1 (Residential Cooling Appliances) has a cost-effectiveness value of \$648/MMtCO$_2$e and RCI-20 (Home Energy Monitor) has a cost-effectiveness value of \$3,206/MMtCO$_2$e. These measures are not included in the chart due to the effects of the large cost-effectiveness values on the Y-axis scale.

Figure 12. Transportation and Land Use Sectors - Marginal Abatement Cost Curve for Scenario 3, Year 2022



Note: TLU-4 (Salem Area Mass Transit District) has a cost-effectiveness value of \$4,437/MMtCO$_2$e. This measure is not included in the chart due to the effects of its large cost-effectiveness value on the Y-axis scale.

Figure 13. Transportation and Land Use Sectors - Marginal Abatement Cost Curve for Scenario 3, Year 2035

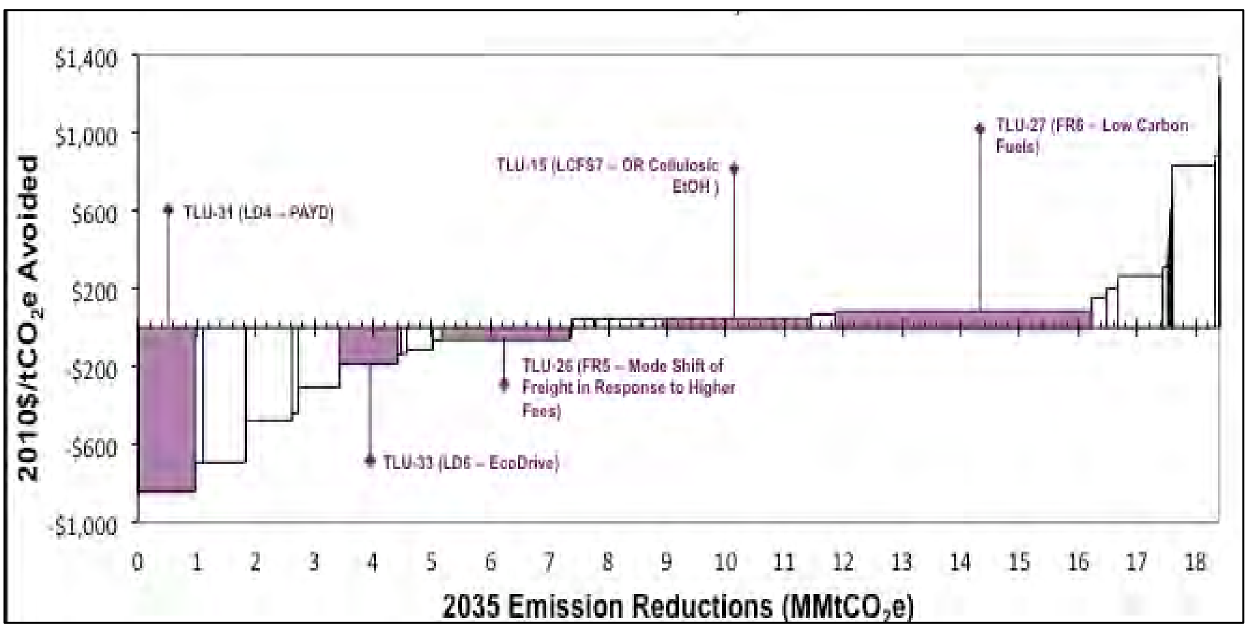
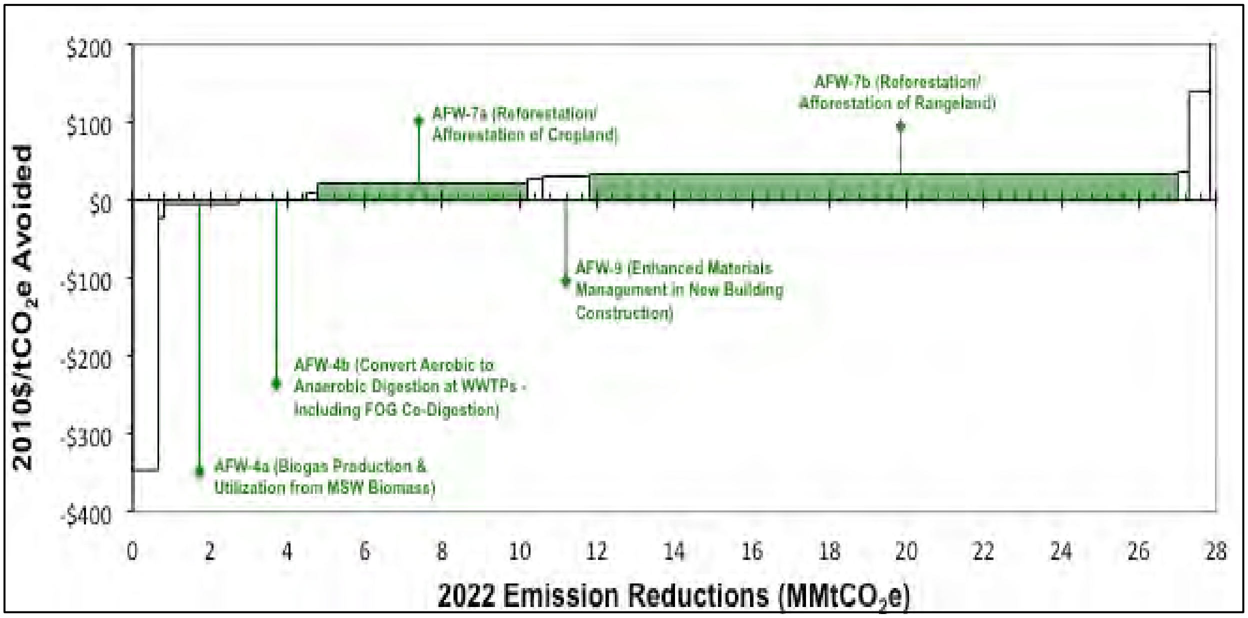
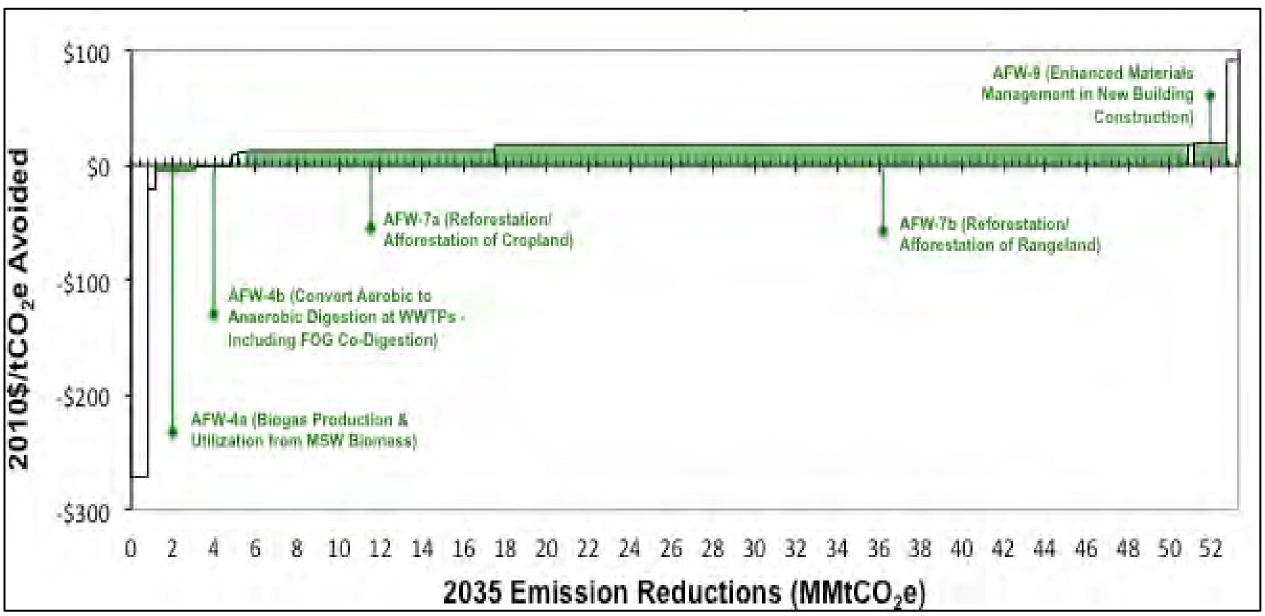


Figure 14. Agricultural, Forestry and Waste Sectors - Marginal Abatement Cost Curve for Scenario 3, Year 2022



Note: AFW-6 (Urban Forestry) has a cost-effectiveness value of $1,475/MMtCO2e and AFW-8b (Forest Management - Riparian Zones) has a cost-effectiveness value of $1,000/MMtCO2e. These measures are not included in the chart due to the effects of the large cost-effectiveness values on the Y-axis scale.

Figure 15. Agricultural, Forestry and Waste Sectors - Marginal Abatement Cost Curve for Scenario 3, Year 2035



Note: AFW-6 (Urban Forestry) has a cost-effectiveness value of $331/MMtCO$_2$e and AFW-8b (Forest Management - Riparian Zones) has a cost-effectiveness value of $746/MMtCO$_2$e. These measures are not included in the chart due to the effects of the large cost-effectiveness values on the Y-axis scale.

2.5 Foundational Macroeconomic Modeling - Marginal Abatement Cost Curves Used for Least-Cost Forecasts for Scenario 2 and Scenario 3

This section presents marginal abatement cost curves for Scenario 2 and Scenario 3 for 2022 and 2035 that were used for the foundation modeling least-cost forecasts. The measure-level data presented for each scenario and year have been adjusted to account for obvious overlaps between sectors. However, a complete analysis of measure interactions and overlaps was not possible given the time and resource constraints associated with this project. Thus, it important to note the uncertainty here related to the use of these cumulative emission reductions for a list of measures for which a comprehensive assessment has been completed to fully account for all interactions and overlaps. The results of the foundational modeling for Scenario 2 and Scenario 3 are presented in Chapter 3.

As input to the Macroeconomic modeling, the RCI measures were combined into more aggregated groups of measures addressing similar end-uses and/or with likely similar modes of implementation. This was done to create, on average, larger capital cost increments to better match with the capabilities of the REMI model to resolve the impacts of cost flows in the Oregon economy, and to create a smaller number (in this case, 55 rather than 136) number of measures for ease in handling in the REMI model. The 55 RCI measure groups used as inputs to the REMI model were aggregated from the original 800-plus RCI measures derived largely from Northwest Power and Conservation Council and Energy Trust of Oregon source materials, as were the 136 RCI measures included in the mitigation cost curves described in this Chapter. For additional details on this aggregation, see Appendix B, and the worksheet "Aggregation_Assignments" in the RCI measure analysis workbook "ODOE-RCI-Options-Final.xlsx".

2.5.1 Scenario 2 (Moderate Increase in Federal Action)

Figure 16. Foundational Modeling - Marginal Abatement Cost Curve for Scenario 2, Year 2022

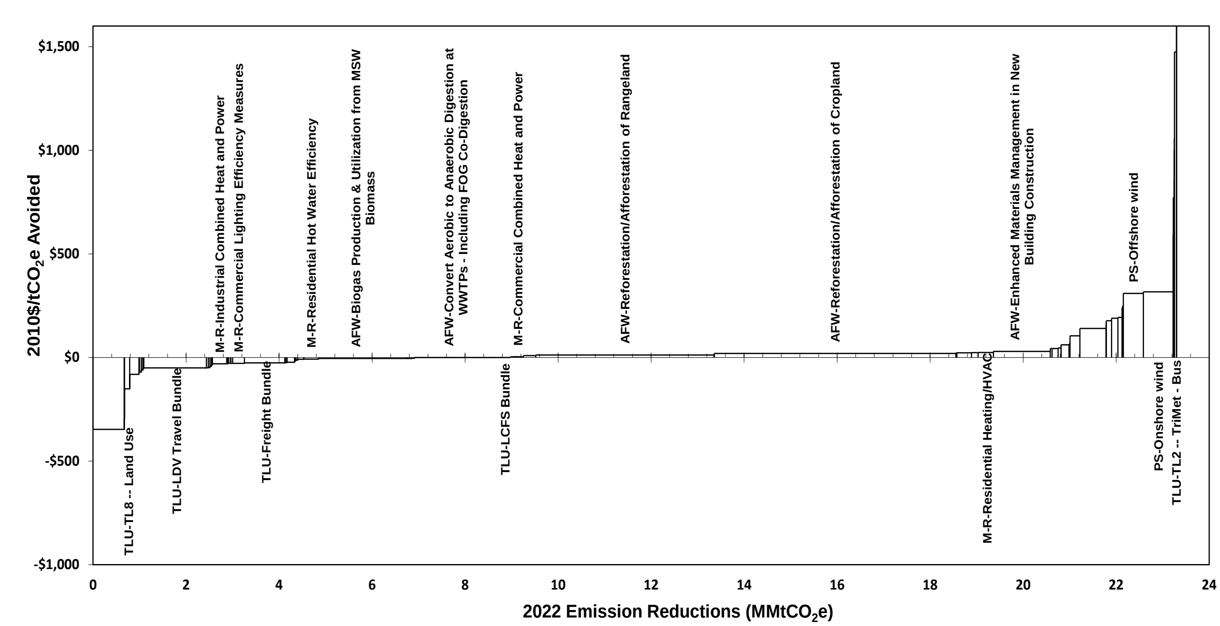


Figure 17. Foundational Modeling - Marginal Abatement Cost Curve for Scenario 2, Year 2035

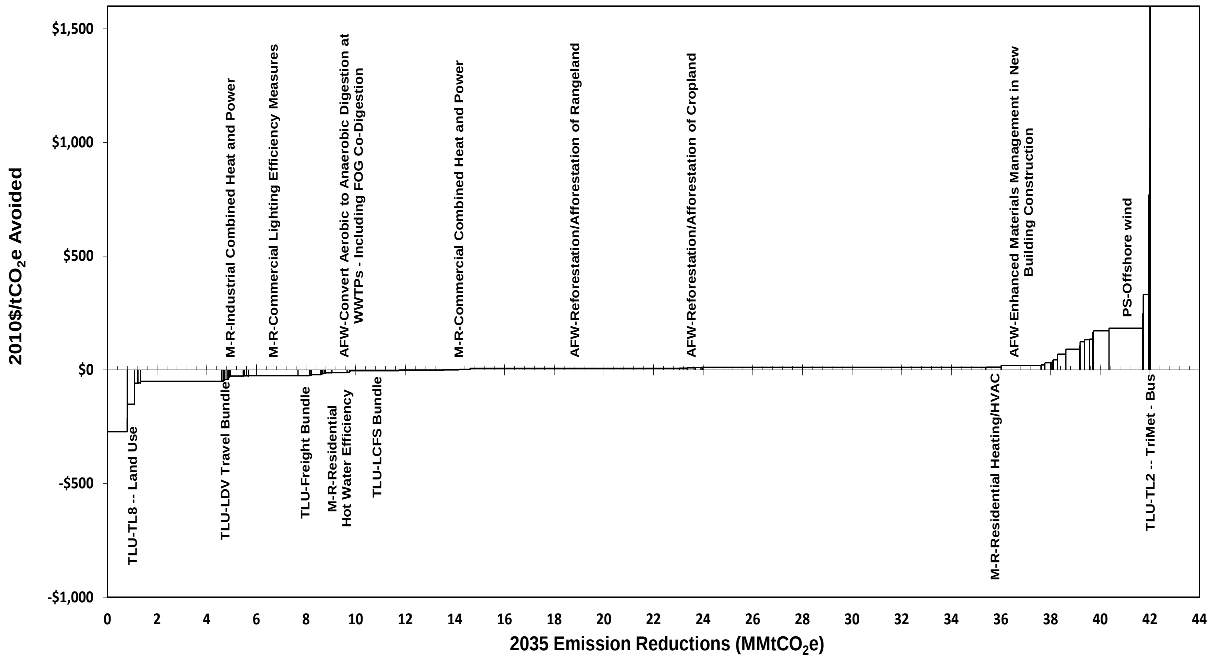


Table 11. Foundational Modeling - Marginal Abatement Cost Curve for Scenario 2, Year 2022

Measure Number	Measure Group Name	Included in 2020 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
AFW-10	Waste Prevention	Y	0.669	0.669	3.512	-$1,218	-$347
M-RCI-28	Commercial Laundry Appliances Measures	Y	0.008	0.677	0.037	-$11	-$293
TLU-8	TL8 -- Land Use	Y	0.111	0.788	0.273	-$212	-$151
M-RCI-10	Residential Lighting	Y	0.200	0.988	1.278	-$103	-$81
M-RCI-49	Industrial Wood Products Measures	Y	0.008	0.996	0.038	-$3	-$71
M-RCI-52	Industrial Space/Water Heating and Weatherization Measures	Y	0.042	1.037	0.222	-$16	-$70
M-RCI-39	Industrial Lighting and Control Measures	Y	0.034	1.072	0.166	-$10	-$60
M-RCI-47	Industrial Arc Furnace Measures	Y	0.000	1.072	0.001	$0	-$59
M-RCI-32	Commercial Water Heating Efficiency Measures	Y	0.021	1.092	0.099	-$5	-$52

Measure Number	Measure Group Name	Included in 2020 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
TLU-28-37	LDV Travel Bundle	Y	1.346	2.439	17.252	-$870	-$50
M-RCI-26	Commercial Building Insulation Measures	Y	0.040	2.479	0.187	-$9	-$49
M-RCI-23	Commercial Chillers Measures	Y	0.034	2.513	0.160	-$8	-$49
M-RCI-50	Industrial Agricultural Irrigation Measures	Y	0.032	2.545	0.154	-$6	-$42
M-RCI-27	Commercial Refrigeration Measures	Y	0.017	2.562	0.072	-$3	-$36
M-RCI-40	Industrial Motors Measures	Y	0.004	2.566	0.018	-$1	-$31
M-RCI-53	Industrial Combined Heat and Power	Y	0.308	2.874	1.172	-$36	-$31
M-RCI-30	Commercial Cooking Appliances Measures	Y	0.019	2.893	0.081	-$2	-$31
M-RCI-29	Commercial Electronics/Transformer Measures	Y	0.026	2.919	0.122	-$3	-$28
M-RCI-22	Commercial HVAC Control Measures	Y	0.040	2.959	0.179	-$5	-$28
M-RCI-43	Industrial Transformers	Y	0.004	2.963	0.019	-$1	-$28
M-RCI-46	Industrial Food Processing/Storage Measures	Y	0.037	3.000	0.176	-$5	-$28
M-RCI-18	Commercial Lighting Efficiency Measures	Y	0.256	3.256	1.173	-$33	-$28
TLU-22-27	Freight Bundle	Y	0.867	4.123	10.406	-$267	-$26
M-RCI-24	Commercial HVAC System Improvements	Y	0.021	4.144	0.095	-$2	-$25
M-RCI-20	Commercial Lighting Controls Measures	Y	0.028	4.172	0.121	-$3	-$24
AFW-3	Nutrient Management	Y	0.159	4.332	0.877	-$20	-$23
M-RCI-48	Industrial Pulp and Paper Industry Measures	Y	0.009	4.341	0.044	-$1	-$19
M-RCI-38	Industrial Air Compressor Measures	Y	0.018	4.359	0.085	-$1	-$15
M-RCI-33	Commercial Solar Water Heating	Y	0.008	4.367	0.040	-$1	-$14
M-RCI-41	Industrial Fan Efficiency Measures	Y	0.033	4.400	0.158	-$2	-$12
M-RCI-44	Industrial Energy Management	Y	0.130	4.530	0.625	-$5	-$9
M-RCI-45	Industrial Electronics Manufacturing Measures	Y	0.004	4.534	0.020	$0	-$8

Measure Number	Measure Group Name	Included in 2020 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
M-RCI-6	Residential Hot Water Efficiency	Y	0.313	4.847	1.378	-$11	-$8
AFW-4a	Biogas Production & Utilization from MSW Biomass	Y	1.905	6.753	8.010	-$37	-$5
M-RCI-25	Commercial Commissioning Measures	Y	0.096	6.849	0.472	-$2	-$5
M-RCI-14	Residential Electronics	Y	0.064	6.913	0.390	-$1	-$3
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	Y	1.778	8.691	7.312	-$1	$0
TLU-9-21	LCFS Bundle	Y	0.277	8.967	4.036	$1	$0
M-RCI-42	Industrial Pump Efficiency Measures	Y	0.031	8.998	0.148	$0	$3
M-RCI-19	Commercial Daylighting Measures	Y	0.019	9.017	0.072	$0	$3
M-RCI-35	Commercial Combined Heat and Power	Y	0.235	9.253	0.835	$3	$4
AFW-5	Landfill Gas Collection & Use	Y	0.267	9.520	2.034	$18	$9
AFW-7b	Reforestation/Afforestation of Rangeland	Y	3.833	13.353	21.081	$250	$12
M-RCI-9	Residential Refrigerators/Freezers	Y	0.004	13.357	0.019	$0	$17
AFW-7a	Reforestation/Afforestation of Cropland	Y	5.195	18.553	28.575	$556	$19
M-RCI-17	Residential Biomass Heating	Y	0.024	18.577	0.104	$2	$22
AFW-2	Co-Digestion of Food Waste with Dairy Methane	Y	0.312	18.889	1.974	$45	$23
M-RCI-4	Residential Windows	Y	0.141	19.030	0.680	$16	$24
M-RCI-2	Residential Heating/HVAC	Y	0.330	19.360	1.468	$36	$25
AFW-9	Enhanced Materials Management in New Building Construction	Y	1.224	20.584	6.288	$188	$30
M-RCI-16	Residential CHP	Y	0.039	20.623	0.149	$6	$43
M-RCI-36	Commercial Heating Systems--Biomass	Y	0.001	20.624	0.006	$0.2	$43
M-RCI-3	Residential Insulation/Weatherization	Y	0.128	20.753	0.585	$25	$43
M-RCI-15	Residential Heating Duct Sealing/Multi-Measure	Y	0.063	20.816	0.345	$16	$47
M-RCI-54	Industrial Non-energy GHG Reduction	Y	0.171	20.987	0.936	$57	$61

Measure Number	Measure Group Name	Included in 2020 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
	Measures						
M-RCI-34	Commercial Heating Systems Measures--Conventional	Y	0.017	21.004	0.088	$6	$63
M-RCI-11	Residential Cooking Appliances	Y	0.006	21.010	0.026	$2	$70
M-RCI-12	Residential Solar Hot Water	Y	0.210	21.220	1.028	$108	$105
AFW-8a	Forest Management - Rotation Schedules	Y	0.560	21.780	3.080	$431	$140
M-RCI-8	Residential Dishwasher	Y	0.004	21.784	0.019	$3	$156
M-RCI-21	Commercial Building Windows Measures	Y	0.003	21.787	0.015	$3	$167
M-RCI-55	Industrial Solar PV	Y	0.115	21.901	0.553	$98	$178
M-RCI-37	Commercial Solar PV	Y	0.135	22.037	0.652	$124	$190
M-RCI-5	Residential Solar PV	Y	0.089	22.125	0.429	$83	$193
M-RCI-7	Residential Laundry Appliances	Y	0.011	22.136	0.049	$12	$240
TLU-1	TL1 -- TriMet - Rail	Y	0.017	22.154	0.035	$49	$248
PS-offshore wind	Offshore wind	Y	0.432	22.585	1.497	$463	$310
PS-onshore wind	Onshore wind	Y	0.640	23.226	3.925	$1,244	$317
TLU-6	TL6 -- Bend Area Transit	Y	0.001	23.227	0.002	$6	$491
TLU-4	TL4 -- Salem Area Mass Transit District	Y	0.000	23.227	0.001	$2	$593
TLU-7	TL7 -- City of Corvallis	Y	0.000	23.227	0.001	$2	$593
TLU-2	TL2 -- TriMet - Bus	Y	0.019	23.246	0.038	$168	$772
TLU-5	TL5 -- Rogue Valley Transportation District	Y	0.001	23.247	0.001	$6	$856
AFW-8b	Forest Management - Riparian Zones	Y	0.005	23.252	0.028	$28	$1,001
TLU-3	TL3 -- Lane Transit District	Y	0.003	23.254	0.005	$33	$1,058
AFW-6	Urban Forestry	Y	0.042	23.297	0.150	$221	$1,475
M-RCI-13	Residential Energy Monitor	Y	0.000	23.297	0.002	$8	$3,753
M-RCI-1	Residential Cooling	Y	0.000	23.298	0.001	$6	$5,491

Table 12. Foundational Modeling - Marginal Abatement Cost Curve for Scenario 2, Year 2035

Measure Number	Measure Group Name	Included in 2035 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
AFW-10	Waste Prevention	Y	0.795	0.795	13.081	-$3,554	-$272
M-RCI-28	Commercial Laundry Appliances Measures	Y	0.015	0.810	0.190	-$40	-$211
TLU-8	TL8 -- Land Use	Y	0.273	1.083	3.233	-$488	-$151
M-RCI-10	Residential Lighting	Y	0.134	1.217	3.230	-$189	-$59
M-RCI-49	Industrial Wood Products Measures	Y	0.013	1.230	0.170	-$10	-$58
M-RCI-52	Industrial Space/Water Heating and Weatherization Measures	Y	0.098	1.328	1.157	-$66	-$57
TLU-28-37	LDV Travel Bundle	Y	3.271	4.599	39.679	-$2,002	-$50
M-RCI-39	Industrial Lighting and Control Measures	Y	0.064	4.663	0.798	-$40	-$50
M-RCI-47	Industrial Arc Furnace Measures	Y	0.000	4.664	0.005	$0	-$49
M-RCI-50	Industrial Agricultural Irrigation Measures	Y	0.026	4.690	0.506	-$23	-$46
M-RCI-32	Commercial Water Heating Efficiency Measures	Y	0.041	4.730	0.495	-$22	-$44
M-RCI-26	Commercial Building Insulation Measures	Y	0.088	4.818	1.031	-$43	-$42
M-RCI-23	Commercial Chillers Measures	Y	0.051	4.869	0.741	-$31	-$42
M-RCI-27	Commercial Refrigeration Measures	Y	0.035	4.904	0.415	-$13	-$32
M-RCI-30	Commercial Cooking Appliances Measures	Y	0.032	4.937	0.443	-$13	-$29
M-RCI-40	Industrial Motors Measures	Y	0.007	4.944	0.088	-$3	-$29
M-RCI-53	Industrial Combined Heat and Power	Y	0.527	5.471	6.496	-$177	-$27
M-RCI-29	Commercial Electronics/Transformer Measures	Y	0.051	5.522	0.617	-$16	-$27
M-RCI-46	Industrial Food Processing/Storage Measures	Y	0.072	5.594	0.871	-$23	-$27
M-RCI-43	Industrial Transformers	Y	0.007	5.601	0.092	-$2	-$27
M-RCI-22	Commercial HVAC Control Measures	Y	0.079	5.680	0.947	-$25	-$26

Measure Number	Measure Group Name	Included in 2035 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
TLU-22-27	Freight Bundle	Y	1.995	7.675	23.935	-$615	-$26
M-RCI-18	Commercial Lighting Efficiency Measures	Y	0.456	8.131	5.757	-$147	-$26
M-RCI-24	Commercial HVAC System Improvements	Y	0.033	8.164	0.444	-$11	-$25
M-RCI-20	Commercial Lighting Controls Measures	Y	0.056	8.219	0.666	-$16	-$25
AFW-3	Nutrient Management	Y	0.367	8.586	4.400	-$92	-$21
M-RCI-48	Industrial Pulp and Paper Industry Measures	Y	0.017	8.604	0.215	-$4	-$20
M-RCI-33	Commercial Solar Water Heating	Y	0.016	8.620	0.199	-$3	-$17
M-RCI-38	Industrial Air Compressor Measures	Y	0.033	8.653	0.409	-$7	-$17
M-RCI-14	Residential Electronics	Y	0.075	8.728	1.265	-$21	-$16
M-RCI-41	Industrial Fan Efficiency Measures	Y	0.061	8.789	0.760	-$12	-$15
M-RCI-44	Industrial Energy Management	Y	0.243	9.032	3.014	-$38	-$13
M-RCI-45	Industrial Electronics Manufacturing Measures	Y	0.008	9.040	0.096	-$1	-$12
M-RCI-6	Residential Hot Water Efficiency	Y	0.613	9.653	7.406	-$87	-$12
M-RCI-25	Commercial Commissioning Measures	Y	0.088	9.741	1.633	-$17	-$10
M-RCI-42	Industrial Pump Efficiency Measures	Y	0.058	9.799	0.714	-$3	-$4
M-RCI-19	Commercial Daylighting Measures	Y	0.041	9.839	0.464	-$2	-$4
AFW-4a	Biogas Production & Utilization from MSW Biomass	Y	1.905	11.744	32.771	-$131	-$4
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	Y	1.777	13.521	30.418	-$17	-$1
TLU-9-21	LCFS Bundle	Y	0.626	14.147	9.284	$1	$0
M-RCI-9	Residential Refrigerators/Freezers	Y	0.008	14.155	0.101	$0	$0
M-RCI-35	Commercial Combined Heat and Power	Y	0.452	14.608	5.084	$12	$2
AFW-7b	Reforestation/Afforestation of Rangeland	Y	8.433	23.040	105.406	$679	$6
AFW-2	Co-Digestion of Food Waste with Dairy Methane	Y	0.313	23.353	6.184	$46	$7

Measure Number	Measure Group Name	Included in 2035 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
AFW-5	Landfill Gas Collection & Use	Y	0.324	23.677	5.909	$52	$9
M-RCI-4	Residential Windows	Y	0.235	23.912	3.230	$34	$11
M-RCI-17	Residential Biomass Heating	Y	0.046	23.959	0.560	$6	$12
AFW-7a	Reforestation/Afforestation of Cropland	Y	11.430	35.389	142.875	$1,651	$12
M-RCI-2	Residential Heating/HVAC	Y	0.615	36.004	7.708	$92	$12
AFW-9	Enhanced Materials Management in New Building Construction	Y	1.620	37.624	24.975	$480	$19
M-RCI-15	Residential Heating Duct Sealing/Multi-Measure	Y	0.144	37.768	1.734	$37	$21
M-RCI-36	Commercial Heating Systems--Biomass	Y	0.003	37.772	0.037	$1	$24
M-RCI-3	Residential Insulation/Weatherization	Y	0.220	37.992	2.918	$92	$32
M-RCI-16	Residential CHP	Y	0.063	38.055	0.792	$26	$33
M-RCI-34	Commercial Heating Systems Measures--Conventional	Y	0.037	38.092	0.443	$15	$34
M-RCI-11	Residential Cooking Appliances	Y	0.012	38.105	0.148	$6	$43
M-RCI-54	Industrial Non-energy GHG Reduction Measures	Y	0.175	38.280	3.193	$141	$44
M-RCI-12	Residential Solar Hot Water	Y	0.333	38.613	4.738	$328	$69
AFW-8a	Forest Management - Rotation Schedules	Y	0.560	39.173	10.360	$945	$91
M-RCI-21	Commercial Building Windows Measures	Y	0.007	39.180	0.079	$8	$99
M-RCI-8	Residential Dishwasher	Y	0.008	39.188	0.099	$11	$107
M-RCI-55	Industrial Solar PV	Y	0.173	39.360	2.521	$312	$124
M-RCI-37	Commercial Solar PV	Y	0.204	39.564	2.973	$395	$133
M-RCI-5	Residential Solar PV	Y	0.134	39.698	1.954	$265	$136
M-RCI-7	Residential Laundry Appliances	Y	0.022	39.720	0.263	$44	$167
PS-offshore wind	Offshore wind	Y	0.631	40.351	9.167	$1,574	$172
PS-onshore wind	Onshore wind	Y	1.347	41.698	18.931	$3,463	$183
TLU-1	TL1 -- TriMet - Rail	Y	0.035	41.733	0.458	$113	$248

Measure Number	Measure Group Name	Included in 2035 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
AFW-6	Urban Forestry	Y	0.219	41.951	1.815	$602	$331
TLU-6	TL6 -- Bend Area Transit	Y	0.002	41.954	0.030	$15	$491
TLU-4	TL4 -- Salem Area Mass Transit District	Y	0.001	41.954	0.007	$4	$593
TLU-7	TL7 -- City of Corvallis	Y	0.001	41.955	0.007	$4	$593
AFW-8b	Forest Management - Riparian Zones	Y	0.005	41.960	0.093	$69	$746
TLU-2	TL2 -- TriMet - Bus	Y	0.038	41.998	0.501	$387	$772
TLU-5	TL5 -- Rogue Valley Transportation District	Y	0.001	41.999	0.017	$14	$856
TLU-3	TL3 -- Lane Transit District	Y	0.005	42.004	0.071	$76	$1,058
M-RCI-13	Residential Energy Monitor	Y	0.001	42.005	0.010	$28	$2,809
M-RCI-1	Residential Cooling	Y	0.000	42.005	0.005	$21	$3,997

2.5.2 Scenario 3 (Moderate Increase in Federal Action plus additional State Action)

Figure 18. Foundational Modeling - Marginal Abatement Cost Curve for Scenario 3, Year 2022

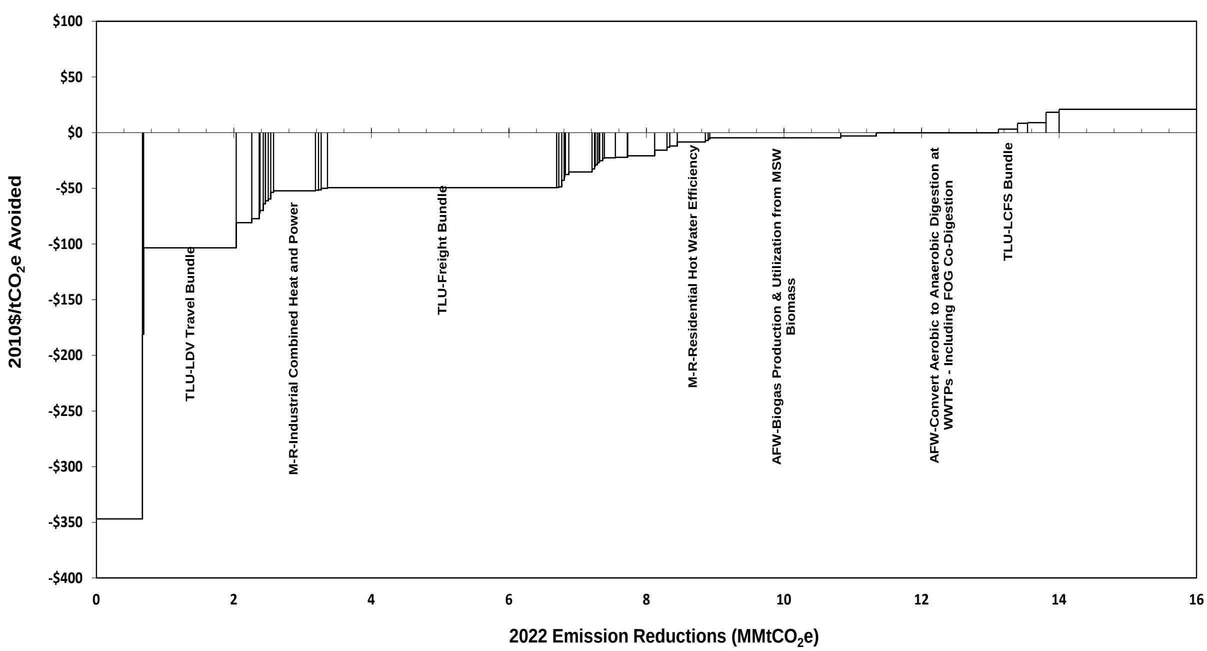


Figure 19. Foundational Modeling - Marginal Abatement Cost Curve for Scenario 3, Year 2035

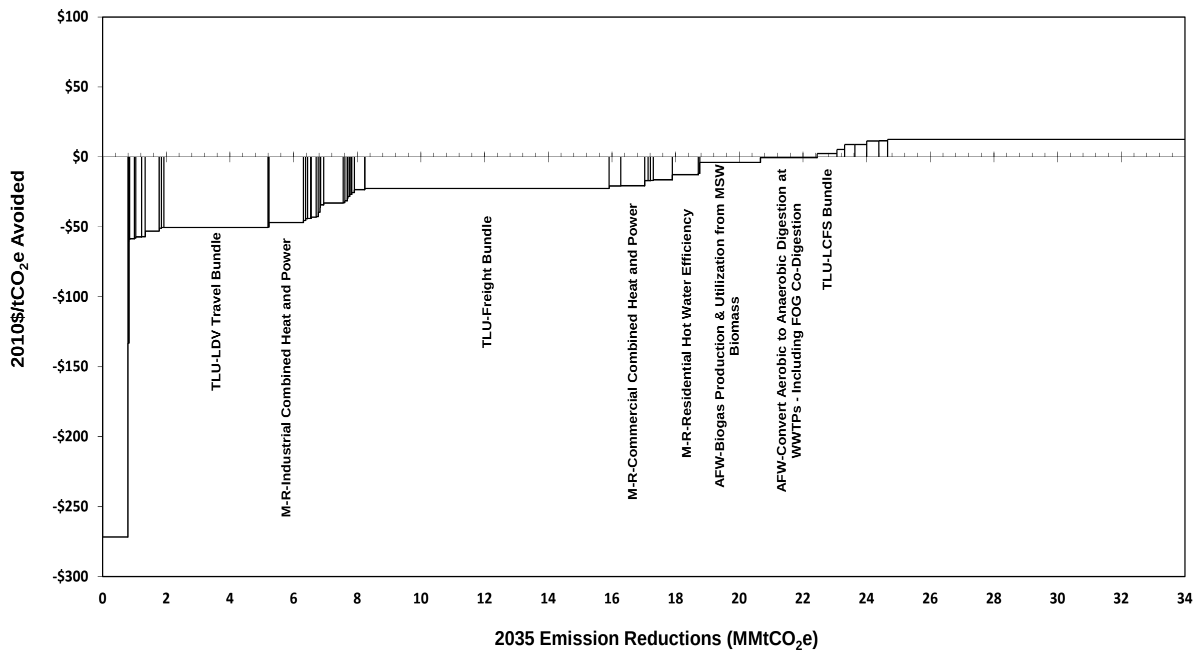


Table 13. Foundational Modeling - Marginal Abatement Cost Curve for Scenario 3, Year 2022

Measure Number	Measure Group Name	Included in 2020 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
AFW-10	Waste Prevention	Y	0.669	0.669	3.512	-$1,218	-$347
M-RCI-28	Commercial Laundry Appliances Measures	Y	0.017	0.686	0.080	-$15	-$181
TLU-28-37	LDV Travel Bundle	Y	1.346	2.033	16.817	-$1,741	-$103
M-RCI-10	Residential Lighting	Y	0.228	2.261	1.461	-$118	-$81
M-RCI-29	Commercial Electronics/Transformer Measures	Y	0.108	2.369	0.426	-$33	-$77
M-RCI-51	Industrial Street and Traffic Lighting	Y	0.001	2.370	0.006	$0	-$74
M-RCI-49	Industrial Wood Products Measures	Y	0.010	2.380	0.051	-$4	-$72
M-RCI-52	Industrial Space/Water Heating and Weatherization Measures	Y	0.047	2.427	0.253	-$18	-$70

Measure Number	Measure Group Name	Included in 2020 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
M-RCI-31	Commercial Water/Wastewater Measures	Y	0.032	2.459	0.153	-$10	-$64
M-RCI-47	Industrial Arc Furnace Measures	Y	0.000	2.459	0.001	$0	-$62
M-RCI-39	Industrial Lighting and Control Measures	Y	0.039	2.499	0.189	-$12	-$61
M-RCI-32	Commercial Water Heating Efficiency Measures	Y	0.037	2.535	0.179	-$11	-$60
M-RCI-30	Commercial Cooking Appliances Measures	Y	0.041	2.577	0.185	-$10	-$54
M-RCI-53	Industrial Combined Heat and Power	Y	0.608	3.185	2.346	-$122	-$52
M-RCI-26	Commercial Building Insulation Measures	Y	0.046	3.231	0.213	-$11	-$52
M-RCI-23	Commercial Chillers Measures	Y	0.039	3.269	0.183	-$9	-$51
M-RCI-22	Commercial HVAC Control Measures	Y	0.091	3.361	0.435	-$22	-$50
TLU-22-27	Freight Bundle	Y	3.333	6.693	18.330	-$906	-$49
M-RCI-27	Commercial Refrigeration Measures	Y	0.031	6.725	0.134	-$7	-$49
M-RCI-50	Industrial Agricultural Irrigation Measures	Y	0.043	6.767	0.206	-$10	-$49
M-RCI-24	Commercial HVAC System Improvements	Y	0.035	6.803	0.155	-$7	-$43
M-RCI-40	Industrial Motors Measures	Y	0.005	6.808	0.024	-$1	-$40
M-RCI-43	Industrial Transformers	Y	0.005	6.813	0.025	-$1	-$38
M-RCI-46	Industrial Food Processing/Storage Measures	Y	0.049	6.862	0.234	-$9	-$38
M-RCI-18	Commercial Lighting Efficiency Measures	Y	0.338	7.200	1.528	-$54	-$35
M-RCI-20	Commercial Lighting Controls Measures	Y	0.036	7.236	0.155	-$5	-$33
M-RCI-48	Industrial Pulp and Paper Industry Measures	Y	0.012	7.248	0.059	-$2	-$30
M-RCI-9	Residential Refrigerators/Freezers	Y	0.029	7.277	0.121	-$4	-$29
M-RCI-36	Commercial Heating Systems--Biomass	Y	0.011	7.288	0.044	-$1	-$28
M-RCI-38	Industrial Air Compressor Measures	Y	0.024	7.311	0.113	-$3	-$27

Measure Number	Measure Group Name	Included in 2020 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
M-RCI-33	Commercial Solar Water Heating	Y	0.011	7.322	0.053	-$1	-$26
M-RCI-41	Industrial Fan Efficiency Measures	Y	0.044	7.366	0.210	-$5	-$25
M-RCI-21	Commercial Building Windows Measures	Y	0.025	7.391	0.126	-$3	-$23
AFW-3	Nutrient Management	Y	0.159	7.551	0.877	-$20	-$23
M-RCI-44	Industrial Energy Management	Y	0.173	7.724	0.834	-$18	-$22
M-RCI-45	Industrial Electronics Manufacturing Measures	Y	0.005	7.730	0.026	-$1	-$22
M-RCI-35	Commercial Combined Heat and Power	Y	0.392	8.122	1.392	-$29	-$21
TLU-8	TL8 -- Land Use	Y	0.178	8.300	1.072	-$17	-$16
M-RCI-42	Industrial Pump Efficiency Measures	Y	0.041	8.341	0.197	-$3	-$13
M-RCI-25	Commercial Commissioning Measures	Y	0.111	8.452	0.544	-$7	-$12
M-RCI-6	Residential Hot Water Efficiency	Y	0.408	8.859	1.847	-$15	-$8
M-RCI-34	Commercial Heating Systems Measures--Conventional	Y	0.041	8.900	0.214	-$2	-$7
M-RCI-19	Commercial Daylighting Measures	Y	0.023	8.923	0.085	$0	-$6
AFW-4a	Biogas Production & Utilization from MSW Biomass	Y	1.905	10.828	8.010	-$37	-$5
M-RCI-14	Residential Electronics	Y	0.516	11.344	3.120	-$9	-$3
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	Y	1.778	13.122	7.312	-$1	$0
TLU-9-21	LCFS Bundle	Y	0.277	13.398	2.040	$7	$3
M-RCI-16	Residential CHP	Y	0.147	13.545	0.558	$5	$8
AFW-5	Landfill Gas Collection & Use	Y	0.267	13.812	2.034	$18	$9
M-RCI-17	Residential Biomass Heating	Y	0.190	14.003	0.833	$15	$18
AFW-7a	Reforestation/Afforestation of Cropland	Y	5.423	19.426	29.825	$625	$21
M-RCI-4	Residential Windows	Y	0.164	19.590	0.787	$19	$25
M-RCI-2	Residential Heating/HVAC	Y	0.387	19.977	1.724	$44	$26
AFW-2	Co-Digestion of Food Waste with Dairy Methane	Y	0.400	20.376	2.292	$63	$28

Measure Number	Measure Group Name	Included in 2020 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2022 (MMtCO2e)	Cumulative Annual GHG Reductions, 2022 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2022	Net Present Value (Million 2010 $), 2013-2022	Average Cost Effectiveness, 2013-2022 ($/tCO2e) [Y-Axis]
AFW-9	Enhanced Materials Management in New Building Construction	Y	1.224	21.601	6.288	$188	$30
M-RCI-54	Industrial Non-energy GHG Reduction Measures	Y	0.428	22.028	2.341	$75	$32
AFW-7b	Reforestation/Afforestation of Rangeland	Y	15.182	37.210	83.500	$2,744	$33
M-RCI-15	Residential Heating Duct Sealing/Multi-Measure	N	0.070	37.280	0.387	$18	$45
M-RCI-3	Residential Insulation/Weatherization	N	0.160	37.440	0.724	$35	$48
M-RCI-11	Residential Cooking Appliances	N	0.050	37.490	0.210	$15	$70
M-RCI-55	Industrial Solar PV	N	0.200	37.690	0.968	$87	$90
M-RCI-37	Commercial Solar PV	N	0.225	37.915	1.087	$114	$104
M-RCI-12	Residential Solar Hot Water	N	0.239	38.154	1.167	$123	$105
AFW-8a	Forest Management - Rotation Schedules	N	0.560	38.714	3.080	$431	$140
M-RCI-8	Residential Dishwasher	N	0.034	38.748	0.155	$24	$156
M-RCI-5	Residential Solar PV	N	0.118	38.867	0.572	$111	$193
M-RCI-7	Residential Laundry Appliances	N	0.089	38.955	0.392	$94	$240
PS-offshore wind	Offshore wind	N	0.216	39.171	0.523	$154	$295
PS-onshore wind	Onshore wind	N	0.635	39.806	4.003	$1,251	$312
M-RCI-1	Residential Cooling	N	0.002	39.808	0.010	$7	$648
TLU-1	TL1 -- TriMet - Rail	N	0.026	39.834	0.199	$130	$657
AFW-8b	Forest Management - Riparian Zones	N	0.005	39.839	0.028	$28	$1,001
TLU-6	TL6 -- Bend Area Transit	N	0.002	39.841	0.011	$13	$1,221
TLU-7	TL7 -- City of Corvallis	N	0.000	39.841	0.003	$3	$1,229
TLU-2	TL2 -- TriMet - Bus	N	0.029	39.870	0.187	$246	$1,315
AFW-6	Urban Forestry	N	0.042	39.912	0.150	$221	$1,475
TLU-5	TL5 -- Rogue Valley Transportation District	N	0.001	39.913	0.006	$12	$1,977
TLU-3	TL3 -- Lane Transit District	N	0.004	39.917	0.026	$63	$2,380
M-RCI-13	Residential Energy Monitor	N	0.005	39.922	0.021	$68	$3,206
TLU-4	TL4 -- Salem Area Mass Transit District	N	0.000	39.922	0.004	$18	$4,437

Table 14. Foundational Modeling - Marginal Abatement Cost Curve for Scenario 3, Year 2035

Measure Number	Measure Group Name	Included in 2035 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
AFW-10	Waste Prevention	Y	0.795	0.795	13.081	-$3,553.72	-$271.66
M-RCI-28	Commercial Laundry Appliances Measures	Y	0.033	0.828	0.409	-$54.36	-$132.93
M-RCI-51	Industrial Street and Traffic Lighting	Y	0.002	0.830	0.028	-$1.72	-$60.37
M-RCI-49	Industrial Wood Products Measures	Y	0.017	0.847	0.227	-$13.38	-$59.01
M-RCI-10	Residential Lighting	Y	0.153	1.001	3.692	-$216.19	-$58.56
M-RCI-31	Commercial Water/Wastewater Measures	Y	0.044	1.044	0.681	-$39.46	-$57.95
M-RCI-29	Commercial Electronics/Transformer Measures	Y	0.182	1.226	2.487	-$142.31	-$57.22
M-RCI-52	Industrial Space/Water Heating and Weatherization Measures	Y	0.111	1.337	1.314	-$75.04	-$57.13
TLU-8	TL8 -- Land Use	Y	0.439	1.775	5.194	-$275.33	-$53.01
M-RCI-47	Industrial Arc Furnace Measures	Y	0.001	1.776	0.006	-$0.33	-$51.45
M-RCI-39	Industrial Lighting and Control Measures	Y	0.074	1.850	0.912	-$46.45	-$50.93
M-RCI-32	Commercial Water Heating Efficiency Measures	Y	0.074	1.923	0.896	-$45.22	-$50.49
TLU-28-37	LDV Travel Bundle	Y	3.271	5.194	39.679	-$2,001.58	-$50.44
M-RCI-50	Industrial Agricultural Irrigation Measures	Y	0.034	5.229	0.674	-$33.69	-$49.98
M-RCI-53	Industrial Combined Heat and Power	Y	1.079	6.308	13.161	-$618.20	-$46.97
M-RCI-30	Commercial Cooking Appliances Measures	Y	0.070	6.378	0.946	-$43.06	-$45.49
M-RCI-23	Commercial Chillers Measures	Y	0.059	6.436	0.849	-$37.50	-$44.15
M-RCI-26	Commercial Building Insulation Measures	Y	0.100	6.537	1.178	-$51.84	-$43.99
M-RCI-22	Commercial HVAC Control Measures	Y	0.153	6.690	2.009	-$86.59	-$43.10

Measure Number	Measure Group Name	Included in 2035 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
M-RCI-27	Commercial Refrigeration Measures	Y	0.062	6.752	0.736	-$31.47	-$42.75
M-RCI-24	Commercial HVAC System Improvements	Y	0.060	6.812	0.773	-$30.54	-$39.51
M-RCI-40	Industrial Motors Measures	Y	0.009	6.821	0.117	-$4.24	-$36.26
M-RCI-43	Industrial Transformers	Y	0.010	6.831	0.122	-$4.20	-$34.35
M-RCI-46	Industrial Food Processing/Storage Measures	Y	0.096	6.928	1.162	-$39.86	-$34.31
M-RCI-18	Commercial Lighting Efficiency Measures	Y	0.610	7.538	7.642	-$251.80	-$32.95
M-RCI-21	Commercial Building Windows Measures	Y	0.054	7.592	0.649	-$21.20	-$32.67
M-RCI-20	Commercial Lighting Controls Measures	Y	0.071	7.662	0.846	-$26.54	-$31.38
M-RCI-36	Commercial Heating Systems--Biomass	Y	0.027	7.689	0.295	-$9.25	-$31.37
M-RCI-48	Industrial Pulp and Paper Industry Measures	Y	0.023	7.713	0.287	-$8.43	-$29.42
M-RCI-9	Residential Refrigerators/Freezers	Y	0.057	7.770	0.680	-$19.29	-$28.36
M-RCI-38	Industrial Air Compressor Measures	Y	0.044	7.814	0.546	-$14.69	-$26.92
M-RCI-33	Commercial Solar Water Heating	Y	0.021	7.835	0.263	-$7.06	-$26.86
M-RCI-41	Industrial Fan Efficiency Measures	Y	0.082	7.917	1.014	-$25.91	-$25.56
M-RCI-44	Industrial Energy Management	Y	0.324	8.241	4.018	-$94.27	-$23.46
M-RCI-45	Industrial Electronics Manufacturing Measures	Y	0.010	8.252	0.128	-$2.96	-$23.19
TLU-22-27	Freight Bundle	Y	7.665	15.917	91.984	-$2,083.12	-$22.65
AFW-3	Nutrient Management	Y	0.367	16.284	4.400	-$91.66	-$20.83
M-RCI-35	Commercial Combined Heat and Power	Y	0.754	17.037	8.474	-$174.63	-$20.61
M-RCI-25	Commercial Commissioning Measures	Y	0.104	17.141	1.896	-$32.33	-$17.05
M-RCI-42	Industrial Pump Efficiency Measures	Y	0.077	17.217	0.952	-$16.19	-$17.02
M-RCI-34	Commercial Heating Systems Measures--Conventional	Y	0.089	17.307	1.071	-$18.08	-$16.89
M-RCI-14	Residential Electronics	Y	0.601	17.907	10.118	-$166.24	-$16.43

Measure Number	Measure Group Name	Included in 2035 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
M-RCI-6	Residential Hot Water Efficiency	Y	0.814	18.721	9.829	-$124.60	-$12.68
M-RCI-19	Commercial Daylighting Measures	Y	0.048	18.769	0.548	-$6.48	-$11.81
AFW-4a	Biogas Production & Utilization from MSW Biomass	Y	1.905	20.674	32.771	-$130.71	-$3.99
AFW-4b	Convert Aerobic to Anaerobic Digestion at WWTPs - Including FOG Co-Digestion	Y	1.777	22.451	30.418	-$16.81	-$0.55
TLU-9-21	LCFS Bundle	Y	0.626	23.077	9.284	$22.47	$2.42
M-RCI-16	Residential CHP	Y	0.237	23.314	2.969	$15.67	$5.28
AFW-5	Landfill Gas Collection & Use	Y	0.324	23.638	5.909	$51.82	$8.77
M-RCI-17	Residential Biomass Heating	Y	0.371	24.008	4.477	$39.36	$8.79
AFW-2	Co-Digestion of Food Waste with Dairy Methane	Y	0.383	24.392	7.427	$84.50	$11.38
M-RCI-4	Residential Windows	Y	0.274	24.666	3.755	$43.18	$11.50
AFW-7a	Reforestation/Afforestation of Cropland	Y	11.930	36.596	149.125	$1,858.44	$12.46
M-RCI-2	Residential Heating/HVAC	Y	0.723	37.319	9.059	$114.09	$12.59
AFW-7b	Reforestation/Afforestation of Rangeland	Y	33.400	70.719	417.500	$7,463.07	$17.88
AFW-9	Enhanced Materials Management in New Building Construction	N	1.620	72.339	24.975	$479.67	$19.21
M-RCI-54	Industrial Non-energy GHG Reduction Measures	N	0.439	72.778	7.981	$159.80	$20.02
M-RCI-15	Residential Heating Duct Sealing/Multi-Measure	N	0.162	72.939	1.940	$40.00	$20.62
M-RCI-3	Residential Insulation/Weatherization	N	0.277	73.216	3.636	$127.78	$35.14
M-RCI-11	Residential Cooking Appliances	N	0.099	73.315	1.180	$50.65	$42.92
M-RCI-55	Industrial Solar PV	N	0.302	73.617	4.411	$229.02	$51.92
M-RCI-37	Commercial Solar PV	N	0.339	73.957	4.955	$309.46	$62.46
M-RCI-12	Residential Solar Hot Water	N	0.377	74.334	5.375	$374.73	$69.72
AFW-8a	Forest Management - Rotation Schedules	N	0.560	74.894	10.360	$944.70	$91.19

Measure Number	Measure Group Name	Included in 2035 Goal Macro Analysis (Y/N)	Annual GHG Emissions Reductions, 2035 (MMtCO2e)	Cumulative Annual GHG Reductions, 2035 (MMtCO2e) [X-Axis]	Cumulative Emissions Reductions by Measure from 2013-2035	Net Present Value (Million 2010 $), 2013-2035	Average Cost Effectiveness, 2013-2035 ($/tCO2e) [Y-Axis]
M-RCI-8	Residential Dishwasher	N	0.064	74.958	0.789	$84.69	$107.32
M-RCI-5	Residential Solar PV	N	0.178	75.136	2.605	$353.11	$135.56
PS-offshore wind	Offshore wind	N	0.631	75.768	7.673	$1,173.58	$152.94
M-RCI-7	Residential Laundry Appliances	N	0.174	75.942	2.104	$351.20	$166.89
PS-onshore wind	Onshore wind	N	2.273	78.215	30.200	$5,537.96	$183.37
AFW-6	Urban Forestry	N	0.219	78.434	1.815	$601.52	$331.34
M-RCI-1	Residential Cooling	N	0.004	78.438	0.049	$22.08	$454.62
TLU-6	TL6 -- Bend Area Transit	N	0.003	78.441	0.046	$27.95	$612.80
TLU-1	TL1 -- TriMet - Rail	N	0.052	78.494	0.693	$504.12	$727.06
AFW-8b	Forest Management - Riparian Zones	N	0.005	78.499	0.093	$69.02	$746.17
TLU-7	TL7 -- City of Corvallis	N	0.001	78.499	0.011	$8.09	$754.83
TLU-4	TL4 -- Salem Area Mass Transit District	N	0.001	78.500	0.011	$8.09	$754.83
TLU-2	TL2 -- TriMet - Bus	N	0.057	78.558	0.760	$763.96	$1,005.48
TLU-5	TL5 -- Rogue Valley Transportation District	N	0.002	78.559	0.026	$29.20	$1,140.38
TLU-3	TL3 -- Lane Transit District	N	0.008	78.568	0.108	$169.71	$1,568.97
M-RCI-13	Residential Energy Monitor	N	0.007	78.575	0.096	$229.48	$2,388.43

CHAPTER 3. PRELIMINARY BASELINE MACROECONOMIC FOUNDATIONAL MODELING

3.1 Overview

This chapter summarizes the methods, data sources, assumptions used for, and results of, the initial foundational modeling work designed to establish baseline macroeconomic information and illustrative scenarios of potential impacts associated with using the GHG marginal abatement cost curves. The intent of this initial work is to provide a foundation for future policy analysis and additional modeling to inform the Ten Year Energy Action Plan. This work is not a macroeconomic modeling analysis of the Ten Year Energy Action Plan, in either its draft form (released in June of 2012) or the final version (which has yet to be completed).

The foundational macroeconomic modeling was conducted for the following forecast scenarios to estimate potential net impacts on state GDP, jobs, industry, and other key macroeconomic indicators:

- Business-as-Usual (BAU) forecast for Oregon.
- Forecast of Oregon's renewable portfolio standard (RPS) (http://oregon-rps.org) as it is currently formulated (i.e., assuming no changes in policy or structure in the future).
- A least-cost forecast using the marginal abatement cost curve results for each of two of the marginal abatement cost curves presented in Chapter 2, namely Scenario 2 and Scenario 3. For both of these scenarios, model runs were completed for the set of measures needed to meet Oregon's 2020 GHG emissions reduction goal and the set of measures that would reduce statewide emissions in 2035 to keep Oregon on the path to meet the state's 2050 GHG emissions reduction goal. (It is important to note that least-cost approaches do not always maximize net added value of a measure or policy. For instance, employment and economic growth gains can be greater under certain conditions for approaches that are not least cost. Similarly, energy security, health, and environmental gains could be higher. Least-cost approaches may maximize compliance with direct budget constraints, but may or may not provide the greatest indirect revenue gains associated with economic expansion when weighed against alternative investments. The sources of revenues, as well as the spending effects of revenue uses, are important macroeconomic variables for analysis.)

The two time periods used for the macroeconomic modeling were first, through the end of 2022 (in accordance with the Ten Year Energy Action Plan timeline) and, secondly, through 2035 (i.e., at the end point of the marginal abatement cost curves assessment) as measures of where the state will be at that point along the path toward meeting Oregon's 2050 emission reduction goals.

The costs/savings of the GHG mitigation measures presented in Chapter 2 were used as inputs for preparing the foundational macroeconomic modeling of the forecast scenarios. The costs/savings estimated for the mitigation measures represents the direct impacts on industry and consumers associated with implementing the measures. For example, the direct costs of an energy efficiency measure may include energy ratepayers' payment for the program and consumers' expenditures on energy efficiency equipment and devices. The direct savings and costs of this measure only consider impacts to those new costs or savings. Understanding macroeconomic impacts requires modeling how changes in these initial costs and savings affect other sectors. The direct changes in expenditures generate ripple effects throughout the economy in response to changes in purchases and in relative prices, including production costs. Direct impacts are specified and inserted into the macroeconomic model that estimate such secondary, or ripple, effects.

The foundational macroeconomic modeling analysis was conducted using the Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI+) 169-sector model for Oregon and the GHG marginal abatement cost curve data for the each measure (or group of measures) included in the forecast scenarios to estimate the following potential impacts:

- Economic growth, or change in state Gross Domestic Product (GDP) and output by year
- Employment (job creation or losses)
- Personal Income
- Government revenues

The remainder of this chapter provides a brief summary of Oregon's economy, followed by Section 3.3 that provides a summary of the REMI PI+ 169-sector model for Oregon. Section 3.4 provides details on how the costs/savings associated with the mitigation measures were prepared for input into the REMI PI+ model and identifies key macroeconomic modeling assumptions, and Section 3.5 describes the REMI PI+ simulation methodology. Section 3.6 presents the macroeconomic modeling results for each of the forecast scenarios. Section 3.7 offers suggestions for future research. References related to macroeconomic modeling of GHG emissions reduction measures and policies are provided in Section 3.8.

3.2 The Oregon Economy

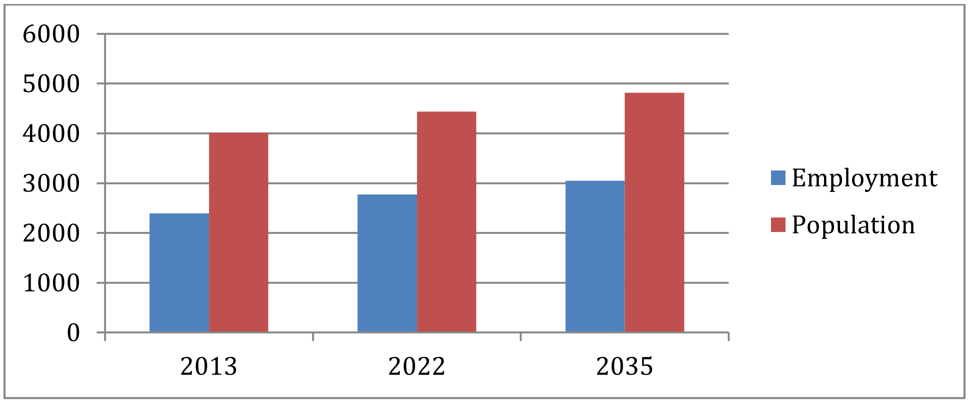
Oregon's population is expected to be 4.0 million people by 2013 and is expected to grow to 4.4 million in 2022 and 4.8 million by 2035.[1] Oregon's 2.2 million person labor force has a median annual income of approximately $46,000, a figure that is projected to grow to $69,000 by 2022.

The Service sector represents a very large share of the State's economy, particularly in the areas of real estate, financial, and administrative services which is 21.5% of gross output. The next five largest sectors comprise another 29% of output. They are, in descending order, wholesale trade, computer manufacturing, broadcasting, chemical manufacturing, insurance, securities and trucking. Altogether these sectors account for about 50% of the total gross output in the region (REMI, 2012). By 2022 the rankings of the largest-output industries in Oregon are expected to remain approximately the same, although the value of food manufacturing output is expected to grow slightly larger than trucking industry output and become the 10th largest sector for a period of time. The 10 largest industries are expected to grow to approximately 53% of total output by 2022 and 56% by 2035.

Oregon (2013) is projected to show increases in population and employment in the coming decades (see Figure 20). Population is expected to increase by 20% between 2013 and 2035. Employment is expected to increase by 27% by 2035 reflecting an increase in labor force participation. Total gross output in 2011 was about $332 billion (in 2012$). A baseline forecast indicates that regional gross output for Oregon will reach $557 billion in 2035, with a projected average annual growth rate of 2.4% between 2022 and 2035 (REMI, 2012).

[1] The first year of the analysis period for the forecast scenarios is 2013.

Figure 20. Expected Population and Labor Force Growth in Oregon



3.3 The Regional Economic Models, Inc. (REMI) Model

Several modeling approaches can be used to estimate the total regional economic impacts of environmental policy, including both direct (on-site) effects and various types of indirect (off-site) effects. These include: input-output (I-O), computable generated equilibrium (CGE), mathematical programming (MP), and macroeconometric (ME) models. Each has its own strengths and weaknesses (see, e.g., Rose and Miernyk, 1989; Partridge and Rickman, 2010). The choice of which model to use depends on the purpose of the analysis and various considerations that can be considered as performance criteria, such as accuracy, transparency, manageability, and costs. After careful consideration of these criteria, the Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI^+) Model was selected to support the foundational modeling analysis. The REMI PI^+ Model is superior to the others in terms of its forecasting ability and is comparable to CGE models in terms of analytical power and accuracy. With careful explanation of the model, its application, and its results, it can be made as transparent as any of the others.[2] Moreover, the research team has used the model successfully in similar analyses in the states of Florida, Pennsylvania, Michigan, Wisconsin and New York (Miller et al., 2010; Rose et al., 2011; Wei and Rose, 2011; Rose and Wei, 2012).

The REMI Model has evolved over the course of 30 years of refinement (see, e.g., Treyz, 1993). It is a packaged program but is built with a combination of national and region-specific data. Government agencies in practically every state in the U.S. have used a REMI Model for a variety of purposes, including evaluating the impacts of the change in tax rates, the exit or entry of major

[2] There is a debate about the size of the multipliers used in different regional policy analysis models. Rickman and Schwer (1995) compared the default multipliers in three of these models: IMPLAN, REMI and RIMS II. The comparison shows that the default multipliers have significant differences. Comparatively speaking, IMPLAN estimates the largest multipliers, while REMI estimates the smallest multipliers. The differences stem from three major causes. However, the REMI model has its special features that are important to our policy analysis. First, both IMPLAN and RIMS II are static input-output models, while the REMI model is dynamic. Thus, the REMI model has the capability to analyze the time path of impacts of the simulated policy change and is superior to the other two models in terms of its forecasting ability. In fact, the implicit multipliers of REMI vary from year to year. Second, the REMI model is non-linear. Therefore, in contrast to the other two models, the REMI simulation results are not dependent on fixed multipliers or linear relationship with the input data. In the REMI analysis, changes in the magnitude of the inputs will lead to an appropriate variation in the model's multipliers. Moreover, since the REMI multipliers are generally smaller than the multipliers of the other two models, this means that our impacts lean to the more conservative side, i.e., positive economic impacts are more likely to be understated than overstated.

businesses in particular or economic programs in general, and, more recently, the impacts of energy and/or environmental policy actions.

The following is a general summary that provides comparisons between model choice and function. A macroeconometric forecasting model covers the entire economy, typically in a "top-down" manner, based on macroeconomic aggregate relationships such as consumption and investment. REMI differs somewhat in that it includes some key relationships, such as exports, in a bottom-up approach. In fact, it makes use of the finely-grained sectoring detail of an I-O model, i.e., it divides the economy into 169 sectors, thereby allowing important differentials between them. This is especially important in a context of analyzing the impacts of GHG mitigation measures, where various options were fine-tuned to a given sector or where they directly affect several sectors somewhat differently.

The macroeconomic character of the model is able to analyze the interactions between sectors (ordinary multiplier effects) but with some refinement for price changes not found in I-O models. In other words, the REMI model incorporates the responses of the producers and consumers to price signals in the simulation. In contrast, in a basic input-output model, the change in prices is not readily taken into account. More specifically, a basic input-output model separates the determinants of quantity and prices, i.e., price changes will not generate any substitution effects in an I-O analysis, while the REMI model is capable to capture this and other price-quantity interactions.[3] The REMI Model also brings into play features of labor and capital markets, as well as trade with other states or countries, including changes in competitiveness.

The econometric feature of the model refers to two considerations. The first is that the model is based on inferential statistical estimation of key parameters based on pooled time series and regional (panel) data across all states of the U.S. (the other candidate models use "calibration," based on a single year's data).[4] This gives the REMI PI^+ model an additional capability of being better able to extrapolate the future course of the economy, a capability the other models lack. The major limitation of the REMI PI^+ model versus the others is that it is pre-packaged and not readily adjustable to any unique features of the case in point. The other models, because they are based on less data and a less formal estimation procedure, can more readily accommodate data changes in technology that might be inferred, for example from engineering data. However, our assessment of the REMI PI^+ Model is that these adjustments were not needed for the purpose at hand.

3.4 Input Data and Assumptions

Section 2.5 of Chapter 2 identifies the measures included in the foundational modeling analysis for Scenario 2 and Scenario 3. The costs/savings associated with the full-energy cycle emission reduction estimates for the measures included in each scenario were used as inputs for the macroeconomic impact analysis. As discussed in Section 2.5, the measure-level data presented for each scenario and year have been adjusted to account for obvious overlaps between sectors.

[3] The production cost change of each sector in REMI will first affect the price of the goods produced by this sector. Then the price change will generate successive impacts to the down-stream customer sectors that use the product of each sector as an intermediate input.

[4] REMI is the only one of the models that really addresses the fact that many impacts take time to materialize and that the size of impacts changes over time as prices and wages adjust. In short, it better incorporates the actual dynamics of the economy.

For example, the majority of the PS measures have interactions and overlaps with the RCI measures; therefore, except for wind, the PS measures were removed from the foundational macroeconomic modeling analysis for the scenarios. However, a complete analysis of measure interactions and overlaps was not possible given the time and resource constraints associated with this project. Thus, it is important to note the uncertainty here related to the use of these cumulative emission reductions for a list of measures for which a comprehensive assessment has not yet been completed to fully account for all interactions and overlaps.

3.4.1 Mapping of Microeconomic Impact Results for Input into the Macroeconomic Impact Analysis

For Scenario 2 and Scenario 3, due to the time and resource constraints associated with the project, individual measures included in the microeconomic impacts analyses were bundled to facilitate the macroeconomic modeling analysis. Tables 15 and 16 identify the individual TLU and RCI measures, respectively, which were bundled and modeled as a group for the macroeconomic analysis.

Table 15. Mapping of TLU Measure Categories for the Microeconomic Impact Analysis to TLU Bundles for the Macroeconomic Impact Analyses

Measure Number	Measure Bundle for Macroeconomic Analysis	Measure Number	Measure Category for Microeconomic Analysis
TLU-1	TL1 -- TriMet - Rail	TLU-1	TL1 -- TriMet - Rail
TLU-2	TL2 -- TriMet - Bus	TLU-2	TL2 -- TriMet - Bus
TLU-3	TL3 -- Lane Transit District	TLU-3	TL3 -- Lane Transit District
TLU-4	TL4 -- Salem Area Mass Transit District	TLU-4	TL4 -- Salem Area Mass Transit District
TLU-5	TL5 -- Rogue Valley Transportation District	TLU-5	TL5 -- Rogue Valley Transportation District
TLU-6	TL6 -- Bend Area Transit	TLU-6	TL6 -- Bend Area Transit
TLU-7	TL7 -- City of Corvallis	TLU-7	TL7 -- City of Corvallis
TLU-8	TL8 -- Land Use	TLU-8	TL8 -- Land Use
TLU-9-21	LCFS Bundle -- Estimated for one compliance scenario	TLU-9	LCFS1 -- MW Corn Ethanol
		TLU-10	LCFS2 -- OR Corn Ethanol
		TLU-11	LCFS3 -- Imported Cellulosic Ethanol
		TLU-12	LCFS4 -- Oregon Wheat Straw Ethanol
		TLU-13	LCFS5 -- Brazil Sugar Cane Ethanol
		TLU-14	LCFS6 -- Low Carbon MW Corn
		TLU-15	LCFS7 -- OR Cellulosic Ethanol
		TLU-16	LCFS8 -- Cellulosic
		TLU-17	LCFS9 -- CNG from biogas
		TLU-18	LCFS10 -- Camelian RD
		TLU-19	LCFS 11 -- NW Canola
		TLU-20	LCFS 12 -- Waste Oil
		TLU-21	LCFS 13 -- MW Soybean
TLU-22-27	Freight Bundle	TLU-22	FR1 -- Land Use Policy Changes

Measure Number	Measure Bundle for Macroeconomic Analysis	Measure Number	Measure Category for Microeconomic Analysis
		TLU-23	FR2 -- Urban Traffic Congestion Relief
		TLU-24	FR3 -- Idle Reduction Strategies
		TLU-25	FR4 -- More Energy Efficient Transporter Operations
		TLU-26	FR5 -- Mode Shift of Freight in Response to Higher Fees
		TLU-27	FR6 --Low Carbon Fuels
TLU-28-37	LDV Travel Bundle	TLU-28	LD1 -- Transit Growth
		TLU-29	LD2 -- Walk/Bike Short SOV mode shift
		TLU-30	LD3 -- ITS &Operations
		TLU-31	LD4 -- PAYD
		TLU-32	LD5 -- TDM
		TLU-33	LD6 -- EcoDrive
		TLU-34	LD7 -- Parking Management
		TLU-35	LD8 -- Externality Taxes
		TLU-36	LD9 -- Congestion Charges
		TLU-37	LD10 -- Carsharing

Table 16. Mapping of RCI Measure Categories for the Microeconomic Impact Analysis to RCI Bundles for the Macroeconomic Impact Analyses

Measure Number	Measure Bundle for Macroeconomic Analysis	Measure Number	Measure Category for Microeconomic Analysis
M-RCI-1	Residential Cooling	RCI-1	Residential Cooling Appliances
M-RCI-2	Residential Heating/HVAC	RCI-2	Manufactured Home HVAC Conversion/Upgrade
		RCI-24	Residential Gas Furnace Upgrade
		RCI-25	Multifamily HVAC--Gas Heat
		RCI-3	Single Family Home HVAC Conversion/Upgrade
		RCI-3	Single Family Home HVAC Conversion/Upgrade
		RCI-30	Residential Heat/Energy Recovery Ventilation--Gas
M-RCI-3	Residential Insulation / Weatherization	RCI-4	Manufactured Home Weatherization--Insulation
		RCI-6	Multifamily Weatherization--Insulation
		RCI-8	Single Family Weatherization--Insulation
M-RCI-4	Residential Windows	RCI-26	Residential Gas Heat Windows
		RCI-5	Manufactured Home Weatherization--Windows
		RCI-7	Multifamily Weatherization--Windows
		RCI-9	Single Family Weatherization--Windows
M-RCI-5	Residential Solar PV	RCI-10	Residential Solar Photovoltaic
M-RCI-6	Residential Hot Water Efficiency	RCI-11	Residential Electric Water Heat Efficiency
		RCI-12	Residential Heat Pump Water Heater
		RCI-17	Residential Gravity Film Heat Exchanger
		RCI-23	Residential Gas Water Heat Measures
M-RCI-7	Residential Laundry Appliances	RCI-13	Residential Laundry Appliance Improvement
M-RCI-8	Residential Dishwasher	RCI-14	Residential Dishwasher Improvement
M-RCI-9	Residential Refrigerators/Freezers	RCI-15	Residential Refrigerator/Freezer Improvement
		RCI-21	Residential Refrigerator Recycle
M-RCI-10	Residential Lighting	RCI-16	Residential Lighting Improvement
M-RCI-11	Residential Cooking Appliances	RCI-18	Residential Cooking Appliance Improvement
M-RCI-12	Residential Solar Hot Water	RCI-19	Residential Solar Water Heat--Electric Back-up
		RCI-29	Residential Solar Hot Water--Gas Back-up

Measure Number	Measure Bundle for Macroeconomic Analysis	Measure Number	Measure Category for Microeconomic Analysis
M-RCI-13	Residential Energy Monitor	RCI-20	Home Energy Monitor
M-RCI-14	Residential Electronics	RCI-22	Residential Electronics Improvements
M-RCI-15	Residential Heating Duct Sealing/Multi-Measure	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization
		RCI-28	Residential Multi-Measure Gas Heat
M-RCI-16	Residential CHP	RCI-31	Residential CHP
M-RCI-17	Residential Biomass Heating	RCI-32	Residential Wood-fueled Heat Replacing Electric Resistance
		RCI-33	Residential Wood-fueled Heat Replacing Oil/LPG
M-RCI-18	Commercial Lighting Efficiency Measures	RCI-34	Commercial LDP New/Integrated Design
		RCI-34	Commercial LDP New/Integrated Design
		RCI-35	Schools Lighting Measures
		RCI-35	Schools Lighting Measures
		RCI-35	Schools Lighting Measures
		RCI-35	Schools Lighting Measures
		RCI-48	Commercial LDP Natural Replacement/Retrofit
		RCI-48	Commercial LDP Natural Replacement/Retrofit
		RCI-59	Commercial Parking Lighting
		RCI-66	Commercial Exit Signs
		RCI-67	Commercial Signage
		RCI-69	Commercial Street Lighting
M-RCI-19	Commercial Daylighting Measures	RCI-35	Schools Lighting Measures
		RCI-35	Schools Lighting Measures
		RCI-35	Schools Lighting Measures
		RCI-36	Commercial Daylighting New/Integrated Design
		RCI-36	Commercial Daylighting New/Integrated Design
		RCI-49	Commercial Daylighting Natural Replacement/Retrofit
		RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit
M-RCI-20	Commercial Lighting Controls Measures	RCI-35	Schools Lighting Measures
		RCI-35	Schools Lighting Measures
		RCI-37	Commercial Lighting Controls New/Integrated Design
		RCI-37	Commercial Lighting Controls New/Integrated Design
		RCI-37	Commercial Lighting Controls New/Integrated Design
		RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit
M-RCI-21	Commercial Building Windows Measures	RCI-38	Commercial Windows New/Integrated Design
		RCI-38	Commercial Windows New/Integrated Design
		RCI-39	Schools Building Envelope Measures
		RCI-39	Schools Building Envelope Measures
		RCI-39	Schools Building Envelope Measures
		RCI-39	Schools Building Envelope Measures
		RCI-51	Commercial Windows Natural Replacement/Retrofit
		RCI-51	Commercial Windows Natural Replacement/Retrofit
		RCI-51	Commercial Windows Natural Replacement/Retrofit
		RCI-94	Commercial Windows Measures--Gas
M-RCI-22	Commercial HVAC Control Measures	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design
		RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design
		RCI-41	Schools HVAC
		RCI-41	Schools HVAC
		RCI-41	Schools HVAC
		RCI-42	Commercial Demand Control Ventilation New/Integrated Design

Measure Number	Measure Bundle for Macroeconomic Analysis	Measure Number	Measure Category for Microeconomic Analysis
		RCI-42	Commercial Demand Control Ventilation New/Integrated Design
		RCI-43	Commercial ECM on VAV Boxes New/Integrated Design
		RCI-43	Commercial ECM on VAV Boxes New/Integrated Design
		RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro
		RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro
		RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro
		RCI-78	Commercial Economizer Measures
		RCI-79	Commercial Heat Reclamation Measures
		RCI-82	Commercial Energy Management Systems
		RCI-83	Commercial Chiller Tower 6F Approach
M-RCI-23	Commercial Chillers Measures	RCI-44	Commercial Variable Speed Chiller New/Integrated Design
		RCI-44	Commercial Variable Speed Chiller New/Integrated Design
		RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro
M-RCI-24	Commercial HVAC System Improvements	RCI-41	Schools HVAC
		RCI-41	Schools HVAC
		RCI-41	Schools HVAC
		RCI-41	Schools HVAC
		RCI-45	Commercial Package Rooftop Measures New/Integrated Design
		RCI-45	Commercial Package Rooftop Measures New/Integrated Design
		RCI-46	Commercial Premium HVAC New/Integrated Design
		RCI-46	Commercial Premium HVAC New/Integrated Design
		RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro
		RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro
		RCI-57	Commercial Premium HVAC Natural Replacement/Retro
		RCI-68	Commercial Fume Hood
		RCI-85	Commercial Ground-source Heat Pump
M-RCI-25	Commercial Commissioning Measures	RCI-41	Schools HVAC
		RCI-41	Schools HVAC
		RCI-41	Schools HVAC
		RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design
		RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design
		RCI-58	Commercial Controls Commissioning HVAC Retrofit
M-RCI-26	Commercial Building Insulation Measures	RCI-39	Schools Building Envelope Measures
		RCI-52	Commercial Insulation Natural Replacement/Retrofit
		RCI-52	Commercial Insulation Natural Replacement/Retrofit
		RCI-89	Commercial Insulation Measures--Gas Heat
		RCI-93	Commercial Insulation Measures--Gas
M-RCI-27	Commercial Refrigeration Measures	RCI-60	Commercial Refrigeration Improvements
		RCI-70	Commercial Refrigeration Improvements

Measure Number	Measure Bundle for Macroeconomic Analysis	Measure Number	Measure Category for Microeconomic Analysis
		RCI-71	Commercial Ice-Maker Improvements
		RCI-72	Commercial Vending Machines
M-RCI-28	Commercial Laundry Appliances Measures	RCI-73	Commercial Laundry
		RCI-86	Commercial Laundry Equipment--Gas
M-RCI-29	Commercial Electronics/Transformer Measures	RCI-61	Commercial Computer/Server Improvements
		RCI-77	Commercial Transformers
M-RCI-30	Commercial Cooking Appliances Measures	RCI-62	Commercial Cooking/Food Service Improvements
		RCI-65	Commercial DVC Hood
		RCI-87	Commercial Cooking Equipment--Gas
M-RCI-31	Commercial Water/Wastewater Measures	RCI-63	Commercial Wastewater Treatment Improvements
		RCI-64	Commercial Water Supply Improvements
M-RCI-32	Commercial Water Heating Efficiency Measures	RCI-74	Commercial Wastewater Heat Exchanger
		RCI-75	Commercial Hot Water Efficiency Measures
		RCI-76	Commercial Heat Pump Water Heater
		RCI-88	Commercial Hot Water Measures--Gas
		RCI-92	Commercial Wastewater Heat Exchanger--Gas
M-RCI-33	Commercial Solar Water Heating	RCI-80	Commercial Solar Water Heat
		RCI-95	Commercial Solar Hot Water--Gas Back-up
M-RCI-34	Commercial Heating Systems Measures--Conventional	RCI-78	Commercial Economizer Measures
		RCI-81	Commercial Heating Duct Measures
		RCI-84	Commercial Rooftop Condensing Burner
		RCI-90	Commercial Heat Reclamation--Gas
		RCI-91	Commercial Heating Measures--Gas
M-RCI-35	Commercial Combined Heat and Power	RCI-96	Commercial Gas-fired CHP
M-RCI-36	Commercial Heating Systems--Biomass/Biogas	RCI-97	Commercial Wood-fueled Space Heat Replacing Electric
		RCI-98	Commercial Wood-fueled Space Heat Replacing Gas
		RCI-99	Commercial Wood-fueled Space Heat Replacing Oil/LPG
M-RCI-37	Commercial Solar PV	RCI-100	Commercial Solar PV
M-RCI-38	Industrial Air Compressors	RCI-101	Industrial General: Air Compressor Measures
M-RCI-39	Industrial Lighting and Control Measures	RCI-102	Industrial General: Lighting and Controls
M-RCI-40	Industrial Motors Measures	RCI-103	Industrial General: Motors Measures
M-RCI-41	Industrial Fan Efficiency Measures	RCI-104	Industrial General: Fan Measures
M-RCI-42	Industrial Pump Efficiency Measures	RCI-105	Industrial General: Pump Measures
M-RCI-43	Industrial Transformers	RCI-106	Industrial General: Transformers
M-RCI-44	Industrial Energy Management	RCI-107	Industrial General: Materials Movement Measures
		RCI-108	Industrial General: Energy Management
M-RCI-45	Industrial Electronics Manufacturing Measures	RCI-109	Industrial Electronics Chip Fab Measures
		RCI-110	Industrial Electronics Clean Room Measures
M-RCI-46	Industrial Food Processing/Storage Measures	RCI-111	Industrial Food Processing Measures
		RCI-112	Industrial Cold Storage Measures
		RCI-113	Industrial Fruit Storage Measures
		RCI-114	Industrial Food Storage Measures
		RCI-115	Industrial Grocery Distribution Measures
M-RCI-47	Industrial Arc Furnace Measures	RCI-116	Industrial Metals Arc Furnace
M-RCI-48	Industrial Pulp and Paper Industry Measures	RCI-117	Industrial Mechanical Pulp Measures
		RCI-118	Industrial Kraft Pulp Measures
		RCI-119	Industrial Paper Sector Measures
M-RCI-49	Industrial Wood Products Measures	RCI-120	Industrial Lumber Conveyor Replacement

Measure Number	Measure Bundle for Macroeconomic Analysis	Measure Number	Measure Category for Microeconomic Analysis
		RCI-121	Industrial Wood Panels Hydraulic Press
M-RCI-50	Industrial Agricultural Irrigation Measures	RCI-122	Industrial Agriculture Pump and Related Measures
		RCI-123	Industrial Agriculture Irrigation Improvements
M-RCI-51	Industrial Street and Traffic Lighting	RCI-124	Industrial Rural Area Lighting
		RCI-125	Industrial Traffic Signals Relamping
M-RCI-52	Industrial Space/Water Heating and Weatherization Measures	RCI-126	Industrial Boiler Measures
		RCI-127	Industrial Hot Water Measures
		RCI-128	Industrial Space Heating Measures
		RCI-129	Industrial Weatherization Measures
M-RCI-53	Industrial Combined Heat and Power	RCI-130	Industrial Gas-fired CHP
		RCI-131	Industrial Biomass-fired CHP
		RCI-132	Industrial Digester Gas-fired CHP
M-RCI-54	Industrial Non-energy GHG Reduction Measures	RCI-133	Industrial Cement Production Emissions Reduction
		RCI-134	Industrial Electronics Industry Solvent Emissions Reduction
		RCI-135	Industrial Halon Consumption Reduction
M-RCI-55	Industrial Solar PV	RCI-136	Industrial Solar PV

3.4.2 Modeling of Oregon's RPS

This section summarizes the microeconomic data developed for input into the foundational macroeconomic analysis of the RPS forecast scenario. Details on how the macroeconomic analysis estimates were developed for the RPS are discussed in Appendix A to this report. Table 17 shows the retail electric sales targets specified by the RPS, and Table 18 shows the least-cost mix of renewable resource estimated to be needed to comply with the RPS retail sales targets. Tables 19 through 22 provide the capital, operation and maintenance (fixed and variable), and total costs, respectively, associated with meeting the requirements of the RPS by renewable resource type.

Table 17. Targets for the RPS (Senate Bill 838) (Percent of Retail Electric Sales)

Utility Type	2010	2015	2020	2025
Large utilities	0%	15%	20%	25%
Smaller utilities	0%	0%	0%	10%
Smallest utilities	0%	0%	0%	5%

Table 18. Least-Cost Mix of Renewable Resources Added for RPS Compliance (GWh)

Resource	2010	2015	2020	2025	2030	2035
Hydroelectric	0	0	311	447	447	447
Biomass - wood	0	0	0	1,441	1,441	1,441
Geothermal	0	0	1,261	1,261	1,261	1,261
Solar PV	0	0	0	45	534	1,024
Wind-onshore	0	0	0	89	10	358
Wind-offshore	0	0	0	1,577	1,577	1,577
Landfill gas	0	0	0	143	143	143
MSW (biogenic)	0	0	39	159	159	159
Wave	0	0	0	66	437	437
Tidal current	0	0	379	379	379	379
Total	0	0	1,991	5,606	6,388	7,226

Table 19. Capital Costs Associated with Incremental Renewable Generation for RPS Compliance (Million 2010$, undiscounted)

Resource	2010	2015	2020	2025	2030	2035
Hydroelectric	$0	$0	$26	$38	$38	$38
Biomass - wood	$0	$0	$0	$122	$122	$122
Geothermal	$0	$0	$54	$54	$54	$54
Solar PV	$0	$0	$12	$24	$160	$296
Wind-onshore	$0	$0	$0	$2	$0	$32
Wind-offshore	$0	$0	$0	$164	$164	$164
Landfill gas	$0	$0	$0	$7	$7	$7
MSW (biogenic)	$0	$0	$2	$10	$10	$10
Wave	$0	$0	$0	$17	$112	$112
Tidal current	$0	$0	$28	$28	$28	$28
Total	$0	$0	$123	$467	$696	$864

Table 20. Fixed Operation and Maintenance (O&M) Costs Associated with Incremental Renewable Generation for RPS Compliance (Million 2010$, undiscounted)

Resource	2010	2015	2020	2025	2030	2035
Hydroelectric	$0	$0	$2	$2	$2	$2
Biomass - wood	$0	$0	$0	$21	$21	$21
Geothermal	$0	$0	$52	$52	$52	$52
Solar PV	$0	$0	$0	$0	$3	$6
Wind-onshore	$0	$0	$0	$0	$0	$5
Wind-offshore	$0	$0	$0	$36	$36	$36
Landfill gas	$0	$0	$0	$3	$3	$3
MSW (biogenic)	$0	$0	$1	$5	$5	$5
Wave	$0	$0	$0	$1	$7	$7
Tidal current	$0	$0	$2	$2	$2	$2
Total	$0	$0	$57	$123	$131	$139

Table 21. Variable O&M Costs Associated with Incremental Renewable Generation for RPS Compliance (Million 2010$, undiscounted)

Resource	2010	2015	2020	2025	2030	2035
Hydroelectric	$0	$0	$1	$2	$2	$2
Biomass - wood	$0	$0	$0	$15	$15	$15
Geothermal	$0	$0	$0	$0	$0	$0
Solar PV	$0	$0	$0	$0	$0	$0
Wind-onshore	$0	$0	$0	$0	$0	$0
Wind-offshore	$0	$0	$0	$0	$0	$0
Landfill gas	$0	$0	$0	$0	$0	$0
MSW (biogenic)	$0	$0	$0	$0	$0	$0
Wave	$0	$0	$0	$1	$5	$5
Tidal current	$0	$0	$1	$1	$1	$1
Total	$0	$0	$3	$19	$24	$24

Table 22. Total Costs Associated with Incremental Renewable Generation for RPS Compliance (Million 2010$, undiscounted)

Resource	2010	2015	2020	2025	2030	2035
Hydroelectric	$0	$0	$29	$42	$42	$42
Biomass - wood	$0	$0	$0	$159	$159	$159
Geothermal	$0	$0	$106	$106	$106	$106
Solar PV	$0	$0	$12	$25	$163	$301
Wind-onshore	$0	$0	$0	$2	$0	$37
Wind-offshore	$0	$0	$0	$201	$201	$201
Landfill gas	$0	$0	$0	$11	$11	$11
MSW (biogenic)	$0	$0	$4	$15	$15	$15
Wave	$0	$0	$0	$19	$124	$124
Tidal current	$0	$0	$31	$31	$31	$31
Total	$0	$0	$182	$609	$851	$1,026

3.4.3 Major Modeling Assumptions

All economic models require at some level assumptions to facilitate modeling. Several modeling assumptions went into the analysis of the measures previously described. These assumptions simplify the modeling process and in some cases make the modeling process possible. This section discusses the key assumptions used for this analysis.

The major data sources of the analysis below are the microeconomic analysis results of the cost/savings estimated for each measure. However, in the REMI PI+ analysis some assumptions are necessary to prepare microeconomic costs/savings for use in the macroeconomic model. Below is the list of major assumptions adopted for this analysis:

1. For the RPS forecast, capital investments are assumed to occur within Oregon. Capital investments for energy production are therefore assumed to displace power generation that Pacificorp would otherwise make in other states. Pacificorp has not historically built major fossil fuel energy projects in Oregon. The net impact is an increase in investment spending in

Oregon by 28% of renewable energy investment spending under RPS scenarios, corresponding with the relative share of Pacificorp's share of the market.

2. For the RCI measures, the energy consumers' participant costs of energy efficiency programs are estimated for the RCI sectors by the microeconomic analysis group. Installation of RCI efficiency measure is expected to be performed by professional building contractors.
3. For measures where savings occur over broad industry cross sections and to the general public, savings are represented as aggregate reductions in cost to consumers.
4. For the Restoration/Afforestation measure, it is assumed that the costs are borne by the private sector (farmers and rangeland owners). The potential future cost savings from forest products (e.g., merchantable timber or bioenergy feedstocks) are not taken into account, since these cost savings would most likely not be realized during the period of this analysis.
5. For the Urban Forestry measure, it is assumed that all the costs will be borne by the local government. It is also assumed that increasing the government spending in the urban forestry program will be offset by a decrease in the same amount of government spending on other goods and services. Heating and cooling effects of urban forests result in significant energy savings which are modeled as reduced costs to households.
6. For energy investments by non-energy companies, revenues from energy sales are represented as increased revenues to affected industries while corresponding decreases affect utility sales. Investment spending is represented in the model as a stimulus to the economy, as with all of the other investments considered for this analysis.
7. For the TLU measures related to fuel cost changes for heavy-duty trucks, fuel savings are represented as savings to the truck transportation sector.
8. For TLU measures related to transit, cost savings from reduced automobile use are represented in reduced consumer costs for applicable sectors while increased costs for operating transit are represented as operating costs for the transit sector.

3.5 REMI PI+ Simulation Methodology

3.5.1 REMI PI+ Model Input Development

The direct costs/savings calculated for each measure are prepared for input into the REMI PI+ model by selecting appropriate variables, referred to as "policy levers" in the model, to map the costs/savings to each sector of the economy directly affected by the measure. Multiple policy levers are specified for each measure to reflect investment, cost of production, energy usage, and other factors relevant to the measure. Tables 23 through 26 provide examples of how we translate – or map –the estimated direct effects of a measure into REMI PI+ economic variable inputs from each of the four sectors.

Table 23 shows the microeconomic policy levers used to simulate the macroeconomic outcomes associated with the RPS. The RPS requires that utilities supply a determined proportion of retail sales from eligible renewable energy sources on a progressive scale over time.

Table 23. Mapping of Power Supply Measure and RPS Scenario Microeconomic Results to REMI PI+ Model

Quantification Results	REMI PI+ Model Input Location
Operations and Maintenance	Compensation, Prices, and Costs, operating costs of electric power sectors, increase
Net Capital Investment	Output and Demand Block, Investment Spending, Durable Equipment
Spending transferred from out of State to Oregon	Output and Demand Block, exogenous final demand, electric power sectors, increase
Avoided Cost of Natural Gas	Compensation, Prices, and Costs, cost of electricity fuels, electric power sectors, decrease

New RPS generation will replace generation that would otherwise be built out of state, particularly with regard to Pacificorp, which tends to build thermal generating assets in other states. The REMI PI$^+$ model captures these costs as increases in investment. Increases in production costs of electricity generation are modeled as increases in production cost for the electricity sectors. These policy levers are shown in the first two rows of Table 23. The REMI policy variable "Capital Cost" for "Electric power generation, transmission, and distribution" is used to capture incremental costs of capital and equipment, while the "Production Cost" variable is used to capture those of operations and maintenance.

Investment in new plant and equipment will increase construction demand. It is assumed that utilities will maintain their overall capital structure balancing equity and debt according to the risk portfolio perceived by management at each firm. In the near term, specific projects are assumed to be debt financed although firms will schedule projects according to overall capital structure goals. The REMI PI$^+$ model uses increases in "Exogenous Final Demand" for electric power sectors to capture the costs of administering and maintaining projects. Avoided costs of traditional natural gas fired generation are reflected as avoided costs of electricity purchases by utilities. Because natural gas fired generation is the marginal electric energy source, electricity purchases reflect the market value of energy the RPS sources replace.

Table 24 shows how the microeconomic results associated with RCI energy efficiency measures are translated, or mapped, into REMI economic variable inputs. The first set of inputs in Table 24 is the decrease in costs to businesses and households due to decreased energy consumption. These are simulated by decreases in costs of production for business and in consumer prices for households. The second set of inputs is the impact of reduced energy consumption on utilities through reduced consumption of their product.

Investments in energy saving technologies are stimulative to the economy much as investments in other improvements in automation are stimulative investments incented by reduced costs and increased margins. It is assumed that construction industry professionals will take the lead in implementing these measures on the ground.

Table 24. Mapping of RCI Measure Microeconomic Results to REMI PI+ Model

Quantification Results	REMI PI+ Model Input Location
Energy Savings to Customers- business	Wages, prices and costs block, electricity fuel cost (amount), commercial and industrial sectors, decrease
Energy Savings to Customers- households	Wages, prices and costs block, consumer prices, decrease
Energy Customer Spending- gas	Output and Demand, firm sales, natural gas, decrease
Energy Customer Spending- electricity	Output and Demand, firm sales, electricity, decrease
Investment in EE Technologies- households	Output and Demand, exogenous final demand, construction, increase
Investment in EE Technologies- business	Output and Demand, investment in EE technologies, construction, increase
Program budget spending	Output and Demand, industry demand, construction, increase

Table 25 shows the policy levers used to simulate costs and benefits of shifting transportation modes from auto and truck to transit and rail. This policy option will generate investment in non-road transportation construction and the purchase of capital equipment to facilitate rail and transit transportation. Investment in rail capacity is captured by increasing "Exogenous Final Demand" for the "Construction" sector, as shown in the first two rows. Federal funding and State and local debt financing are assumed sources of capital for rail and transit projects. With respect to transit, federal funding is assumed to be the primary source of capital investment.

Operational cost differences are captured by reducing operational costs in the transit and truck transportation sectors.

Table 25. Mapping of TLU Measure Microeconomic Results to REMI PI+ Model

Quantification Results	REMI PI+ Model Input Location
Capital Investment	Output and Demand, Exogenous Final Demand, construction, increase
Fuel	Compensation, Prices, and Costs, production costs, transit and truck, increase
Operation and Maintenance (O&M)	Compensation, Prices, and Costs, production costs, transit and truck, increase
Vehicle O&M	Compensation, Prices, and Costs, consumer prices, vehicle maintenance, decrease
Fare Revenue	Output and Demand, firm sales, transit, increase

Similarly, operations and maintenance increases at transit districts are simulated with increases to O&M costs in the transit sector. Private automobiles are however used less in TLU scenarios and therefore consumers receive substantial benefit from reduced vehicle use. Farebox revenue is modeled as a direct increase in sales at transit agencies.

Table 26 shows the diverse industries affected by AFW measures. Generally AFW measures are modeled in the 'Compensation Prices and Cost' and the 'Output and Demand' model blocks of the REMI PI+ software.

Table 26. Mapping of AFW Measure Microeconomic Results to REMI PI+ Model

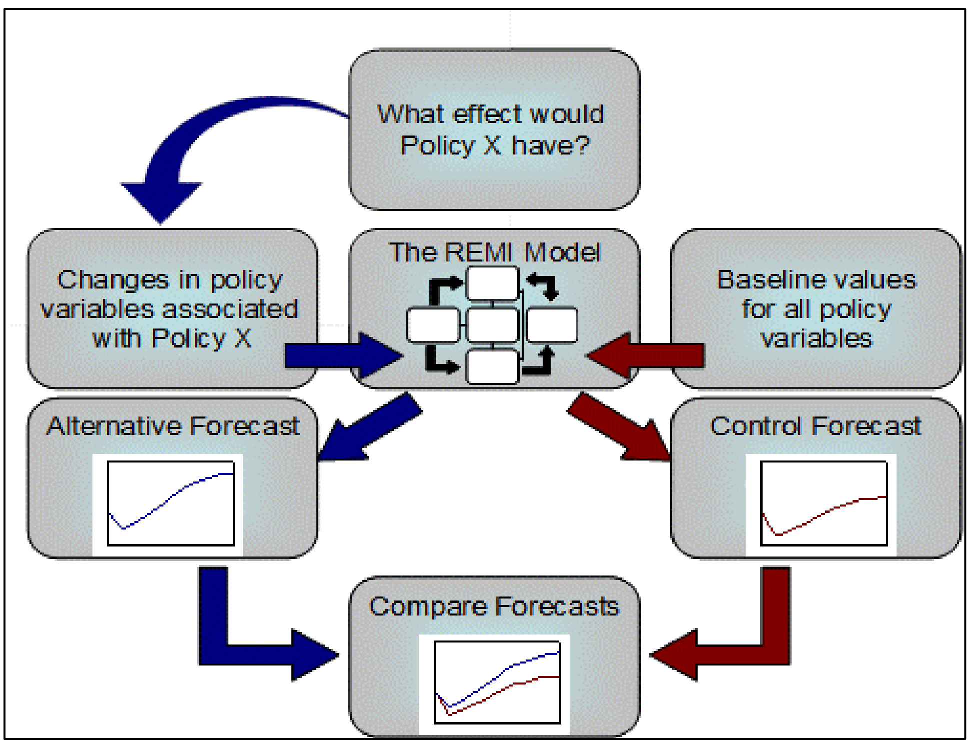
Quantification Results	REMI PI+ Model Input Location
Biogas from Dairies	
Capital Investment in plant	Output and Demand Block, investment spending
O&M	Compensation, Prices, and Costs, production cost, dairy manufacturing, increase
Avoided Cost of Natural Gas	Compensation, Prices, and Costs, production cost, electric power, decrease
Electricity Sales by Dairies	Output and Demand, output and demand, firm sales, dairy manufacturing, increase
Nutrient Management	
Net costs	Compensation, Prices, and Costs, farm compensation
Biogas production from waste	
Capital Investment	Output and Demand Block, investment spending, increase
Operations and Maintenance	Compensation, Prices, and Costs, electric power sectors, increase
Avoided Cost of Natural Gas	Compensation, Prices, and Costs
Biogas from wastewater	
Capital Investment	Output and Demand Block, investment spending, increase
O&M	Compensation, Prices, and Costs, production cost, water sewer, increase
Avoided Cost of Natural Gas	Compensation, Prices, and Costs, production cost, electric power sector, decrease
Electricity Revenue	Output and Demand Block, firm sales, water sewer, increase
Landfill Gas Collection and Use	
Capital Investment	Output and demand, capital spending, waste management, increase
O & M	Compensation, Prices, and Costs
Retail Value of Electricity Generated ($MM)	net from O & M
Urban Forestry	
Capital and O & M	Compensation, Prices, and Costs, Local and State government compensation, increase
Electricity and Gas Savings	Compensation, Prices, and Costs, consumer prices, decrease
Opportunity Cost	Output and Demand Block, firm sales, decrease
Afforestation	
Rangeland	Compensation, Prices, and Costs, farm compensation, increase
Riparian	Compensation, Prices, and Costs
Building material	
Program costs	Compensation, Prices, and Costs, State and Local Gov. compensation, increase
Materials and operating	Compensation, Prices, and Costs, production cost, construction, increase
Waste reduction	
Program Costs	Compensation, Prices, and Costs, State and Local Gov. compensation, increase
Waste savings	Output and Demand, retail trade, decrease

3.5.2 Simulation Set-Up in REMI PI+

Figure 21 shows the approach to policy simulations in the REMI PI$^+$ model. A first step is to form a policy question such as, "What would be the economic impact of Scenario 2?" Second, the policy question guides selection of relevant policy variables within the REMI PI$^+$ model. For example, for RCI energy efficiency measures for buildings, investments affect the building trades in particular which would install the contemplated energy savings measures. Avoided cost of generation by fossil fuels and the impacts of investment transferred from out of state to Oregon. A baseline forecast is developed for the REMI model using conventional macroeconomic assumptions based on historical data and recent trends. Fourth, an alternative forecast is generated by changing policy variables to represent direct effects guided by the policy question. For the RCI sector, costs of constructing energy saving improvements, savings and costs to consumers and reductions in energy sales by the utility sector are inputs to the REMI PI+ model. Fifth, the effects of policy scenarios are measured by comparing the baseline forecast and the alternative forecast. Future research may include sensitivity analyses of individual measures. Such sensitivity analyses might include identification of initiatives with particularly strong negative or positive impact to the job market, or to region economic growth.

For each forecast scenario, the REMI model was run for all of the measures combined assuming they are together implemented (i.e., a *simultaneous* simulation run) to determine their net cumulative impacts relative to the BAU forecast.

Figure 21. Process of Policy Simulation using REMI PI+



Source: REMI Policy Insight 9.5 User Guide

3.6 Foundational Modeling Results

This section summarizes the potential net macroeconomic impacts associated with measures included in the analysis for the Scenario 2 least-cost forecast, the two Scenario 3 least-cost forecasts, and the RPS forecast modeled incremental to the BAU base case forecast for Oregon. Tables 27 and 28 show the cumulative impacts associated with each of the forecast scenarios for the time periods 2013 through 2022 and 2013 through 2035, respectively. Overall, the initial modeling results show positive gains for all of the economic categories. Both of the Scenario 3 forecasts show higher gains for all of the economic categories relative to Scenario 2.

Table 27. Cumulative Impacts (2013 through 2022)

Category	Units	Renewable Portfolio Standard	Scenario 2 Least-Cost Forecast (2020 & 2050 Goals)	Scenario 3 Least-Cost Forecast (2020 Goal)	Scenario 3 Least-Cost Forecast (2050 Goal)
State Tax Revenues	2010 NPV $ Million	$3	$875	$1,430	$1,669
Employment	Job-Years*	1,233	122,106	155,729	195,273
GDP	2010 NPV $ Million	$104	$5,070	$7,349	$10,915
Output	2010 NPV $ Million	$169	$7,607	$8,328	$14,230
Disposable Personal Income	2010 NPV $ Million	$56	$7,988	$14,266	$16,052

* A “Job-Year” refers to a year of employment for one person. Employment gains in each year contain those from the year prior, as well as additional new employment growth. As such, they represent continuations of jobs created before, as well as the creation of more new positions. When aggregating a total result, the total represents years of employment rather than a total number of entirely new positions.

Table 28. Cumulative Impacts (2013 through 2035)

Category	Units	Renewable Portfolio Standard	Scenario 2 Least-Cost Forecast (2020 & 2050 Goals)	Scenario 3 Least-Cost Forecast (2020 Goal)	Scenario 3 Least-Cost Forecast (2050 Goal)
State Tax Revenues	2010 NPV $ Million	$32	$2,085	$3,960	$4,818
Employment	Job-Years	18,284	220,304	422,052	574,498
GDP	2010 NPV $ Million	$1,298	$4,372	$15,222	$28,919
Output	2010 NPV $ Million	$2,101	$5,757	$17,205	$36,345
Disposable Personal Income	2010 NPV $ Million	$937	$18,728	$41,162	$49,419

Tables 29 and 30 show net annual impacts associated with each of the forecast scenarios for both time periods. Table 29 provides estimated employment impacts for the base case gross employment forecast for Oregon, and the incremental impacts for each forecast scenario on an annual basis. Table 30 provides estimated impacts on state GDP for the base case gross employment forecast for Oregon, and the incremental impacts for each forecast scenario on an annual basis. These sets of results provide insight on the trend in the potential economic impacts associated with each of the scenarios.

Table 29. Net Annual Employment Impacts of Oregon GHG Scenarios

	2015	2020	2022	2025	2030	2035
Oregon Base Case	2,504,062	2,735,161	2,774,870	2,829,005	2,923,061	3,046,385
Scenario 2 Least-Cost Forecast (2020 & 2050 Goals)	8,776	6,411	8,525	4,802	2,077	-10,150
Scenario 3 Least-Cost Forecast (2020 Goal)	11,590	9,323	11,909	9,994	6,716	-8,056
Scenario 3 Least-Cost Forecast (2050 Goal)	14,558	16,288	17,317	17,929	18,731	19,542
Renewable Portfolio Standard	0	372	357	1,171	1,383	1,211

Table 30. Net Annual Gross State Product (Millions 2010 Dollars)

	2015	2020	2022	2025	2030	2035
Oregon Base Case	$203,735	$235,898	$245,276	$259,795	$287,390	$321,333
Scenario 2 Least-Cost Forecast (2020 & 2050 Goals)	$724	$403	$515	$369	-$14	-$1,590
Scenario 3 Least-Cost Forecast (2020 Goal)	$817	$869	$1,120	$1,171	$1,184	-$18
Scenario 3 Least-Cost Forecast (2050 Goal)	$1,019	$1,160	$1,251	$1,333	$1,431	$1,537
Renewable Portfolio Standard	$0	$47	$44	$154	$181	$171

For the RPS forecast scenario, the mix of renewal resource measures developed for this analysis to simulate the current RPS (see Appendix A for details) were modeled using estimates of each measure's incremental capital and operation and maintenance costs, and the avoided cost of power produced from natural gas. The incremental costs associated with the mix of renewal energy resource measures produces a stimulative to the economy to the extent that they represent increase capital spending in Oregon, especially where renewable energy projects in Oregon will displace generation in other states. A further area of research is to identify the extent to which Portland General Electric relies on market power which is produced in other states.
For both Scenario 2 and Scenario 3 (2020 goal), the potential annual economic impacts begin to decline after 2022 and show negative impacts toward the end of the 2035 analysis period. For Scenario 3 (2050 goal) forecast, annual impacts show a steady positive gain through to the end of the 2035 analysis period.

Further analysis of these scenarios identified the following three measures that were the primary contributors to the negative impacts for the Scenario 2 and Scenario 3 (2020 goal) forecasts: AFW-7 (Reforestation/Afforestation of Rangeland and Cropland), AFW-9 (Enhanced Materials Management in New Building Construction), and M-RCI-54 (Industrial Non-energy GHG Reduction Measures). The cumulative impacts associated with these three measures are shown in Tables 31 and 32. For the Scenario 3 (2050 goal) forecast, the set of least-cost measures needed to keep Oregon on its path to meet its 2050 goal excluded AFW-9 and M-RCI-54; as a result, the potential impacts associated with this scenario relative to Scenario 2 and Scenario 3 (2020 goal) were eliminated.

Another factor contributing to the negative impacts toward the end of the analysis period for Scenario 2 and Scenario 3 is associated with the design of AFW-7. For this measure, all of the reforestation/afforestation projects covering rangeland and cropland are completed by 2035. Consequently, capital investment associated with the measure abruptly ends in 2034 resulting in rapid job losses beginning in 2035. For AFW-9, the negative impacts are associated with increased costs to the construction sector. Costs of administering the program and implementing it with more expensive material outweigh direct savings to contractors. For M-RCI-54, the negative impacts are associated with operating costs of the program. Operating costs outweigh savings from energy use reductions and are not offset by stimulative capital investment as are operating costs in many of the other measures.

Table 31. Cumulative Impacts Associated with AFW-7, AFW-9 and M-RCI-54 (2013 through 2022)

Category	Units	AFW-7 (Reforestation / Afforestation of Rangeland and Cropland)	AFW-9 (Enhanced Materials Management in New Building Construction)	M-RCI-54 (Industrial Non-energy GHG Reduction Measures)
State Tax Revenues	2010 NPV $ Million	$270	-$58	-$116
Employment	Job-Years*	-15,880	-12,993	-24,381
GDP	2010 NPV $ Million	-$455	-$1,084	-$2,365
Output	2010 NPV $ Million	-$3,943	-$1,731	-$3,774
Disposable Personal Income	2010 NPV $ Million	$5,407	-$575	-$1,297

Table 32. Cumulative Impacts Associated with AFW-7, AFW-9 and M-RCI-54 (2013 through 2035)

Category	Units	AFW-7 (Reforestation / Afforestation of Rangeland and Cropland)	AFW-9 (Enhanced Materials Management in New Building Construction)	M-RCI-54 (Industrial Non-energy GHG Reduction Measures)
State Tax Revenues	2010 NPV $ Million	$531	-$159	-$427
Employment	Job-Years*	-45,021	-35,848	-93,778
GDP	2010 NPV $ Million	-$1,344	-$2,806	-$8,008
Output	2010 NPV $ Million	-$8,510	-$4,480	-$12,690
Disposable Personal Income	2010 NPV $ Million	$12,796	-$1,831	-$5,574

In summary, this initial foundational modeling analysis suggests that the macroeconomic impacts of the various scenarios analyzed vary depending on the individual measures modeled in each scenario and how the economic effects of the measures interact with the Oregon economy. While an initial analysis isolated three measures that had significant negative impacts, further work is recommended to determine how these measures may need certain assumptions revisited and be redesigned to improve their economic performance, as well as to identify other measures that may contribute negative impacts that are offset by the positive impacts of other measures.

Tables 33 through 36 provide additional information regarding the modeling results for the RPS forecast and Scenarios 2 and 3. These tables show for each of the economic categories the BAU forecast for Oregon, the cumulative results associated with adding the RPS or scenario forecast impacts with the BAU forecast, the incremental impacts of the RPS or scenario forecast relative to the BAU forecast, and the percent change in economic impacts associated with the RPS or scenario forecast relative to the BAU forecast.

Table 33. Integrated Macroeconomic Impact Analysis Results: RPS Forecast

Category	Units	2015	2020	2022	2025	2030	2035
Baseline Business as Usual Forecast for Oregon							
State Tax Revenues	2010 $ million	$16,954	$18,803	$19,332	$20,082	$21,412	$23,140
Employment	Jobs	2,504,062	2,735,161	2,774,870	2,829,005	2,923,061	3,046,385
GDP	2010 $ million	$203,735	$235,898	$245,276	$259,795	$287,390	$321,333
Output	2010 $ million	$363,316	$413,215	$429,731	$455,291	$502,767	$557,241
Disposable Personal Income	2010 $ million	$187,382	$247,445	$268,609	$304,699	$378,301	$481,827
Population	Number of People	4,104,693	4,318,594	4,398,222	4,508,091	4,666,832	4,812,912
Per Capita Earnings	2010 $	$60,171	$72,262	$77,262	$86,150	$104,044	$127,783
PCE-Price Index	2005=100	124	138	145	157	181	209
Baseline plus RPS Policy							
State Tax Revenues	2010 $ million	$16,954	$18,804	$19,333	$20,086	$21,417	$23,144
Employment	Jobs	2,504,062	2,735,533	2,775,227	2,830,176	2,924,444	3,047,596
GDP	2010 $ million	$203,735	$235,945	$245,319	$259,950	$287,571	$321,504
Output	2010 $ million	$363,316	$413,291	$429,802	$455,542	$503,060	$557,514
Disposable Personal Income	2010 $ million	$363,316	$413,238	$429,757	$455,379	$502,904	$557,394
Population	Number of People	4,104,693	4,318,607	4,398,236	4,508,083	4,666,739	4,812,418
Per Capita Earnings	2010 $	$60,171	$72,265	$77,266	$86,163	$104,068	$127,814
PCE-Price Index	2005=100	124	138	145	157	181	209
Incremental Effect of RPS Policy							
State Tax Revenues	2010 $ million	$0	$1	$1	$4	$5	$3
Employment	Jobs	0	372	357	1,171	1,383	1,211
GDP	2010 $ million	$0	$47	$44	$154	$181	$171
Output	2010 $ million	$0	$76	$71	$250	$294	$273
Disposable Personal Income	2010 $ million	$0	$23	$25	$88	$137	$153
Population	Number of People	0	13	14	-8	-93	-494
Per Capita Earnings	2010 $	$0	$3	$4	$13	$24	$31
PCE-Price Index	2005=100	0.0	0.0	0.0	0.0	0.1	0.1
Percent Change							
State Tax Revenues	2010 $million	0.00%	0.01%	0.01%	0.02%	0.02%	0.01%
Employment	Jobs	0.00%	0.01%	0.01%	0.04%	0.05%	0.04%
GDP	2010 $ million	0.00%	0.02%	0.02%	0.06%	0.06%	0.05%
Output	2010 $ million	0.00%	0.02%	0.02%	0.05%	0.06%	0.05%
Disposable Personal Income	2010 $ million	0.00%	0.01%	0.01%	0.02%	0.03%	0.03%
Population	people	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%
Per Capita Earnings	2010 $	0.00%	0.00%	0.01%	0.02%	0.02%	0.02%

Table 34. Integrated Macroeconomic Impact Analysis Results: Scenario 2 Least-Cost Forecast Associated with Achieving Oregon's 2020 and 2050 GHG Reduction Goals

Category	Units	2015	2020	2022	2025	2030	2035
Baseline Business as Usual Forecast for Oregon							
State Tax Revenues	2010 $ million	$16,954	$18,803	$19,332	$20,082	$21,412	$23,140
Employment	Jobs	2,504,062	2,735,161	2,774,870	2,829,005	2,923,061	3,046,385
GDP	2010 $ million	$203,735	$235,898	$245,276	$259,795	$287,390	$321,333
Output	2010 $ million	$363,316	$413,215	$429,731	$455,291	$502,767	$557,241
Disposable Personal Income	2010 $ million	$187,382	$247,445	$268,609	$304,699	$378,301	$481,827
Population	Number of People	4,104,693	4,318,594	4,398,222	4,508,091	4,666,832	4,812,912
Per Capita Earnings	2010 $	$60,171	$72,262	$77,262	$86,150	$104,044	$127,783
PCE-Price Index	2005=100	124	138	145	157	181	209
Baseline plus Scenario 2							
State Tax Revenues	2010 $ million	$17,040	$18,924	$19,477	$20,239	$21,581	$23,213
Employment	Jobs	2,516,041	2,744,320	2,786,305	2,839,205	2,931,547	3,040,763
GDP	2010 $ million	$204,459	$236,301	$245,791	$260,164	$287,376	$319,743
Output	2010 $ million	$364,477	$413,708	$430,428	$455,793	$502,667	$554,598
Disposable Personal Income	2010 $ million	$187,383	$247,446	$268,611	$304,700	$378,302	$481,827
Population	Number of People	4,115,588	4,342,133	4,426,532	4,541,604	4,706,463	4,848,043
Per Capita Earnings	2010 $	$60,171	$72,262	$77,262	$86,150	$104,044	$127,782
PCE-Price Index	2005=100	124	138	144	156	180	208
Incremental Effect of Scenario 2							
State Tax Revenues	2010 $ million	$86	$122	$145	$157	$169	$72
Employment	Jobs	11,979	9,159	11,435	10,200	8,486	-5,622
GDP	2010 $ million	$724	$403	$515	$369	-$14	-$1,590
Output	2010 $ million	$1,161	$493	$697	$502	-$100	-$2,643
Disposable Personal Income	2010 $ million	$1	$1	$1	$1	$2	$0
Population	Number of People	10,896	23,539	28,310	33,513	39,631	35,131
Per Capita Earnings	2010 $	$0	$0	$0	$0	$0	$0
PCE-Price Index	2005=100	-0.2	-0.4	-0.5	-0.6	-0.7	-0.4
Percent Change							
State Tax Revenues	2010 $ million	0.51%	0.65%	0.75%	0.78%	0.79%	0.31%
Employment	jobs	0.48%	0.33%	0.41%	0.36%	0.29%	-0.18%
GDP	2010 $ million	0.36%	0.17%	0.21%	0.14%	0.00%	-0.49%
Output	2010 $ million	0.32%	0.12%	0.16%	0.11%	-0.02%	-0.47%
Disposable Personal Income	2010 $ million	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Population	people	0.27%	0.55%	0.64%	0.74%	0.85%	0.73%
Per Capita Earnings	2010 $	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 35. Integrated Macroeconomic Impact Analysis Results: Scenario 3 Least-Cost Forecast Associated with Achieving Oregon's 2020 GHG Reduction Goal

Category	Units	2015	2020	2022	2025	2030	2035
Business as Usual Forecast for Oregon							
State Tax Revenues	2010 $ million	$16,954	$18,803	$19,332	$20,082	$21,412	$23,140
Employment	Jobs	2,504,062	2,735,161	2,774,870	2,829,005	2,923,061	3,046,385
GDP	2010 $ million	$203,735	$235,898	$245,276	$259,795	$287,390	$321,333
Output	2010 $ million	$363,316	$413,215	$429,731	$455,291	$502,767	$557,241
Disposable Personal Income	2010 $ million	$247,445	$187,382	$268,609	$304,699	$378,301	$481,827
Population	Number of People	4,104,693	4,318,594	4,398,222	4,508,091	4,666,832	4,812,912
Per Capita Earnings	2010 $	$60,171	$72,262	$77,262	$86,150	$104,044	$127,783
PCE-Price Index	2005=100	124	138	145	157	181	209
Baseline plus Scenario 3							
State Tax Revenues	2010 $ million	$17,083	$19,015	$19,588	$20,374	$21,767	$23,412
Employment	Jobs	2,516,777	2,749,492	2,792,962	2,847,865	2,943,927	3,056,507
GDP	2010 $ million	$204,551	$236,767	$246,395	$260,967	$288,574	$321,315
Output	2010 $ million	$364,309	$414,070	$431,002	$456,674	$504,157	$557,017
Disposable Personal Income	2010 $ million	$248,802	$189,391	$271,067	$307,651	$382,255	$484,640
Population	Number of People	4,116,969	4,351,600	4,440,179	4,561,339	4,737,044	4,888,341
Per Capita Earnings	2010 $	$60,172	$72,262	$77,262	$86,150	$104,044	$127,783
PCE-Price Index	2005=100	124	137	144	156	179	208
Incremental Effect of Scenario 3							
State Tax Revenues	2010 $ million	$129	$213	$256	$292	$355	$271
Employment	Jobs	12,715	14,332	18,092	18,860	20,865	10,122
GDP	2010 $ million	$817	$869	$1,120	$1,171	$1,184	-$18
Output	2010 $ million	$993	$855	$1,271	$1,383	$1,391	-$224
Disposable Personal Income	2010 $ million	$1,357	$2,008	$2,458	$2,952	$3,954	$2,813
Population	Number of People	12,276	33,005	41,957	53,248	70,212	75,429
Per Capita Earnings	2010 $	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4
PCE-Price Index	2005=100	-0.3	-0.7	-0.8	-0.9	-1.2	-1.0
Percent Change							
State Tax Revenues	2010 $ million	0.76%	1.13%	1.32%	1.46%	1.66%	1.17%
Employment	Jobs	0.51%	0.52%	0.65%	0.67%	0.71%	0.33%
GDP	2010 $ million	0.40%	0.37%	0.46%	0.45%	0.41%	-0.01%
Output	2010 $ million	0.27%	0.21%	0.30%	0.30%	0.28%	-0.04%
Disposable Personal Income	2010 $ million	0.55%	1.07%	0.92%	0.97%	1.05%	0.58%
Population	Number of People	0.30%	0.76%	0.95%	1.18%	1.50%	1.57%
Per Capita Earnings	2010 $	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 36. Integrated Macroeconomic Impact Analysis Results: Scenario 3 Least-Cost Forecast Associated with Achieving Oregon's 2050 GHG Reduction Goal

Category	Units	2015	2020	2022	2025	2030	2035
Business as Usual Forecast for Oregon							
State Tax Revenues	2010 $ million	$16,954	$18,803	$19,332	$20,082	$21,412	$23,140
Employment	Jobs	2,504,062	2,735,161	2,774,870	2,829,005	2,923,061	3,046,385
GDP	2010 $ million	$203,735	$235,898	$245,276	$259,795	$287,390	$321,333
Output	2010 $ million	$363,316	$413,215	$429,731	$455,291	$502,767	$557,241
Disposable Personal Income	2010 $ million	$187,382	$247,445	$268,609	$304,699	$378,301	$481,827
Population	Number of People	4,104,693	4,318,594	4,398,222	4,508,091	4,666,832	4,812,912
Per Capita Earnings	2010 $	$60,171	$72,262	$77,262	$86,150	$104,044	$127,783
PCE-Price Index	2005=100	124	138	145	157	181	209
Baseline plus Scenario 3							
State Tax Revenues	2010 $ million	$17,096	$18,970	$19,522	$20,295	$21,648	$23,398
Employment	Jobs	2,518,620	2,751,449	2,792,188	2,846,934	2,941,792	3,065,927
GDP	2010 $ million	$204,753	$237,059	$246,526	$261,128	$288,821	$322,870
Output	2010 $ million	$364,642	$414,715	$431,342	$456,993	$504,588	$559,204
Disposable Personal Income	2010 $ million	$188,828	$249,110	$270,452	$306,710	$380,481	$484,181
Population	Number of People	4,118,703	4,337,747	4,422,630	4,537,730	4,701,844	4,853,344
Per Capita Earnings	2010 $	$60,575	$72,703	$77,716	$86,628	$104,529	$127,678
PCE-Price Index	2005=100	124	137	144	156	180	208
Incremental Effect of Scenario 3							
State Tax Revenues	2010 $ million	$142	$168	$191	$213	$236	$258
Employment	Jobs	14,558	16,288	17,317	17,929	18,730	19,542
GDP	2010 $ million	$1,019	$1,160	$1,251	$1,333	$1,431	$1,537
Output	2010 $ million	$1,325	$1,500	$1,611	$1,702	$1,821	$1,963
Disposable Personal Income	2010 $ million	$1,446	$1,666	$1,843	$2,011	$2,181	$2,354
Population	Number of People	14,010	19,153	24,408	29,639	35,012	40,432
Per Capita Earnings	2010 $	$404	$441	$455	$479	$485	-$105
PCE-Price Index	2005=100	-0.4	-0.4	-0.5	-0.6	-0.7	-0.8
Percent Change							
State Tax Revenues	2010 $ million	0.84%	0.89%	0.99%	1.06%	1.10%	1.11%
Employment	Jobs	0.58%	0.60%	0.62%	0.63%	0.64%	0.64%
GDP	2010 $ million	0.50%	0.49%	0.51%	0.51%	0.50%	0.48%
Output	2010 $ million	0.36%	0.36%	0.37%	0.37%	0.36%	0.35%
Disposable Personal Income	2010 $ million	0.77%	0.67%	0.69%	0.66%	0.58%	0.49%
Population	Number of People	0.34%	0.44%	0.55%	0.66%	0.75%	0.84%
Per Capita Earnings	2010 $	0.67%	0.61%	0.59%	0.56%	0.47%	-0.08%

3.7 Future Research

Further investigation may be particularly fruitful in distinguishing GHG mitigation measures that stimulate new investment by creating new markets from those that merely displace product in existing markets. For example, efficiency improvements in lighting, air handling and insulation may have much different macroeconomic impacts than technologies that make use of new technology at the expense of lower-cost existing technologies. Addressing the issue of whether new efficiency measures are displacing existing economic activity or enhancing that activity is critical to understanding the way GHG mitigation measures behave in the market and affect the lives of Oregonians.

As noted at the outset of this chapter, the choice of investment mechanism (where the money comes from) can be as important as the program outlays (where the money goes) in determining macroeconomic performance of measures, particularly those with high spending profiles and/or new revenue streams. As a result, the effects of alternative choices of investment mechanisms may be important in future research. For instance, investments made for regulatory compliance purposes may come from different sources than investments made for the purpose of increasing the bottom line, and assumptions about the sources of these investment dollars are made for every macroeconomic analysis. Refinement of assumptions as to where and how investment dollars are generated, as well as why they are invested, may be the most productive 'next steps' to inform decisions on how to design implementation mechanisms, including financing, for mitigation measures so as to maximize positive macroeconomic impacts for Oregon's economy.

As noted earlier, the design of specific measures (timing, level of effort, coverage of parties, eligibility provisions, etc.) as well as implementation mechanisms and performance assumptions as to value-added returns on investment may have the potential to significantly alter the economic performance of some measures, and bears consideration. Included in these alternative design choices are options that are not least cost but are potentially expansionary economically.

3.8 References

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Appendix A: Power Supply Measure Descriptions and Related Materials

PS-Renewable

Measure Descriptions

The power supply cost curve analysis considered a total of 17 greenhouse gas (GHG) mitigation technologies in the renewable energy category. A brief description of each of these technologies is provided in the bullets below and is based mostly on information in the Sixth Northwest Conservation and Electric Plan. A summary of cost and performance characteristics of these technologies is summarized in tabular form in the next section.

- *PS-1: New hydropower:* The potential for new hydropower of the Northwest is been estimated to be about 20,500 average megawatts of energy. Though this hydroelectric power potential is large, most economically and environmentally feasible sites have already been developed and the remaining opportunities are a diversity of small-scale projects. Conventional hydro technology is considered. In a technology, water is stored in a dam and passed through a turbine and generator set before being released back into the river downstream. The power station does not consume any water in this process, it only uses the energy contained in running water to turn its turbines. The size of a new hydropower unit is assumed to be 10 megawatt (MW) and operates at an average capacity factor of 50%.
- *PS-2: Existing hydropower:* The potential for upgrades to existing hydropower sites on the Columbia River Basin is been estimated to be about 0.6 megawatts of energy. Conventional hydro technology is considered (see technology description above) due to the comparatively higher costs of hydrokinetic technology. The size of a hydropower unit upgrade is assumed to be 100 kilowatt (kW) and operates at an average capacity factor of 50%.
- *PS-3: Wastewater treatment gas:* Sludge collected in the clarification stage of waste water treatment is commonly processed in anaerobic digesters to remove volatile organic materials. Anaerobic digestion produces a low- British thermal unit (Btu) gas consisting largely of methane and carbon dioxide. This gas can be treated to remove moisture, siloxanes, hydrogen sulfide, and other impurities and used to fuel an electric generating plant. Reject heat from the engine is used to maintain optimum digester temperature. The gas from the anaerobic digesters is used in a reciprocating engine generating unit whose size is assumed to be 0.85 MW, operating at an average capacity factor of 85%.
- *PS-4: Landfill gas:* A landfill gas energy recovery plant uses the methane content of the gas produced as a result of the decomposition of landfill contents to generate electric power. The complete recovery system includes an array of collection wells, collection piping, gas cleanup equipment, and one or more generator sets, usually using reciprocating engines. Typically, the gas collection system is installed as a requirement of landfill operation and the raw gas sold to the operator of the power plant. The gas from the landfill is used in a reciprocating engine generating unit whose size is assumed to be 1.6 MW, operating at an average capacity factor of 85%.

- *PS-5: Animal manure:* The energy value of certain agricultural and food wastes can be recovered waste materials in anaerobic digesters. This yields a combustible gas that thermal electric power generator. The most widely employed anaerobic digestion technology at present, uses animal manure in liquid or slurry form. The principal source of suitable feedstock is from manure handling systems at large concentrated animal feeding operations. The gas from these operations is used in a reciprocating engine generating unit whose size is assumed to be 0.85 MW, operating at an average capacity factor of 75%.
- *PS-6: Woody Residues (greenfield):* Woody residue includes mill residues, logging slash, urban construction and demolition debris, urban forest and landscaping debris, unmerchantable products of commercial forest management and ecosystem restoration and woody energy crops. A greenfield plant using woody residues corresponds to a plant using new equipment, at a greenfield site and no cogeneration load. The plant is developed primarily to operate on woody residue from commercial forest thinning, harvest, and forest ecological restoration projects. In the near-term, woody residues are assumed to be used in new conventional steam-electric plants whose size is assumed to be 25 MW (net), operating at an average capacity factor of 80%.
- *PS-7: Woody Residues (brownfield):* A brownfield plant using woody residues case is one that is sited at a brownfield site with existing transportation, water, and transmission infrastructure. Locally available mill residue and other residue fuels are assumed sufficient to supply the plant's fuel requirements. Refurbished salvaged equipment is available for the steam turbine-generator and other major equipment. Woody residues are assumed to be used in new conventional steam-electric plants whose size is assumed to be 13.2 MW (net), operating at an average capacity factor of 80%.
- *PS-8: Geothermal (binary):* For the Northwest, binary-cycle or heat-pump technology is emerging because of modularity, applicability to lower temperature geothermal resources, and the environmental advantages of a closed geothermal-fluid cycle. In binary plants, the geothermal fluid is brought to the surface using wells, and passed through a heat exchanger where the energy is transferred to a low boiling point fluid. The vaporized low boiling point fluid is used to drive a turbine generator, then condensed and returned to the heat exchanger. The cooled geothermal fluid is re-injected to the geothermal reservoir. This technology operates as a baseload resource and releases no carbon dioxide. Geothermal resources are assumed to be used in new binary cycle plants that employ closed loop organic Rankine cycle technology suitable for low geothermal fluid temperatures. Plant size is assumed to be 40 MW (net), operating at an average capacity factor of 80%.
- *PS-10: Tidal current:* There are several coastal location where tidal current may provide a suitable energy resource for power generation in Oregon, although the overall resource potential is uncertain. Rather than using a dam structure, the devices are placed directly "in-stream" and generate energy from the flow of marine water. There are a number of different technologies for extracting energy from marine currents, including horizontal and vertical-axis turbines, as well as others such as venturis and oscillating foils. Horizontal-axis turbines are perhaps the most common means of extracting power from marine currents and are somewhat similar in design to those used for wind power. This type is assumed with a unit size of 17.3 MW (net) operating at a capacity factor of 50%.

- *PS-11: Wave:* Wave power corresponds to the energy in ocean surface waves. The capture of that energy can be done to generate electricity. Technology to exploit wave power consists of turbine to captures the energy of waves and a wave energy converter to converts this energy to electrical power. Wave power is distinct from tidal current power described above. Total resource potential for Oregon is conservatively estimated to be 20 MW. The installation size is assumed to be 5.2 MW (net), operating at an average capacity factor of 48%.
- *PS-12: Offshore wind:* Oregon has a large offshore wind resources, estimate at nearly 220 GW at wind speeds greater than 7 meters per second. Offshore wind turbines are able to harness the energy of the moving air over the oceans and convert it to electricity. Since offshore winds tend to flow at higher speeds than onshore winds, offshore turbines can produce more electricity. An offshore wind farm is assumed to be 100 MW (net), operating at an average capacity factor of 36%.
- *PS-13: Solar Photovoltaic (PV):* A wide variety of photovoltaic plant designs are possible with various combinations of cell, module, and mounting design. Technology was assumed to be flat plate (non-concentrating) single crystalline modules mounted on single-axis trackers. DC power is converted to AC for grid interconnection using solid-state inverters. The plant also includes step-up transformers, switchgear and interconnection facilities and security, control and maintenance facilities. Plant size is 20 MW (net) and operates at a capacity factor of 25%.
- *PS-14: Concentrating solar power:* Parabolic trough concentrating solar thermal power plants use a synthetic oil primary heat transfer fluid and a supplementary natural gas boiler in the secondary water heat transfer loop for output stabilization and extended operation into the evening hours. Concentrating solar technologies require high direct normal solar irradiation for efficient operation, which is largely unavailable in Oregon. Plants are assumed to be located in Bonneville's Nevada service territory and have a size of 100 MW (net) and operate at a capacity factor of 36%.
- *PS-15 through PS-18: Onshore wind:* Wind power is modeled by defining a reference wind plant then applying transmission costs and losses appropriate to the location of the wind resource and the load center served. Plant capacity factors are adjusted to reflect the quality of the various wind resource areas. Five wind resource areas were considered, including the Columbia basin (eastern Washington and Oregon), southern Idaho, central Montana, southern Alberta, and eastern Wyoming. Plants are assumed to have a size of 100 MW (net) and operate at a capacity factor of 32% in eastern Washington and Oregon, and 38% in the other locations.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: For the cost curve analysis, the goal for each of the renewable technologies is assumed to be its available potential, as summarized in the table below.

No.	Resource	Technology	Unit size (net MW)	Assumed Potential (net MW)	Earliest service year
PS-1	Hydropower	New projects	10	100	2016
PS-2		Conventional hydro upgrades in OR	0.1	21.19	2016
PS-3	Wastewater treatment gas	Reciprocating engines	0.85	3.5	2012
PS-4	Landfill gas	Reciprocating engine	1.6	35	2012
PS-5	Animal manure	Reciprocating engine	0.85	25	2012
PS-6	Woody residues	Steam-electric - brownfield	13.2	203	2014
PS-7		Steam-electric - greenfield	25	203	2014
PS-8	Geothermal	Binary hydrothermal	40	150	2017
PS-10	Tidal current	Water current turbines	17.3	50	2016
PS-11	Wave	Various buoy & overtopping devices	5.2	20	2016
PS-12	Offshore Wind	Floating WTG	100	500	2016
PS-13	Solar	Utility-scale Photovoltaic arrays	20	150	2013
PS-14	Solar (Nevada)	Parabolic trough	100	150	2015
PS-15	Wind (in OR/WA)	Wind turbine generators	100	705	2013
PS-16	Wind (from Alberta to OR/WA)	Wind turbine generators	100	760	2015
PS-17	Wind (from Montana to OR/WA)	Wind turbine generators	100	570	2015
PS-18	Wind (from Wyoming to OR/WA)	Wind turbine generators	100	570	2015
PS-19	Waste heat	Bottoming Rankine cycle	5	25	2014

Timing (Start, Phase In, End): The earliest in-service date for each technology is shown in the above table.

Parties Involved: OR Department of Energy.

Data Sources and Additional Background:

- Chapter 6 of the Sixth Northwest Conservation and Electric Power Plan, prepared by the Northwest Power and Conservation Council, February 2010 (available at http://www.nwcouncil.org/energy/powerplan/6/default.htm; accessed 20 June 2012)
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Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

		GHG reductions (million tCO2e)				NPV (million 2010$)		Cost-effectiveness ($2010/tCO2e saved)	
				Cumulative					
Option	Resource	2022	2035	2010-2022	2010-2035	2010-2022	2010-2035	2010-2022	2010-2035
PS-1	Hydropower	0.22	0.16	1.34	3.62	$70	$131	$52	$36
PS-2	Hydropower	0.05	0.03	0.28	0.77	$78	$164	$276	$214
PS-3	Wastewater treatment gas	0.01	0.01	0.12	0.26	$11	$16	$90	$61
PS-4	Landfill gas	0.08	0.04	0.59	1.22	$52	$62	$89	$51
PS-5	Animal manure	0.08	0.06	0.76	1.61	$56	$77	$74	$48
PS-6	Woody residues (brownfield)	0.26	0.16	1.85	4.30	$160	$252	$86	$59
PS-7	Woody residues (greenfield)	0.28	0.18	2.01	4.65	$348	$596	$173	$128
PS-8	Geothermal	0.60	0.43	3.12	9.28	$117	$232	$38	$25
PS-9	Geothermal (enhanced)	NA	NA	NA	NA	NA	NA	NA	NA
PS-10	Tidal current	0.18	0.13	0.93	2.78	$55	$100	$59	$36
PS-11	Wave	0.21	0.15	1.28	3.48	$472	$997	$367	$287
PS-12	Offshore Wind	0.50	0.36	2.05	7.31	$412	$820	$201	$112
PS-13	Solar	0.41	0.29	2.22	6.48	$1,822	$3,095	$822	$478
PS-14	Solar (Nevada)	0.57	0.41	2.96	8.92	$1,403	$2,703	$473	$303
PS-15	Wind (in OR/WA)	0.63	0.45	2.35	8.94	$885	$1,395	$377	$156
PS-16	Wind (from Alberta to OR/WA)	0.80	0.58	3.41	11.85	$1,292	$2,437	$379	$206
PS-17	Wind (from Montana to OR/WA)	0.60	0.43	2.56	8.88	$1,072	$2,030	$419	$229
PS-18	Wind (from Wyoming to OR/WA)	0.60	0.43	2.56	8.88	$1,151	$2,188	$450	$246

Full Energy-Cycle Results:

		GHG reductions (million tCO2e)				NPV (million 2010$)		Cost-effectiveness ($2010/tCO2e saved)	
				Cumulative					
Option	Resource	2022	2035	2010-2022	2010-2035	2010-2022	2010-2035	2010-2022	2010-2035
PS-1	Hydropower	0.26	0.20	1.59	4.34	$70	$131	$44	$30
PS-2	Hydropower	0.05	0.04	0.34	0.92	$78	$164	$232	$179
PS-3	Wastewater treatment gas	0.02	0.01	0.14	0.31	$11	$16	$75	$51
PS-4	Landfill gas	0.10	0.06	0.82	1.74	$52	$62	$63	$36
PS-5	Animal manure	0.10	0.07	0.90	1.94	$56	$77	$61	$40
PS-6	Woody residues (brownfield)	0.24	0.14	1.68	3.88	$160	$252	$95	$65
PS-7	Woody residues (greenfield)	0.26	0.16	1.82	4.20	$348	$596	$191	$142
PS-8	Geothermal	0.70	0.53	3.70	11.13	$117	$232	$32	$21
PS-9	Geothermal (enhanced)	NA	NA	NA	NA	NA	NA	NA	NA
PS-10	Tidal current	0.21	0.16	1.18	3.50	$55	$100	$47	$29
PS-11	Wave	0.25	0.19	1.53	4.17	$472	$997	$309	$239
PS-12	Offshore Wind	0.63	0.49	2.95	9.87	$412	$820	$140	$83
PS-13	Solar	0.50	0.39	3.12	8.56	$1,822	$3,095	$584	$362
PS-14	Solar (Nevada)	0.70	0.54	3.98	11.58	$1,403	$2,703	$353	$233
PS-15	Wind (in OR/WA)	0.79	0.61	3.95	12.63	$885	$1,395	$224	$110
PS-16	Wind (from Alberta to OR/WA)	1.01	0.79	5.05	16.17	$1,292	$2,437	$256	$151
PS-17	Wind (from Montana to OR/WA)	0.75	0.59	3.79	12.13	$1,072	$2,030	$283	$167
PS-18	Wind (from Wyoming to OR/WA)	0.75	0.59	3.79	12.13	$1,151	$2,188	$304	$180

Quantification Methods and Results:

GHG Reductions. GHG reductions are computed relative to the average annual CO2e intensity of the OR power sector for point-of-combustion and full fuel cycle emission factors. Intermittent renewable energy includes additional costs associated with system balancing and integration services, as shown on the table below. The average annual CO2e emission intensities associated with these balancing services are also shown on the table below.

Table: Balancing services for intermittent renewables, costs and CO2e intensity

Year	Cost of balancing services (2010$/MWh)	CO2e intensity associated with balancing services (tCO2e/MWh)
2010	$8.85	1.032
2011	$8.99	1.032
2012	$9.14	1.032
2013	$9.29	0.813
2014	$9.43	0.659
2015	$9.58	0.575
2016	$9.73	0.522
2017	$9.87	0.468

Year	Cost of balancing services (2010$/MWh)	CO2e intensity associated with balancing services (tCO2e/MWh)
2018	$10.02	0.420
2019	$10.17	0.381
2020	$10.31	0.350
2021	$10.46	0.326
2022	$10.61	0.303
2023	$10.75	0.282
2024	$10.90	0.269
2025	$10.90	0.252
2026	$10.90	0.240
2027	$10.90	0.229
2028	$10.90	0.217
2029	$10.90	0.212
2030	$10.90	0.212
2031	$10.90	0.212
2032	$10.90	0.212
2033	$10.90	0.212
2034	$10.90	0.212
2035	$10.90	0.212

Net Societal Costs. Net societal costs were calculated on the basis of the methodology described in the CCS quantification memo. The cost and performance of renewable technologies used to calculate net societal costs are summarized in the table below.

No.	Resource	Firm capacity value	Heat rate (Btu/kWh)	Capacity factor (%)	Economic life (years)	Overnight capital cost (2010$/kW)	Total average levelized cost (2010$/MWh)	CO2e e-factor (tCO2e/MWh)
PS-1	Hydropower	100%	NA	50%	30	$3,064.34	$91.52	0.00 (direct combustion and fuel cycle)
PS-2		100%	NA	50%	30	$5,107.23	$228.31	
PS-3	Wastewater treatment gas	100%	10,250	85%	20	$5,107.23	$98.88	
PS-4	Landfill gas	100%	10,060	85%	20	$2,400.40	$74.16	0.13 (direct combustion) 0.21 (fuel cycle)
PS-5	Animal manure	100%	10,250	75%	15	$5,107.23	$90.09	0.00 (direct combustion and fuel cycle)
PS-6	Woody residues	100%	15,500	80%	20	$3,064.34	$92.13	0.03 (direct combustion) 0.22 (fuel cycle)
PS-7		100%	15,500	80%	20	$4,085.78	$128.91	0.03 (direct combustion) 0.22 (fuel cycle)
PS-8	Geothermal	100%	28,500	90%	30	$4,902.94	$84.17	0.00 (direct combustion
PS-10	Tidal current	100%	NA	50%	30	$2,137.08	$81.44	

No.	Resource	Firm capacity value	Heat rate (Btu/kWh)	Capacity factor (%)	Economic life (years)	Overnight capital cost (2010$/kW)	Total average levelized cost (2010$/MWh)	CO2e e-factor (tCO2e/MWh)
PS-11	Wave	100%	NA	48%	30	$9,301.92	$284.00	and fuel cycle)
PS-12	Offshore Wind	5%	NA	36%	20	$4,175.25	$105.42	
PS-13	Solar	30%	NA	25%	25	$9,193.01	$260.88	
PS-14	Solar (Nevada)	30%	NA	36%	30	$4,800.79	$207.35	
PS-15	Wind (in OR/WA)	5%	NA	32%	20	$2,145.04	$105.21	
PS-16	Wind (from Alberta to OR/WA)	5%	NA	38%	20	$2,145.04	$138.92	
PS-17	Wind (from Montana to OR/WA)	5%	NA	38%	20	$2,145.04	$148.11	
PS-18	Wind (from Wyoming to OR/WA)	5%	NA	38%	20	$2,145.04	$155.26	

Key Assumptions & Uncertainties (including sensitivities)

- These estimates should be seen as the upper end potential for these measures in OR.

PS-Advanced Fossil

Measure Descriptions

The power supply cost curve analysis considered a total of 4 GHG mitigation technologies in the advanced fossil category. A brief description of each of these technologies is provided in the bullets below and is based mostly on information in the Sixth Northwest Conservation and Electric Plan. A summary of cost and performance characteristics of these technologies is summarized in tabular form in the next section.

- *PS-19: Waste heat:* Certain industrial processes and engines reject energy at sufficient temperature and volume to justify capturing the energy for electricity production, a process known as Recovered Energy Generation (REG), and a form of cogeneration. Heat recovery boilers with steam- turbine generators are the conventional approach to using waste heat for electric power generation. The resource potential in Oregon is assumed to be 20 MW. Plants are assumed to be an organic Rankine cycle generating facility using 900 degree gas turbine exhaust heat. The size of the unit is assumed to be 5 MW (net) and operates at a capacity factor of 80%.
- *PS-20: Super-critical coal w/CO2 capture (90%):* Coal-fired supercritical power plants operate at very high temperature and pressure (around 580 degrees centigrade with a pressure of about 23 MPa). This results in higher heat rates (i.e., 7,400 btu/kWh prior to the installation of carbon capture equipment) compared to sub-critical coal-fired plants which operates at 455 degree centigrade and heat rate of around 10,000 btu/kWh. The size of a new unit is assumed to be 450 MW, operates at an average capacity factor of 80%, and

incorporate capacity derating and a heat rate penalty associated with carbon capture equipment.

- *PS-21: Ultra-supercritical coal w/CO2 capture (90%):* Coal-fired ultra-supercritical power plants operate at very high temperature and pressure (around 593 degrees centigrade with a pressure of about 35 MPa). This results in higher heat rates (i.e., 6,400 btu/kWh prior to the installation of carbon capture equipment) compared to sub-critical coal-fired plants which operates at 455 degree centigrade and heat rate of around 10,000 btu/kWh. The size of a new unit is assumed to be 450 MW, operates at an average capacity factor of 80%, and incorporates capacity derating and a heat rate penalty associated with oxy-firing carbon capture equipment capable of capturing 90% of emissions.

- *PS-22: Petroleum coke/coal mix (50/50) gasification combined-cycle w/CO2 capture (90%):* Coal gasification allows the application of efficient gas turbine combined cycle technology to coal-fired generation. This reduces fuel consumption, improves operating flexibility, and lowers CO2 production. Mixing in equal amounts with petroleum coke, a lower carbon-intensive fuel, leads to additional reductions in emissions. The plant operates at an efficiency of 10,760 btu/kWh. The size of a new unit is assumed to be 518 MW, operates at an average capacity factor of 80%, and incorporates capacity derating and a heat rate penalty associated with oxy-firing carbon capture equipment capable of capturing 90% of emissions.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: For the cost curve analysis, the goal for each of the advanced fossil technologies is assumed to be its available potential, as summarized in the table below.

No.	Resource	Technology	Unit size (net MW)	Assumed Potential (net MW)	Earliest service year
PS-19	Waste heat	Bottoming Rankine cycle	5	25	2014
PS-20	Coal	Supercritical w/CO2 capture (90%)	450	450	2025
PS-21	Coal	Ultra-Supercritical w/CO2 capture (90%)	450	450	2025
PS-22	Coal/petroleum coke (50-50)	Gasification combined-cycle w/CO2 capture (90%)	518	518	2025

Timing (Start, Phase In, End): The earliest in-service date for each technology is shown in the above table.

Parties Involved: OR Department of Energy.

Data Sources and Additional Background:

- Chapter 6 of the Sixth Northwest Conservation and Electric Power Plan, prepared by the Northwest Power and Conservation Council, February 2010 (available at http://www.nwcouncil.org/energy/powerplan/6/default.htm; accessed 20 June 2012)

- Appendix I of the Sixth Northwest Conservation and Electric Power Plan, prepared by the Northwest Power and Conservation Council, February 2010 (available at http://www.nwcouncil.org/energy/powerplan/6/default.htm; accessed 20 June 2012)
- "Cost and Performance Assumptions for Modeling Electricity Generation Technologies", prepared by NREL, 2010 (available at http://www.nrel.gov/docs/fy11osti/48595.pdf; accessed 21 June 2012).

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

		GHG reductions (million tCO2e)				NPV (million 2010$)		Cost-effectiveness ($2010/tCO2e saved)	
				Cumulative					
Option	Resource	2022	2035	2010-2022	2010-2035	2010-2022	2010-2035	2010-2022	2010-2035
PS-19	Waste heat	0.09	0.06	0.68	1.59	$9	$5	$13	$3
PS-20	Supercritical coal w/CO2 capture (90%)	0.00	0.78	0.00	8.58	$0	$1,291	$0	$150
PS-21	Ultra-supercritical coal w/CO2 capture (90%)	0.00	0.83	0.00	9.16	$0	$1,142	$0	$125
PS-22	Coal/petroleum coke (50-50), gasification combined cycle w/CO2 capture (90%)	0.00	0.93	0.00	10.19	$0	$1,220	$0	$120

Full Energy-Cycle Results:

		GHG reductions (million tCO2e)				NPV (million 2010$)		Cost-effectiveness ($2010/tCO2e saved)	
				Cumulative					
Option	Resource	2022	2035	2010-2022	2010-2035	2010-2022	2010-2035	2010-2022	2010-2035
PS-19	Waste heat	0.10	0.08	0.81	1.91	$9	$5	$11	$2
PS-20	Supercritical coal w/CO2 capture (90%)	0.00	1.03	0.00	11.37	$0	$1,291	$0	$114
PS-21	Ultra super-critical coal w/CO2 capture (90%)	0.00	1.09	0.00	11.95	$0	$1,142	$0	$96
PS-22	Coal/petroleum coke (50-50), gasification combined cycle w/CO2 capture (90%)	0.00	1.10	0.00	12.11	$0	$1,220	$0	$101

Quantification Methods and Results:

GHG Reductions. GHG reductions are computed relative to the average annual CO2e intensity of the OR power sector for point-of-combustion and full fuel cycle emission factors.

Net Societal Costs. Net societal costs were calculated on the basis of the methodology described in the CCS quantification memo. The cost and performance of advanced fossil technologies used to calculate net societal costs are summarized in the table below.

No.	Resource	Firm capacity value	Heat rate (Btu/kWh)	Capacity factor (%)	Economic life (years)	Overnight capital cost (2010$/kW)	Total average levelized cost (2010$/MWh)	CO2e e-factor (tCO2e/MWh)
PS-19	Waste heat	100%	38,000	80%	20	$3,575.06	$63.13	0.00 (direct combustion and fuel cycle)
PS-20	Coal	100%	11,880	80%	30	$5,755.85	$156.28	0.116 (direct combustion) 0.118 (fuel cycle)
PS-21	Coal	100%	10,170	80%	30	$5,612.84	$146.07	0.099 (direct combustion) 0.101 (fuel cycle)
PS-22	Coal/petroleum coke	100%	10,760	80%	30	$4,902.94	$140.45	0.108 (direct combustion) 0.142 (fuel cycle)

Key Assumptions & Uncertainties (including sensitivities)

- These estimates should be seen as the upper end potential for this measure in OR.

PS-Nuclear

Measure Descriptions

The power supply cost curve analysis considered a total of 2 GHG mitigation technologies in the nuclear category. A brief description of each of these technologies is provided in the bullets below and is based mostly on information in the Sixth Northwest Conservation and Electric Plan. A summary of cost and performance characteristics of these technologies is summarized in tabular form in the next section.[1]

- *PS-28: Advanced light water reactors:* Nuclear power plants produce electricity form energy released by the controlled fission of certain isotopes of heavy elements such as uranium, thorium, and plutonium. Advanced light water reactors are fueled by 3% fissionable U-235 and 97% non-fissionable U-238. The size of a new unit is assumed to be 1,117 MW, and operates at an average capacity factor of 90%. The earliest online year for advanced light water reactors is assumed to be 2023.

[1] Options PS-23 through PS-27 are advanced natural gas options which do not lead to emission reductions and are therefore not included in the write-up.

- *PS-29: Small modular reactors:* Small modular reactors are scalable, factory-assembled plants having a size between 25 and 350 MW. Proposed designs offer improved safety through features such as integral construction, below ground emplacement, and lifetime, factory-installed fuel supplies. The size of a new unit is assumed to be 300 MW, and operates at an average capacity factor of 90%. The earliest online year for advanced light water reactors is assumed to be 2023.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: For the cost curve analysis, the goal for each of the nuclear technologies is assumed to be its available potential, as summarized in the table below.

No.	Resource	Technology	Unit size (net MW)	Assumed Potential (net MW)	Earliest service year
PS-28	Uranium	Advanced light water reactor	1,117	1,117	2023
PS-29	Uranium	Modular reactor	300	300	2023

Timing (Start, Phase In, End): The earliest in-service date for each technology is shown in the above table.

Parties Involved: OR Department of Energy.

Data Sources and Additional Background:

- Chapter 6 of the Sixth Northwest Conservation and Electric Power Plan, prepared by the Northwest Power and Conservation Council, February 2010 (available at http://www.nwcouncil.org/energy/powerplan/6/default.htm; accessed 20 June 2012)
- Appendix I of the Sixth Northwest Conservation and Electric Power Plan, prepared by the Northwest Power and Conservation Council, February 2010 (available at http://www.nwcouncil.org/energy/powerplan/6/default.htm; accessed 20 June 2012)
- page 19 of paper entitled: "Small Modular Reactors – Key to Future Nuclear Power Generation in the U.S.", prepared by Robert Rosner and Stephen Goldberg, Energy Policy Institute at Chicago The Harris School of Public Policy Studies

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

		GHG reductions (million tCO2e)				NPV (million 2010$)		Cost-effectiveness ($2010/tCO2e saved)	
				Cumulative					
Option	Resource	2022	2035	2010-2022	2010-2035	2010-2022	2010-2035	2010-2022	2010-2035
PS-28	Nuclear (advanced light water reactor)	0.00	3.20	0.00	45.94	$0	$2,180	$0	$47
PS-29	Nuclear (small modular reactor)	0.00	0.86	0.00	12.34	$0	$733	$0	$59

Full Energy-Cycle Results:

		GHG reductions (million tCO2e)				NPV (million 2010$)		Cost-effectiveness ($2010/tCO2e saved)	
				Cumulative					
Option	Resource	2022	2035	2010-2022	2010-2035	2010-2022	2010-2035	2010-2022	2010-2035
PS-28	Nuclear (advanced light water reactor)	0.00	3.57	0.00	50.71	$0	$2,180	$0	$43
PS-29	Nuclear (small modular reactor)	0.00	0.96	0.00	13.62	$0	$733	$0	$54

Quantification Methods and Results:

GHG Reductions. GHG reductions are computed relative to the average annual CO2e intensity of the OR power sector for point-of-combustion and full fuel cycle emission factors.

Net Societal Costs. Net societal costs were calculated on the basis of the methodology described in the CCS quantification memo. The cost and performance of nuclear technologies used to calculate net societal costs are summarized in the table below.

No.	Resource	Firm capacity value	Heat rate (Btu/kWh)	Capacity factor (%)	Economic life (years)	Overnight capital cost (2010$/kW)	Total average levelized cost (2010$/MWh)	CO2e e-factor (tCO2e/MWh)
PS-28	Uranium	100%	10,400	90%	30	$5,617.95	$110.32	0.00 (direct combustion) 0.04 (fuel cycle)
PS-29	Uranium	100%	10,400	90%	30	$3,495.39	$121.10	0.00 (direct combustion) 0.040 (fuel cycle)

Key Assumptions & Uncertainties (including sensitivities)

- These estimates should be seen as the upper end potential for this measure in OR.

PS-Electricity

Measure Descriptions

The power supply cost curve analysis considered a total of 3 GHG mitigation technologies in the electricity category. A brief description of each of these technologies is provided in the bullets below. A summary of cost and performance characteristics of these technologies is summarized in tabular form in the next section.[2]

- *PS-30: Smart grid technology – advanced metering infrastructure:* The term "smart grid" has taken on wide range of meanings. Smart grid can be divided into two functional areas: customer load and use management, and transmission and distribution (T&D) monitoring and control. Application of each can result in increased electrical efficiency, utilization, operational efficiency, reliability, or electricity load management. Each of the functional areas relies on advanced monitoring, controls, data analysis, and communications. Oregon's electric utilities are in various stages of deploying advanced metering infrastructure (AMI), or electric meters that are able to record consumption and other data hourly or more frequently, and are capable of two-way communication with a central location. The meters are also capable of communicating with equipment within the customer's premises. In addition to allowing customers to control their own usage more effectively, AMI can enable various pricing strategies designed to effectively implement energy efficiency, conservation, and demand response programs that can reduce GHG emissions.
- *PS-31: Smart grid technology; Additional regulation for intermittent renewables:* Smart grid technology can also help to mitigate challenges for integrating wind and solar intermittent energy resources into the electric system. The integration of intermittent resources poses challenges due to the unpredictability and steep ramp rates of these resources (particularly wind), which must be compensated by the use of more traditional power plants (termed *load following* or *regulation)* that increase costs because of redundancy and maintenance to correct increased wear and tear. Smart grid technologies, primarily additional regulation/communication, can help replace fossil fuel capacity used to overcome the unpredictability and ramping issues, and thereby increase the level of intermittent renewable generation into the electric system.
- *PS-32: Distribution systems upgrades:* There are several benefits from adding capacitors or other sources of volt-ampere-reactive (VAR) support to the distribution system. This type of support added to the distribution system benefits both the distribution and transmission systems. These benefits include loss reduction, reduced capacity requirements, dispatch and operations cost reduction, and increased reliability. The specific technology considered is an improvement of the feeder power factor by increasing additional capacitors on the distribution system.

[2] Options PS-23 through PS-27 are advanced natural gas options which do not lead to emission reductions and are therefore not included in the write-up.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: For the cost curve analysis, the goal for each of the nuclear technologies is assumed to be its available potential, as summarized in the table below.

No.	Resource	Technology	Unit size (net MW)	Assumed Potential (net MW)	Earliest service year
PS-30	Electricity	Smart meters	NA	90.3% of all	2015
PS-31	Electricity	Additional regulation & telecommunication services	NA	0.13% of intermittent renewables	2015
PS-32	Electricity	Distribution system upgrades	NA	15%	2016

Timing (Start, Phase In, End): The earliest in-service date for each technology is shown in the above table.

Parties Involved: OR Department of Energy.

Data Sources and Additional Background:

- Report entitled: "The Smart Grid: An estimation of the Energy and CO2 benefits", prepared by Pacific Northwest National Laboratory (PNNL), 2010 (available at http://energyenvironment.pnl.gov/news/pdf/PNNL-19112_Revision_1_Final.pdf; accessed on 22 June 2012
- US census bureau information for Oregon and Columbia county, OR available at http://quickfacts.census.gov/qfd/states/41/41009.html; accessed on 23 June 2012
- Oregon population forecast from Oregon's Office of Economic Analysis (available at http://oregon.gov/DAS/OEA/demographic.shtml#Long_Term_County_Forecast; accessed on 23 June 2012)
- EIA-861 data available in "File2_2009.xls" for total meters and File8_2009.xls" from smart meters found at http://205.254.135.7/cneaf/electricity/page/eia861.html; accessed 23 June 2012
- presentation entitled "Advanced Metering Infrastructure (AMI) - Overview of System Features and Capabilities", by
Chris King, Co-Chair DRAM Coalition, available at OR PUC website http://www.oregon.gov/PUC/electric_gas/010605/king.pdf?ga=t; accessed on 23 June 2012)
- Quanta Technology, 2008. "NYISO Benefits of Adding Capacitors to the Electric System", prepared by Nagy Abed, Scott Greene, and Thomas Gentile (hard copy only)
- "Power to be efficient" by Enrique Santacana, Tammy Zucco, Xiaoming Feng, Jiuping Pan, Mirrasoul Mousavi, Le Tang, (available at http://www05.abb.com/global/scot/scot271.nsf/veritydisplay/cb8afe88ca4fc8a8c12572fe004dc64f/$file/14-21%202m735_eng72dpi.pdf; accessed 4 July 2012)

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

Option	Resource	GHG reductions (million tCO2e) 2022	2035	Cumulative 2010-2022	Cumulative 2010-2035	NPV (million 2010$) 2010-2022	2010-2035	Cost-effectiveness ($2010/tCO2e saved) 2010-2022	2010-2035
PS-30	Smart meters	1.51	3.45	5.73	37.25	$0	-$1,741	$0	-$47
PS-31	Additional regulation & telecommunication services for intermittent renewables	0.00	0.00	0.02	0.06	$0	-$5	$0	-$78
PS-32	Distribution system upgrades	0.50	0.42	1.70	7.26	$0	-$8	$0	-$1

Full Energy-Cycle Results:

Option	Resource	GHG reductions (million tCO2e) 2022	2035	Cumulative 2010-2022	Cumulative 2010-2035	NPV (million 2010$) 2010-2022	2010-2035	Cost-effectiveness ($2010/tCO2e saved) 2010-2022	2010-2035
PS-30	Smart meters	1.76	4.23	6.80	45.05	-$185	-$1,741	-$27	-$39
PS-31	Additional regulation & telecommunication services for intermittent renewables	0.00	0.00	0.02	0.08	$0	-$5	$0	-$65
PS-32	Distribution system upgrades	0.58	0.52	2.01	8.73	$0	-$8	$0	-$1

Quantification Methods and Results:

GHG Reductions. GHG reductions are computed relative to the average annual CO2e intensity of the OR power sector for point-of-combustion and full fuel cycle emission factors.

Net Societal Costs. Net societal costs were calculated on the basis of the methodology described in the CCS quantification memo. The cost and performance of electricity technologies used to calculate net societal costs are summarized in the table below.

No.	Resource	Firm capacity value	Heat rate (Btu/kWh)	Capacity factor (%)	Economic life (years)	Overnight capital cost (2010$)	Total average levelized cost (2010$/MWh)	CO2e e-factor (tCO2e/ MWh)
PS-30	Smart meters	NA	NA	NA	NA	$484/meter	NA	0.00 (direct combustion and fuel cycle)
PS-31	Additional regulation & telecommunication services	NA	NA	NA	NA	Up to $5/MWh for an additional 0.1% of regulation	NA	
PS-32	Distribution system upgrades	NA	NA	NA	NA	$13/kVA	NA	

Key Assumptions & Uncertainties (including sensitivities)

- These estimates should be seen as the upper end potential for this measure in OR.

PS-Renewable Portfolio Standard

Measure Descriptions

As part of the Oregon Renewable Energy Act of 2007 (Senate Bill 838), the state of Oregon established a renewable portfolio standard (RPS) for electric utilities and retail electricity suppliers. Electricity service suppliers must meet the requirements applicable to the electric utilities that serve the territories in which the electricity service supplier sells electricity to retail consumers. Eligible renewable resources include solar thermal electric, solar photovoltaics, landfill gas, wind (onshore and offshore), biomass, small hydroelectric, geothermal electric, municipal solid waste, hydrogen, anaerobic digestion, tidal energy, wave energy, and ocean thermal.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: The RPS calls for different RPS targets depending on a utility's size. The largest utilities are required to satisfy 25% of their retail sales by renewable generation. Large utilities are defined as those with 3% or more of the state's load. The RPS also allows for up to 50 average megawatt (MWa) of eligible hydro capacity per large utility and up to 40 MWa of eligible hydro capacity for non-utilities.[3] In addition, a carve-out of 20.1 MW of solar photovoltaics was modeled starting in 2020, consistent with OR Administrative Rule 860-084-0000.

Timing (Start, Phase In, End): Two RPS scenarios were analyzed. The first scenario corresponds to the Oregon Renewable Energy Act of 2007. The timing for the phase-in of RPS Scenario #1 is summarized in the upper part of the table below. The second scenario corresponds to a more aggressive RPS that is heuristic in nature. The timing for the phase-in of RPS Scenario #2 is summarized in the lower part of the table below.

Table: Targets for the two RPS scenarios, percent of retail electric sales

Scenario	Type	2010	2015	2020	2025
#1 - Current RPS (Senate Bill 838)	Large utilities	0%	15%	20%	25%
	Smaller utilities	0%	0%	0%	10%
	Smallest utilities	0%	0%	0%	5%
#2 – Aggressive RPS (heuristic)	Large utilities	0%	20%	25%	30%
	Smaller utilities	0%	0%	0%	15%
	Smallest utilities	0%	0%	0%	10%

Parties Involved: OR Department of Energy, electricity providers.

Data Sources and Additional Background:

- OR House Bill 3649 (2010), Legislative Changes to the Oregon Renewable Portfolio Standard (available at

[3] Only 20.8 MWa was modeled in the RPS analysis. This represents the maximum eligible hydro for non-utilities in 2010.

http://www.oregon.gov/energy/RENEW/docs/Legislative%20Changes%20to%20the%20Renewable%20Portfolio%20Standard.pdf; accessed 10 July 2012)

- "Summary of Oregon's Renewable Portfolio Standard", prepared by the OR Department of Energy
- Oregon retail electric sales and net generation statistics for 2010 (available at http://www.puc.state.or.us/puc/docs/statbook2010.pdf; accessed 12 July 2012)
- Appendix C of the Sixth Northwest Conservation and Electric Power Plan, prepared by the Northwest Power and Conservation Council, February 2010 (http://www.nwcouncil.org/energy/powerplan/6/final/SixthPowerPlan_Appendix_C.pdf; accessed 20 June 2012)
- OR Administrative Rule 860-084-0000, Solar Photovoltaic Programs (available at http://arcweb.sos.state.or.us/pages/rules/oars_800/oar_860/860_084.html accessed 15 July 2012)

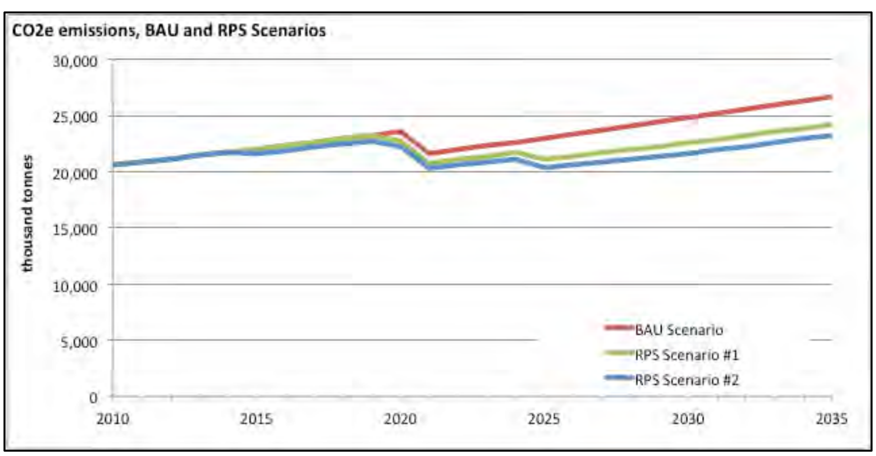
Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Table: Grand summary

		GHG reductions (million tCO2e)			NPV (million 2010$)	Cost-effectiveness ($2010/tCO2e saved)
Option	**Resource**	**2022**	**2035**	**Cumulative**		
RPS Scenario #1	Using point-of-generation emission factors	0.90	2.46	28.40	$1,988	$72
	Using full fuel cycle emission factors	1.09	2.99	34.44	$1,811	$53
RPS Scenario #2	Using point-of-generation emission factors	1.39	3.45	43.22	$3,904	$90
	Using full fuel cycle emission factors	1.72	4.27	53.40	$3,969	$74

Figure: CO2e emissions (point-of-combustion) in the BAU and RPS scenarios, 2010-2035



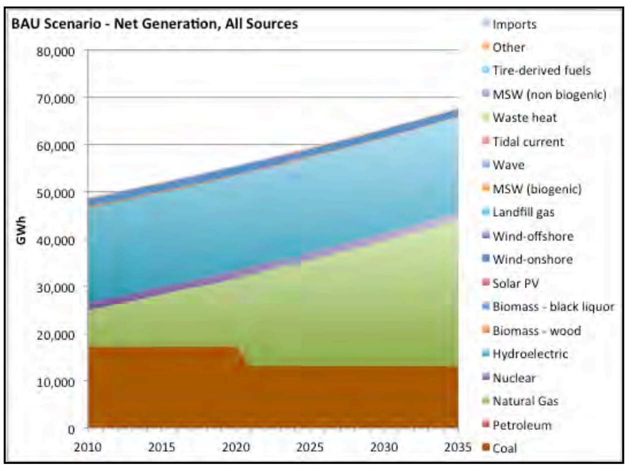
Quantification Methods and Results:

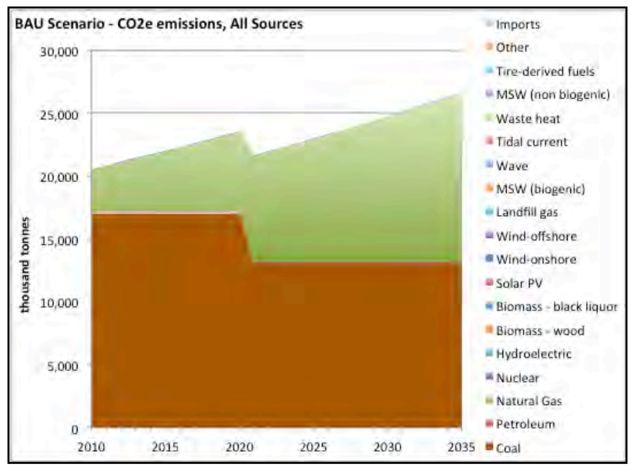
GHG Reductions. GHG reductions are computed relative to the average annual CO2e intensity of the OR power sector for point-of-combustion and full fuel cycle emission factors.

Net Societal Costs. Net societal costs were calculated on the basis of the least-cost approximation methodology described in the bullets and tables below. The cost and performance of electricity technologies used to calculate net societal costs are the same as presented earlier.

- Establish a simplified Business-As-Usual (BAU) power supply Scenario for the period 2010-2035 that provides a reference projection against which an alternative RPS power supply Scenario can be directly compared. The BAU scenario assumes that a) net generation keeps pace with retail sales growth, b) the Boardman coal-fired station is retired at the end of 2020, and c) all generation levels except natural gas are held at their 2010 levels. The resulting generation and CO2e projections (point-of-combustion), aggregated across all utility size classes, are provided in the figures below.

Figure: BAU scenario, net generation and CO2e emissions (point-of-combustion), 2010-2035





- Establish the share of retail sales in 2010 by utility class and assume that these shares apply over the 2011-2025 period for both RPS scenarios. This information is summarized in the table below.

Table: Oregon Electric Power Industry retail sales, cumulative for the 3-year period 2008-2010 (GWh)

	Large utilities						
Parameter	PacifiCorp	Portland General Electric Co	Eugene Water & Electric Board	Electricity Service Providers	Smaller utilities	Smallest utilities	Total
Retail sales	40,158	52,678	7,432	5,677	14,191	21,990	142,127
Retail share	75%				10%	15%	100%

- Establish the retail electric sale trajectory over the period 2010-2025 by sector based on information in Appendix C of the Sixth Northwest Conservation and Electric Power Plan. This information is summarized in the table below.

Table: Oregon Electric Power Industry retail sales, 2010-2025 (GWh)

Sector	2010	2015	2020	2025
Residential	18,839	20,195	21,649	23,207
Commercial	15,454	$16,731	18,112	19,609
Industrial	11,708	$12,184	12,679	13,194
Transport/other	25	28	31	35
Total	46,026	49,138	52,472	56,046

- Establish the effective RPS target for all years, aggregated overall all utility size classes. In 2025, this comes to 11,438 gigawatt hour (GWh), or about 20.4% of retail electricity sales for Scenario #1 and 25.4% for Scenario #2, as summarized in the tables below.

Table: Scenario #1: Required renewable generation to comply with RPS (GWh, unless otherwise noted)

Type	2010	2015	2020	2025	2030	2035
Large utilities	0	5,494	7,823	10,445	11,158	11,924
Smaller utilities	0	0	0	560	598	639
Smallest utilities	0	0	0	434	463	495
Total	0	5,494	7,823	11,438	12,220	13,058
Effective RPS share of retail sales (%)	0.0%	11.2%	14.9%	20.4%	20.4%	20.4%

Table: Scenario #2: Required renewable generation to comply with an aggressive RPS (GWh, unless otherwise noted)

Type	2010	2015	2020	2025	2030	2035
Large utilities	0	7,326	9,779	12,533	13,390	14,309
Smaller utilities	0	0	0	839	897	958
Smallest utilities	0	0	0	867	926	990
Total	0	7,326	9,779	14,240	15,213	16,257
Effective RPS share of retail sales (%)	0.0%	14.9%	18.6%	25.4%	25.4%	25.4%

- Establish total annual levels of incremental renewable generation to satisfy the requirements of the RPS, net of all eligible hydro and other renewable resources already built (i.e., in the Business-as-usual (BAU) scenario), as well as any statutory renewable carve-outs. In 2025, Incremental renewable generation to comply with RPS comes to a total of 5,606 GWh in RPS scenario #1 and 8,408 GWh in RPS scenario #2, as summarized in the tables and figures below. A negative value for incremental renewable generation to comply with RPS indicates that the level of renewable energy from all eligible sources exceeds the RPS requirement. This amount is deducted from additional qualifying hydro generation levels in the final tally.

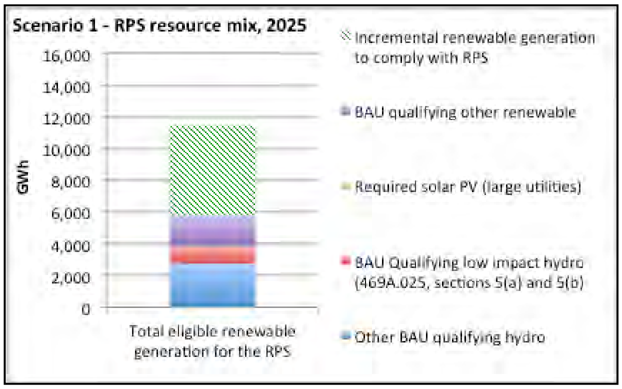
Table: Incremental renewable generation to comply with RPS Scenario #1, 2010-2035 (GWh)

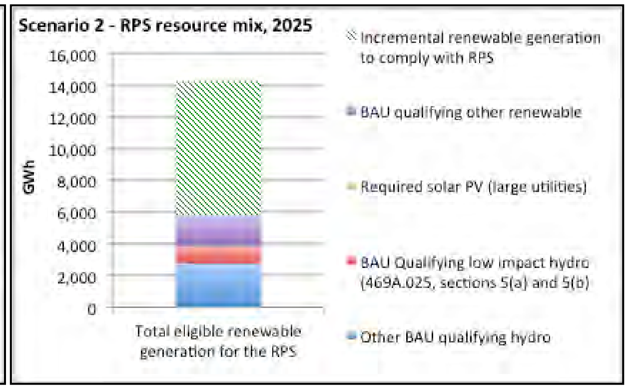
Sector	2010	2015	2020	2025	2030	2035
BAU Qualifying low impact hydro (469A.025, sections 5(a) & 5(b)	0	1,058	1,058	1,058	1,058	1,058
Other BAU qualifying hydro	0	2,761	2,761	2,761	2,761	2,761
Required solar PV (large utilities)	0	0	45	45	45	45
BAU qualifying other renewable	0	1,968	1,968	1,968	1,968	1,968
Incremental renewable generation to comply with RPS	**0**	**0**	**1,991**	**5,606**	**6,388**	**7,226**
Total eligible renewable generation for the RPS	0	5,494	7,823	11,438	12,220	13,058

Table: Incremental renewable generation to comply with RPS Scenario #2, 2010-2035 (GWh)

Sector	2010	2015	2020	2025	2030	2035
BAU Qualifying low impact hydro (469A.025, sections 5(a) & 5(b)	0	1,058	1,058	1,058	1,058	1,058
Other BAU qualifying hydro	0	2,761	2,761	2,761	2,761	2,761
Required solar PV (large utilities)	0	0	45	45	45	45
BAU qualifying other renewable	0	1,968	1,968	1,968	1,968	1,968
Incremental renewable generation to comply with RPS	**0**	**1,539**	**3,947**	**8,408**	**9,382**	**10,425**
Total eligible renewable generation for the RPS	0	7,326	9,779	14,240	15,213	16,257

Figure: RPS resource mix for RPS scenarios, 2025 (GWh)





- Rank all eligible renewable energy options relative to their cost effectiveness (i.e., 2010$/tCO2e avoided) and emission factor assumption (i.e., either point-of-combustion or full fuel cycle CO2e emission factors). This is provided in the tables below for both e-factor assumptions. The use of different emission factors affects the cost-effectiveness of the options, and hence their relative rankings.

Table: Eligible renewable generation resources/technologies, ranked relative to cost-effectiveness (point-of-combustion)

Rank	Resource, technology	Earliest online year	Cost effectiveness (2010$/tCO2e)
1	Geothermal, Binary hydrothermal	2017	$24.9
2	Tidal current, Water current turbines	2016	$35.9
3	Hydropower, New projects	2016	$36.1
4	Animal manure, Reciprocating engine	2012	$47.8
5	Landfill gas, Reciprocating engine	2012	$50.8
6	Woody residues, Steam-electric - brownfield	2014	$58.7
7	Offshore Wind, Floating WTG	2016	$112.3
8	Woody residues, Steam-electric - greenfield	2014	$128.2
9	Wind (in OR/WA), Wind turbine generators	2013	$156.1
10	Wind (from Alberta to OR/WA), Wind turbine generators	2015	$205.7
11	Hydropower, Conventional hydro upgrades in OR	2016	$214.1
12	Wind (from Montana to OR/WA), Wind turbine generators	2015	$228.5
13	Wind (from Wyoming to OR/WA), Wind turbine generators	2015	$246.3
14	Wave, Various buoy & overtopping devices	2016	$286.6

Rank	Resource, technology	Earliest online year	Cost effectiveness (2010$/tCO2e)
15	Solar (Nevada), Parabolic trough	2015	$303.1
16	Solar, Utility-scale Photovoltaic arrays	2013	$478.0

Table: Eligible renewable generation resources/technologies, ranked relative to cost-effectiveness (full fuel cycle)

Rank	Resource, technology	Earliest online year	Cost effectiveness (2010$/tCO2e)
1	Geothermal, Binary hydrothermal	2017	$20.81
2	Tidal current, Water current turbines	2016	$28.53
3	Hydropower, New projects	2016	$30.12
5	Landfill gas, Reciprocating engine	2012	$35.75
4	Animal manure, Reciprocating engine	2012	$39.81
6	Woody residues, Steam-electric - brownfield	2014	$65.07
7	Offshore Wind, Floating WTG	2016	$83.08
9	Wind (in OR/WA), Wind turbine generators	2013	$110.43
8	Woody residues, Steam-electric - greenfield	2014	$142.03
10	Wind (from Alberta to OR/WA), Wind turbine generators	2015	$150.67
12	Wind (from Montana to OR/WA), Wind turbine generators	2015	$167.40
11	Hydropower, Conventional hydro upgrades in OR	2016	$178.61
13	Wind (from Wyoming to OR/WA), Wind turbine generators	2015	$180.40
15	Solar (Nevada), Parabolic trough	2015	$233.38
14	Wave, Various buoy & overtopping devices	2016	$239.07
16	Solar, Utility-scale Photovoltaic arrays	2013	$361.52

- Develop a simplified least-cost schedule of firm incremental renewable generation that accounts for the cost effectiveness and earliest online years for all eligible renewable energy resources/technologies. The resulting phase-in schedule for incremental renewable generation is summarized in the tables below for the period 2015-2035 for both RPS Scenarios, for both emission factor assumptions.

Table: Incremental renewable generation, RPS Scenario #1, 2010-2035 (GWh, ranked relative to cost-effectiveness, point-of-combustion)

Resource & technology	2010	2015	2020	2025	2030	2035
Geothermal, Binary hydrothermal	0	0	1,261	1,261	1,261	1,261
Tidal current, Water current turbines	0	0	379	379	379	379
Hydropower, New projects	0	0	307	438	438	438
Animal manure, Reciprocating engine	0	0	39	134	134	134
Landfill gas, Reciprocating engine	0	0	0	143	143	143
Woody residues, Steam-electric - brownfield	0	0	0	740	740	740
Wastewater treatment gas, Reciprocating engines	0	0	0	25	25	25
Offshore Wind, Floating wind turbine generator (WTG)	0	0	0	1,577	1,577	1,577
Woody residues, Steam-electric - greenfield	0	0	0	701	701	701
Wind (in OR/WA), Wind turbine generators	0	0	0	0	0	280
Wind (from Alberta to OR/WA), Wind turbine generators	0	0	0	0	0	0
Hydropower, Conventional hydro upgrades in OR	0	0	5	9	9	9

Resource & technology	2010	2015	2020	2025	2030	2035
Wave, Various buoy & overtopping devices	0	0	0	66	437	437
Solar (Nevada), Parabolic trough	0	0	0	0	0	0
Solar, Utility-scale Photovoltaic arrays	0	0	0	45	534	1,024
Total	0	0	1,991	5,517	6,378	7,148
Difference from RPS target	0	0	0	-89	-10	-78

Table: Incremental renewable generation, RPS Scenario #1, 2010-2035 (GWh, ranked relative to cost-effectiveness, full fuel cycle)

Resource & technology	2010	2015	2020	2025	2030	2035
Geothermal, Binary hydrothermal	0	0	1,261	1,261	1,261	1,261
Tidal current, Water current turbines	0	0	379	379	379	379
Hydropower, New projects	0	0	307	438	438	438
Landfill gas, Reciprocating engine	0	0	36	143	143	143
Animal manure, Reciprocating engine	0	0	0	134	134	134
Wastewater treatment gas, Reciprocating engines	0	0	0	25	25	25
Woody residues, Steam-electric - brownfield	0	0	0	740	740	740
Offshore Wind, Floating WTG	0	0	0	1,577	1,577	1,577
Wind (in OR/WA), Wind turbine generators	0	0	0	561	561	561
Woody residues, Steam-electric - greenfield	0	0	0	0	526	701
Wind (from Alberta to OR/WA), Wind turbine generators	0	0	0	0	0	0
Hydropower, Conventional hydro upgrades in OR	0	0	8	9	9	9
Wave, Various buoy & overtopping devices	0	0	0	219	437	437
Solar (Nevada), Parabolic trough	0	0	0	0	0	0
Solar, Utility-scale Photovoltaic arrays	0	0	0	45	134	801
Total	0	0	1,991	5,530	6,363	7,206
Difference from RPS target	0	0	0	-76	-25	-20

Table: Incremental renewable generation, RPS Scenario #2, 2010-2035 (GWh, ranked relative to cost-effectiveness, point-of-combustion)

Resource & technology	2010	2015	2020	2025	2030	2035
Geothermal, Binary hydrothermal	0	315	1,261	1,261	1,261	1,261
Tidal current, Water current turbines	0	76	379	379	379	379
Hydropower, New projects	0	44	438	438	438	438
Animal manure, Reciprocating engine	0	134	134	134	134	134
Landfill gas, Reciprocating engine	0	143	143	143	143	143
Woody residues, Steam-electric - brownfield	0	740	740	740	740	740
Wastewater treatment gas, Reciprocating engines	0	25	25	25	25	25
Offshore Wind, Floating WTG	0	0	631	1,577	1,577	1,577
Woody residues, Steam-electric - greenfield	0	0	0	701	701	701
Wind (in OR/WA), Wind turbine generators	0	0	0	1,682	1,682	1,682
Wind (from Alberta to OR/WA), Wind turbine generators	0	0	0	333	666	1,332
Hydropower, Conventional hydro upgrades in OR	0	0	3	9	9	9
Wave, Various buoy & overtopping devices	0	22	109	437	437	437
Solar (Nevada), Parabolic trough	0	0	0	0	0	311
Solar, Utility-scale Photovoltaic arrays	0	0	45	401	1,024	1,024
Total	0	1,500	3,908	8,260	9,216	10,192
Difference from RPS target	0	-39	-39	-149	-166	-233

Table: Incremental renewable generation, RPS Scenario #2, 2010-2035 (GWh, ranked relative to cost-effectiveness, full fuel cycle)

Resource & technology	2010	2015	2020	2025	2030	2035
Geothermal, Binary hydrothermal	0	315	1,261	1,261	1,261	1,261
Tidal current, Water current turbines	0	76	379	379	379	379
Hydropower, New projects	0	44	438	438	438	438
Landfill gas, Reciprocating engine	0	143	143	143	143	143
Animal manure, Reciprocating engine	0	134	134	134	134	134
Wastewater treatment gas, Reciprocating engines	0	25	25	25	25	25
Woody residues, Steam-electric - brownfield	0	740	740	740	740	740
Offshore Wind, Floating WTG	0	0	631	1,577	1,577	1,577
Wind (in OR/WA), Wind turbine generators	0	0	0	1,682	1,682	1,682
Woody residues, Steam-electric - greenfield	0	0	0	701	701	701
Wind (from Alberta to OR/WA), Wind turbine generators	0	0	0	333	333	1,332
Hydropower, Conventional hydro upgrades in OR	0	0	3	9	9	9
Solar (Nevada), Parabolic trough	0	0	0	311	311	311
Wave, Various buoy & overtopping devices	0	22	109	437	437	437
Solar, Utility-scale Photovoltaic arrays	0	0	45	223	1,024	1,024
Total	0	1,500	3,908	8,393	9,194	10,192
Difference from RPS target	0	-39	-39	-16	-188	-233

- Balance the lumpiness in incremental renewable generation through adjustments to eligible resources. For those years when RPS targets are unmet, assume that market purchases of the lowest cost-effective onshore wind resource (i.e., Wind in OR/WA) is purchased to increase to zero any difference from annual RPS targets. The table below summarizes these adjustments for both RPS scenarios, for both emission factor assumptions.

Table: Total adjustments in renewable generation from Wind (in OR/WA) to achieve full compliance with RPS Scenario requirements, 2015-2035 (GWh)

Scenario	Emission factor assumption	2010	2015	2020	2025	2030	2035
#1	point-of-combustion	0	0	0	89	10	78
	full fuel cycle	0	0	0	76	25	20
#2	point-of-combustion	0	39	39	149	166	233
	full fuel cycle	0	39	39	16	188	233

- Assume that natural gas-fired generation is on the margin so that integrating annual incremental renewable generation results in annual decrements to existing BAU levels of natural gas-fired generation. Assume that the value of these decrements is at the avoided cost and that the CO_2e intensity of displaced or back-up natural gas-fired generation is equal to 0.44 tCO_2e/MWh (point-of-combustion basis) and 0.54 tCO_2e/MWh (full fuel cycle basis).

- Establish simplified RPS power supply Scenarios that integrate the impact of the above results to produce a projection of net generation and CO_2e emissions, aggregated across all utility size classes and inclusive of emissions associated with balancing services. This is presented in the figures below for both RPS scenarios for point-of-combustion emission factors.

Figure: RPS scenario #1, net generation and CO2e emissions (point of combustion), 2010-2035

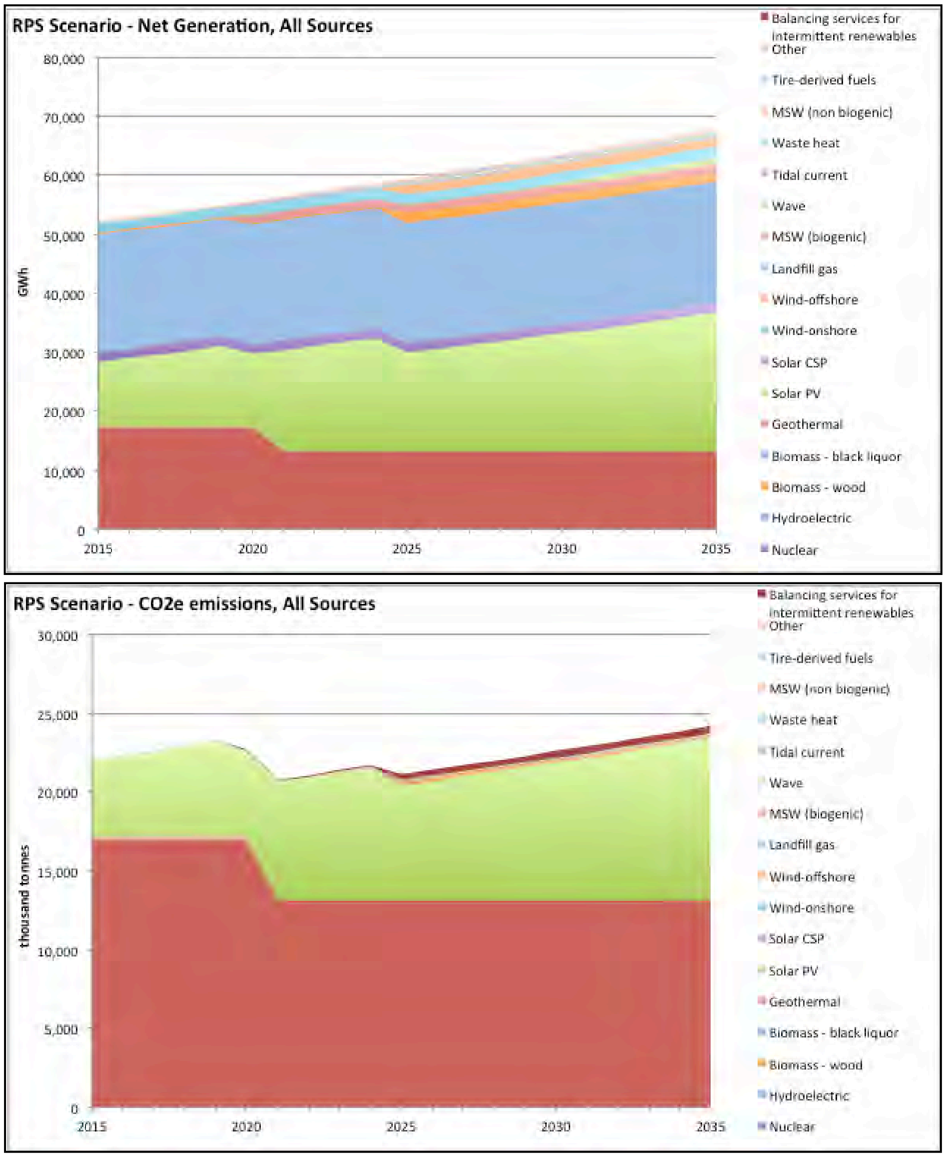


Figure: RPS scenario #1, net generation and CO2e emissions (full fuel cycle), 2010-2035

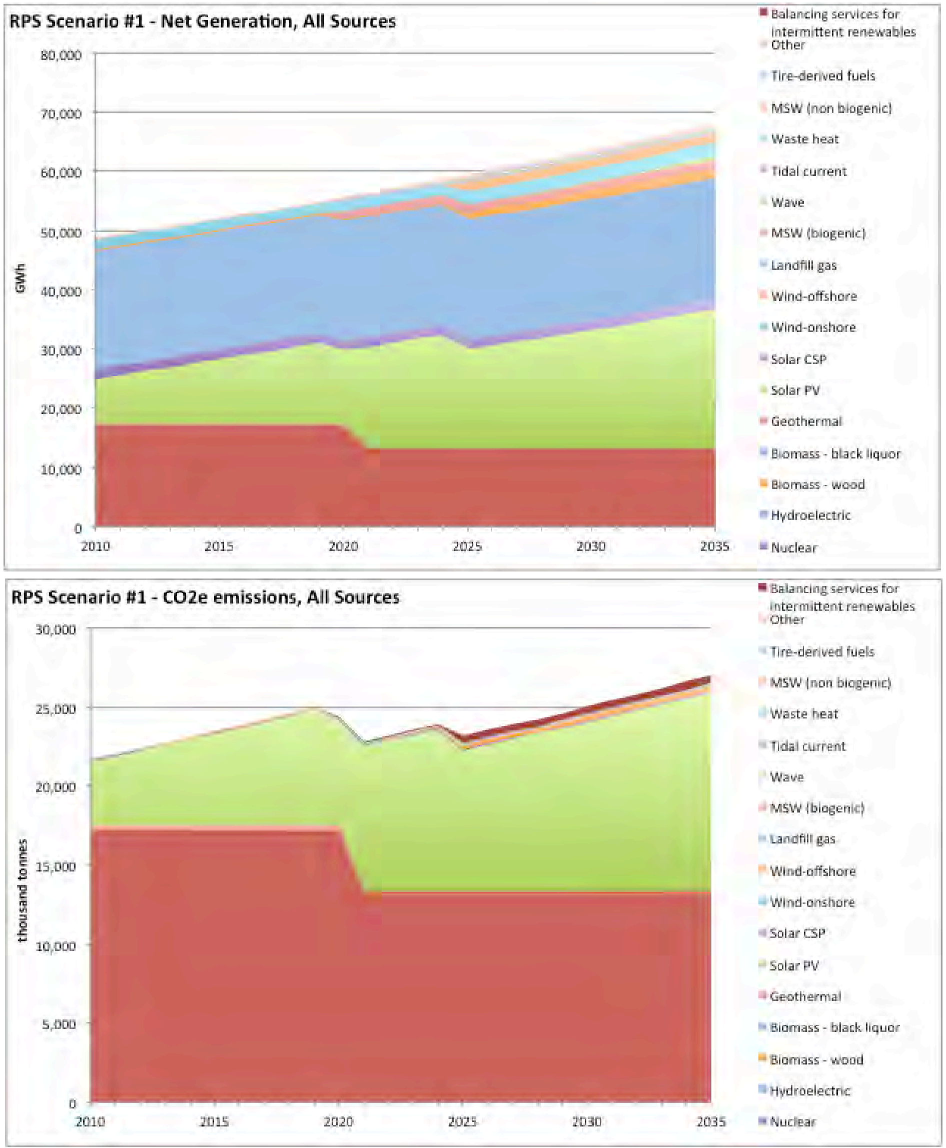
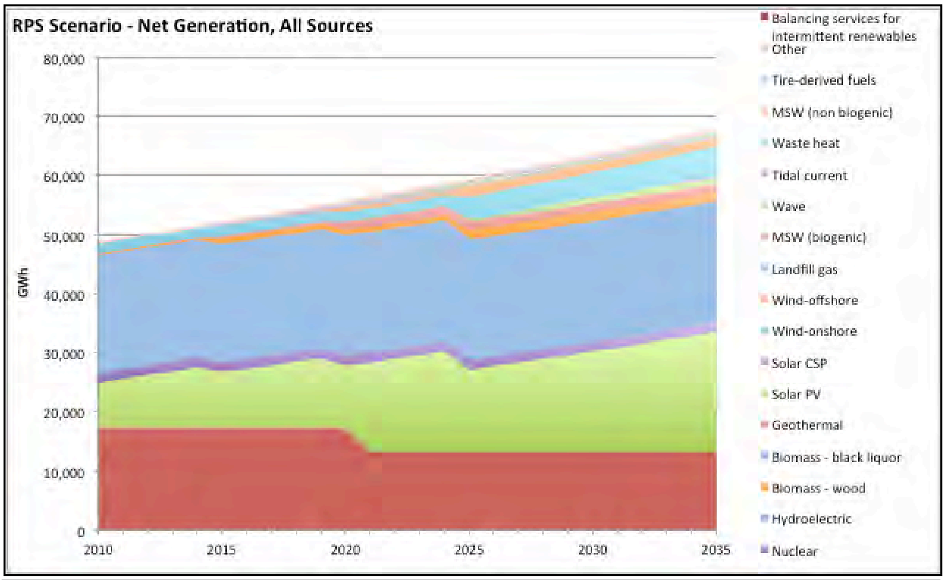


Figure: RPS scenario #2, net generation and CO2e emissions (point of combustion), 2010-2035



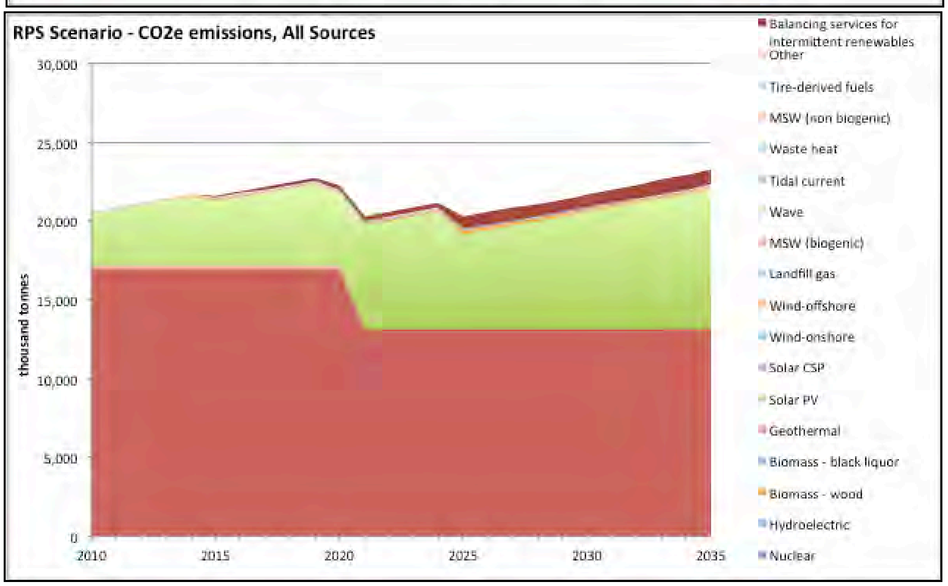
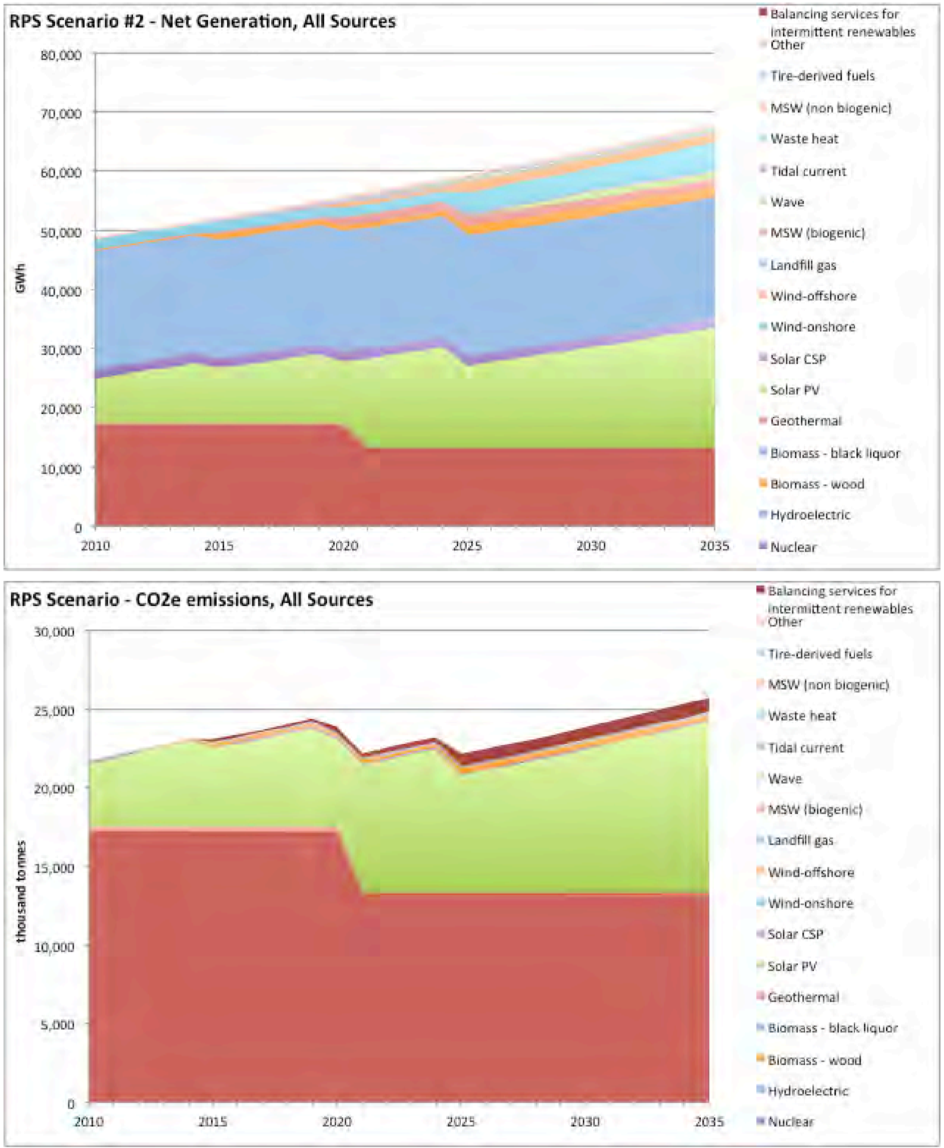


Figure: RPS scenario #2, net generation and CO2e emissions (full fuel cycle), 2010-2035



- The net societal costs and GHG reduction benefits were calculated on the basis of the methodology described in the CCS quantification memo and the results above.

Key Assumptions & Uncertainties (including sensitivities)

- These estimates should be seen as possible configurations of a mix of renewable generation to meet RPS scenario targets.

Appendix B: Residential, Commercial, and Industrial (RCI) Measure Descriptions and Related Materials

R-Set-1: Residential HVAC, Weatherization and Lighting Measures

Measure Description

Improvement of the efficiency of residential heating, ventilation, and air conditioning systems (HVAC), building envelopes, and lighting systems in the residential sector can be achieved through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. Residential HVAC, weatherization/building envelope, and lighting systems are long lasting, and thus affect the energy use, and associated greenhouse gas emissions, of a home for many years to come. Often, installation of these types of measures improves resident comfort and provides other benefits as well, while reducing energy use and expenditures. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, to low-income weatherization assistance, equipment installer incentive programs, tax incentive programs for high-efficiency equipment purchase, and other approaches. Individual cost curve measures included in this set include:

- **HVAC technologies:** Manufactured Home HVAC Conversion/Upgrade (RCI-2), Single Family Home HVAC Conversion/Upgrade (RCI-3)
- **Building envelope/weatherization technologies:** Manufactured Home Weatherization—Insulation (RCI-4), Manufactured Home Weatherization—Windows (RCI-5), Multifamily Weatherization—Insulation (RCI-6), Multifamily Weatherization—Windows (RCI-7), Single Family Weatherization—Insulation (RCI-8), Single Family Weatherization--Windows (RCI-9)
- **Lighting technologies:** Residential Lighting Improvement (RCI-16)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 or 10 percent) of the estimated overall markets for the measures, with the choice of "ramp-in" rate depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, weatherization installation and technical assistance providers (private and public), HVAC installation and technical assistance providers (private and public), lighting installation and technical assistance providers (private and public), US DOE, Oregon and Federal low-income housing weatherization agencies/programs, Internal Revenue Service, and others.

Data Sources and Additional Background: NPCC/RTF, *Supply Curves for 6th Power Plan*; Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope); and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In Table B-1 and Table B-2, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-1: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 1 (R-Set-1) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.58	0.82	2.8	11.9	$13	$153	$5	$13
Fed. Action	0.66	0.92	3.2	13.4	-$21	$54	-$7	$4
OR Action	0.78	1.09	3.8	15.9	-$15	$96	-$4	$6

Table B-2: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 1 (R-Set-1) using energy-cycle emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.67	1.00	3.4	14.3	$13	$153	$4	$11
Fed. Action	0.77	1.13	3.8	16.2	-$21	$54	-$6	$3
OR Action	0.90	1.34	4.5	19.1	-$15	$96	-$3	$5

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-3 for a summary of the specific measures that are summarized by R-Set-1 and the source of each individual measure.

Table B-3: Summary of Individual Measures Included in Measure Set R-Set-1.

Measure Name	RCI Reference Number	Source	Notes
Manufactured Home HVAC Conversion/Upgrade	RCI-2	NPCC/RTF	Conversion of HVAC system to heat pump, duct sealing, commissioning, and evaporative cooling system.
Single Family Home HVAC Conversion/Upgrade	RCI-3	NPCC/RTF and ETO	Conversion of HVAC system to heat pump, duct sealing, commissioning, and evaporative cooling system.
Manufactured Home Weatherization--Insulation	RCI-4	NPCC/RTF	Install wall, floor, and ceiling insulation and seal the envelope for air infiltration.
Manufactured Home Weatherization--Windows	RCI-5	NPCC/RTF	Install windows to increase efficiency of building envelope.
Multifamily Weatherization--Insulation	RCI-6	NPCC/RTF	Install wall, floor, and ceiling insulation and seal the envelope for air infiltration.
Multifamily Weatherization--Windows	RCI-7	NPCC/RTF	Install windows to increase efficiency of building envelope.
Single Family Weatherization--Insulation	RCI-8	NPCC/RTF	Install wall, floor, and ceiling insulation and seal the envelope for air infiltration.
Single Family Weatherization--Windows	RCI-9	NPCC/RTF	Install windows to increase efficiency of building envelope.
Residential Lighting Improvement	RCI-16	NPCC/RTF and ETO	Install high-efficiency lighting and lighting systems, including LED lighting.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-1) or exclude (Table B-2) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

R-Set-2: Residential Appliance, Electronics, and Water Heat Measures

Measure Description

Improvement of the efficiency of Appliance, Electronics, and Water Heat Measures in the residential sector can be achieved through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. Residential appliances, electronics, and water heating technologies have a useful life of between 5 to 20 years and therefore affect the energy use, and associated greenhouse gas emissions during operation. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for equipment operation. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, equipment installer incentive programs, tax incentive programs for high-efficiency equipment purchase, and other approaches. Individual cost curve measures included in this set include:

- **Appliance technologies:** Residential Cooling Appliances (RCI-1), Residential Laundry Appliance Improvement (RCI-13), Residential Dishwasher Improvement (RCI-14), Residential Refrigerator/Freezer Improvement (RCI-15), Residential Cooking Appliance Improvement (RCI-18), Residential Refrigerator Recycle (RCI-21)
- **Electronics technologies:** Home Energy Monitor (RCI-20), Residential Electronics Improvements (RCI-22)
- **Water heating technologies:** Residential Electric Water Heat Efficiency (RCI-11), Residential Heat Pump Water Heater (RCI-12), Residential Gravity Film Heat Exchanger (RCI-17)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In Table B-4 and Table B-5, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-4: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 2 (R-Set-2) using direct emission factors.

Scenario	GHG Reductions (MMtCO_2e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.22	0.40	0.9	4.9	$3	-$25	$3	-$5
Fed. Action	0.33	0.56	1.5	7.2	$17	-$2	$11	$0
OR Action	0.91	1.35	4.6	18.9	$179	$448	$39	$24

Table B-5: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 2 (R-Set-2) using energy-cycle emission factors.

Scenario	GHG Reductions (MMtCO_2e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.25	0.49	1.1	5.9	$3	-$25	$3	-$4
Fed. Action	0.38	0.69	1.8	8.7	$17	-$2	$9	$0
OR Action	1.06	1.65	5.5	22.8	$179	$448	$33	$20

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-6 for a summary of the specific measures that are summarized by R-Set-2 and the source of each individual measure.

Table B-6: Summary of Individual Measures Included in Measure Set R-Set-2.

Measure Name	RCI Reference Number	Source	Notes
Residential Cooling Appliances	RCI-1	NPCC/RTF and ETO	Upgrade window air conditioners.
Residential Electric Water Heat Efficiency	RCI-11	NPCC/RTF and ETO	Install a high-efficiency tank system
Residential Heat Pump Water Heater	RCI-12	NPCC/RTF	Install a high-efficiency heat pump system
Residential Laundry Appliance Improvement	RCI-13	NPCC/RTF	Install a high-efficiency appliance.
Residential Dishwasher Improvement	RCI-14	NPCC/RTF	Install a high-efficiency appliance.
Residential Refrigerator/Freezer Improvement	RCI-15	NPCC/RTF	Install a high-efficiency appliance.
Residential Gravity Film Heat Exchanger	RCI-17	NPCC/RTF	Install a gravity film heat exchanger to capture and utilize heat from wastewater.
Residential Cooking Appliance Improvement	RCI-18	NPCC/RTF	Install a high-efficiency appliance.
Home Energy Monitor	RCI-20	ETO	Install a home energy monitor that provides real-time feedback about energy consumption.
Residential Refrigerator Recycle	RCI-21	ETO	Recycle refrigerator body and refrigerant at the end of its useful life.
Residential Electronics Improvements	RCI-22	NPCC/RTF	Install high-efficiency electronics.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-4) or exclude (Table B-5) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

R-Set-3: Residential Natural Gas Efficiency Measures

Measure Description

Improve the efficiency of heating and ventilation systems, building envelope weatherization, and water heating systems in the residential sector can be achieved through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. Residential HVAC, weatherization/building envelope, and water heating systems are long lasting, and thus affect the energy use, and associated greenhouse gas emissions, of a home for many years to come. Often, installation of these types of measures improves resident comfort and provides other benefits as well, while reducing energy use and expenditures. Saved natural gas consumption reduces the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for heating. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, to low-income weatherization assistance, equipment installer incentive programs, tax incentive programs for high-efficiency equipment purchase, and other approaches. Individual cost curve measures included in this set include:

- **HVAC technologies:** Residential Gas Furnace Upgrade (RCI-24), Multifamily HVAC-Gas Heat (RCI-25), Residential Multi-Measure Gas Heat (RCI-28), Residential Heat/Energy Recovery Ventilation—Gas (RCI-30)
- **Building envelope/weatherization technologies:** Residential Windows with gas heating systems (RCI-26), Residential Gas Heat, Insulation/Ducts/Weatherization (RCI-27),
- **Water Heating Measures:** Residential Gas Water Heat Measures (RCI-23),

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, weatherization installation and technical assistance providers (private and public), US DOE, Oregon and Federal Low-income housing weatherization agencies/programs, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In Table B-7 and Table B-8, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-7: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 3 (R-Set-3) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.08	0.18	0.4	2.2	$17	$32	$39	$14
Fed. Action	0.10	0.22	0.5	2.7	$14	$16	$27	$6
OR Action	0.15	0.34	0.8	4.1	$13	-$7	$15	-$2

Table B-8: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 3 (R-Set-3) using energy-cycle emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.10	0.22	0.5	2.7	$17	$32	$32	$12
Fed. Action	0.12	0.27	0.6	3.2	$14	$16	$22	$5
OR Action	0.18	0.42	1.0	5.0	$13	-$7	$13	-$1

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-9 for a summary of the specific measures that are summarized by R-Set-3 and the source of each individual measure.

Table B-9: Summary of Individual Measures Included in Measure Set R-Set-3.

Measure Name	RCI Reference Number	Source	Notes
Residential Gas Water Heat Measures	RCI-23	ETO	Install high-efficiency natural gas water heating technology.
Residential Gas Furnace Upgrade	RCI-24	ETO	Upgrade existing systems to high-efficiency natural gas heating systems.
Multifamily HVAC-Gas Heat	RCI-25	ETO	Install high-efficiency natural gas heating systems.
Residential Windows (with gas heating systems)	RCI-26	ETO	Install high-efficiency windows in increase efficiency of the building envelope.
Residential Gas Heat, Insulation/Ducts/Weatherization	RCI-27	ETO	Install / upgrade wall, ceiling, floor insulation, seal envelope to reduce air infiltration, relocate and / or seal ducts, and commission systems.
Residential Multi-Measure Gas Heat	RCI-28	ETO	Install high-efficiency natural gas heating systems.
Residential Heat/Energy Recovery Ventilation--Gas	RCI-30	ETO	Install heat recovery systems.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-7) or exclude (Table B-8) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

R-Set-4: Residential Solar PV, Solar Water Heat, CHP, and Biomass Measures

Measure Description

Installation of technologies such as solar PV electric, solar water heating, and biomass heating, or technologies that significantly increase the efficiency of the use of energy derived from the combustion of natural gas such as combined heat and power (CHP) in the residential sector, displace the need for fossil fuels for both electric and thermal loads. All of these technologies are long lasting, and thus affect the energy use, and associated greenhouse gas emissions, of a home for many years to come. Displaced fossil fuel consumption reduces the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, tax incentive programs for equipment purchase, information campaigns, programs through equipment dealers, and other approaches. Individual cost curve measures included in this set include:

- **Solar photovoltaic (PV) electricity generation:** Residential Solar Photovoltaic (RCI-10)

- **Solar water heating:** Residential Solar Water Heat – Electric Backup (RCI-19), Residential Solar Hot Water-Gas Backup (RCI-29)
- **Combined heat and power (CHP) technologies:** Residential CHP (RCI-31)
- **Biomass heating systems:** Residential Wood-fueled Heat Replacing Electric Resistance (RCI-32), Residential Wood-fueled Heat Replacing Oil/LPG (RCI-33)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, US DOE, private installers, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal programs. For CHP and biomass energy-related options, a variety of available sources were used to develop specific analyses. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-10 and Table B-11, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-10: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 4 (R-Set-4) using direct emission factors.

Scenario	GHG Reductions (MMtCO$_2$e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.27	0.41	1.3	5.8	$210	$663	$167	$115
Fed. Action	0.31	0.47	1.4	6.7	$199	$626	$138	$94
OR Action	0.60	0.95	2.6	12.8	$253	$783	$96	$61

Table B-11: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 4 (R-Set-4) using energy-cycle emission factors.

Scenario	GHG Reductions (MMtCO$_2$e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.31	0.50	1.5	7.0	$210	$663	$141	$95
Fed. Action	0.36	0.58	1.7	8.0	$199	$626	$117	$78
OR Action	0.69	1.16	3.1	15.4	$253	$783	$81	$51

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy*

Efficiency Measure Supply Curves in support of the 6th Power Plan, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures, including several measures included in R-Set-4, were developed specifically for this project by the Center for Climate Strategies (CCS) team. See Table B-12 for a summary of the specific measures that are summarized by R-Set-4 and the source of each individual measure.

Table B-12: Summary of Individual Measures Included in Measure Set R-Set-4.

Measure Name	RCI Reference Number	Source	Notes
Residential Solar Photovoltaic	RCI-10	NPCC/RTF	Installation of a 1 kW, PV solar system.
Residential Solar Water Heat – Electric Backup	RCI-19	NPCC/RTF	Installation of a solar water heating system.
Residential Solar Hot Water-Gas Backup	RCI-29	ETO	Installation of a solar water heating system.
Residential CHP	RCI-31	CCS	Installation of a natural gas fired residential combined heat & power (CHP) systems. These systems generate electricity while utilizing the waste heat from gas combustion for the household thermal load.
Residential Wood-fueled Heat Replacing Electric Resistance	RCI-32	CCS	Replace existing electric resistance heating system with biomass heating (e.g. cord wood, wood pellets).
Residential Wood-fueled Heat Replacing Oil/LPG	RCI-33	CCS	Replace existing oil/LPG heating system with biomass heating (e.g. cord wood, wood pellets).

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-10) or exclude (Table B-11) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

C-Set-1: Commercial Lighting, Daylight, and Lighting Controls Measures

Measure Description

Improvement of the efficiency of lighting systems through equipment and controls upgrades and the effective utilization of daylight in the commercial sector can be achieved through the installation of higher-than-standard efficiency technologies and daylighting systems in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. Commercial lighting systems have useful lives of often 15 years and longer, and thus affect commercial electricity use, and associated greenhouse gas emissions, over that period of time. Often, installation of these types of measures improves comfort and productivity in commercial buildings, while reducing energy use and maintenance expenditures. Saved electricity consumption reduces the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity generation. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, equipment installer incentive programs, tax incentive programs for high-efficiency equipment purchase, and other approaches. Individual cost curve measures included in this set include:

- **Lighting:** Commercial LDP New/Integrated Design (RCI-34), Schools Lighting Measures (RCI-35), Commercial LDP Natural Replacement/Retrofit (RCI-48), Commercial Parking Lighting (RCI-59), Commercial Exit Signs (RCI-66), Commercial Signage (RCI-67), Commercial Street Lighting (RCI-69)
- **Daylight:** Commercial Daylighting New/Integrated Design (RCI-36), Commercial Daylighting Natural Replacement/Retrofit (RCI-49)
- **Lighting Controls:** Commercial Lighting Controls New/Integrated Design (RCI-37), Commercial Lighting Controls Natural Replacement/Retrofit (RCI-50)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, installers, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-13 and B-14, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-13: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 1 (C-Set-1) using direct emission factors.

Scenario	GHG Reductions (MMtCO$_2$e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.23	0.40	1.0	5.1	-$25	-$125	-$25	-$25
Fed. Action	0.26	0.45	1.2	5.7	-$35	-$166	-$31	-$29
OR Action	0.34	0.59	1.5	7.5	-$60	-$285	-$40	-$38

Table B-14: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 1 (C-Set-1) using energy-cycle emission factors.

Scenario	GHG Reductions (MMtCO$_2$e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.27	0.49	1.2	6.1	-$25	-$125	-$21	-$20
Fed. Action	0.30	0.55	1.4	6.9	-$35	-$166	-$26	-$24
OR Action	0.40	0.73	1.8	9.0	-$60	-$285	-$34	-$32

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-15 for a summary of the specific measures that are summarized by C-Set-1 and the sources of data for each individual measure.

Table B-15: Summary of Individual Measures Included in Measure Set C-Set-1.

Measure Name	RCI Reference Number	Source	Notes
Commercial LDP New/Integrated Design	RCI-34	NPCC/RTF	Installation of energy efficient lighting system as part of integrated design.
Schools Lighting Measures	RCI-35	NPCC/RTF	Installation of energy efficient lighting system in schools.
Commercial Daylighting New/Integrated Design	RCI-36	NPCC/RTF	Utilization of daylight to displace artificial lighting system as part of integrated design.
Commercial Lighting Controls New/Integrated Design	RCI-37	NPCC/RTF and ETO	Installation of control systems to automatically adjust lighting based on occupancy.
Commercial LDP Natural Replacement/Retrofit	RCI-48	NPCC/RTF	Installation of energy efficient lighting system as part of integrated design.
Commercial Daylighting Natural Replacement/Retrofit	RCI-49	NPCC/RTF	Utilization of daylight to displace artificial lighting system as part of integrated design.
Commercial Lighting Controls Natural Replacement/Retrofit	RCI-50	NPCC/RTF	Installation of control systems to automatically adjust lighting based on occupancy.
Commercial Parking Lighting	RCI-59	NPCC/RTF	Installation of energy efficient parking lighting.
Commercial Exit Signs	RCI-66	NPCC/RTF	Installation of energy efficient exit signs.
Commercial Signage	RCI-67	NPCC/RTF and ETO	Installation of energy efficient signage.
Commercial Street Lighting	RCI-69	NPCC/RTF	Installation of energy efficient streetlights.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-13) or exclude (Table B-14) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

C-Set-2: Commercial Building Envelope, Windows, and Insulation Measures

Measure Description

Improvement of the efficiency of building envelopes in the commercial sector can be achieved through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency materials and components. Commercial weatherization / building envelope improvements are long lasting, and thus affect the energy use, and associated greenhouse gas emissions, of a building for many years to come. Often, installation of these types of measures improves occupant comfort and provides other benefits as well, while reducing energy use and expenditures. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating and cooling. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, cooperative programs with building designers, contractors, and building materials/components providers, tax incentive programs, and other approaches. Individual cost curve measures included in this set include:

- **Building envelope/weatherization technologies:** Schools Building Envelope Measures (RCI-39)
- **Windows:** Commercial Windows New/Integrated Design (RCI-38), Commercial Windows Natural Replacement/Retrofit (RCI-51)
- **Insulation:** Commercial Insulation Natural Replacement/Retrofit (RCI-52)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, weatherization installation and technical assistance providers (private and public), US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-16 and B-17, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-16: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 2 (C-Set-2) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.02	0.05	0.1	0.6	-$5	-$25	-$44	-$40
Fed. Action	0.03	0.06	0.1	0.7	-$7	-$35	-$57	-$49
OR Action	0.04	0.09	0.2	1.1	-$12	-$59	-$63	-$55

Table B-17: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 2 (C-Set-2) using energy-cycle emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.03	0.06	0.1	0.7	-$5	-$25	-$37	-$33
Fed. Action	0.03	0.07	0.2	0.9	-$7	-$35	-$47	-$41
OR Action	0.05	0.11	0.2	1.3	-$12	-$59	-$53	-$46

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy*

Efficiency Measure Supply Curves in support of the 6th Power Plan, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-18 for a summary of the specific measures that are summarized by C-Set-2 and the source of each individual measure.

Table B-18: Summary of Individual Measures Included in this Measure Set C-Set-2.

Measure Name	RCI Reference Number	Source	Notes
Commercial Windows New/Integrated Design	RCI-38	NPCC/RTF	Install high-efficiency windows as part of new, integrated design buildings.
Schools Building Envelope Measures	RCI-39	NPCC/RTF	Install or upgrade insulation and other weatherization measures (e.g. seal for air infiltration).
Commercial Windows Natural Replacement/Retrofit	RCI-51	NPCC/RTF and ETO	Upgrade to high-efficiency windows.
Commercial Insulation Natural Replacement/Retrofit	RCI-52	NPCC/RTF and ETO	Install or upgrade insulation.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-16) or exclude (Table B-17) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

C-Set-3: Commercial HVAC, Buildings Operations, and Energy Management Measures

Measure Description

Improvement of the efficiency of heating, ventilation, and air conditioning systems (HVAC), building operation, and energy management in the commercial sector can be achieved through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. These systems are long lasting, and thus affect the energy use, and associated greenhouse gas emissions, of a home for many years to come. Often, installation of these types of measures improves resident comfort and provides other benefits as well, while reducing energy use and expenditures. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, equipment installer incentive programs, tax incentive programs for high-efficiency equipment purchase, and other approaches. Individual cost curve measures included in this set include:

- **HVAC technologies:** Commercial Low Press. Dist. Complex HVAC New/Integrated Design (RCI-40), Schools HVAC (RCI-41), Commercial ECM on VAV Boxes New/Integrated Design (RCI-43), Commercial Variable Speed Chiller New/Integrated Design (RCI-44), Commercial Premium HVAC New/Integrated Design (RCI-46), Commercial Premium HVAC Natural Replacement/Retro (RCI-57), Heating Duct Measures (RCI-81), Commercial Package Rooftop Measures New/Integrated Design (RCI-45), Commercial Package Rooftop Measures Natural Replacement/Retro (RCI-56)
- **Building Operations:** Commercial Economizer Measures (RCI-78), Commercial ECM on VAV Boxes Natural Replacement/Retro (RCI-54), Commercial Variable Speed Chiller Natural Replacement/Retro (RCI-55), Commercial Demand Control Ventilation New/Integrated Design (RCI-42), Commercial Demand Control Ventilation Natural Replacement/Retrofit (RCI-53).
- **Energy Management:** Commercial Controls Commissioning HVAC Retrofit (RCI-58), Commercial Controls Commissioning HVAC New/Integrated Design (RCI-47).

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-19 and Table B-20, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-19: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 3 (C-Set-3) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.15	0.19	0.7	2.8	-$12	-$66	-$18	-$23
Fed. Action	0.17	0.21	0.8	3.2	-$16	-$80	-$21	-$25
OR Action	0.23	0.30	1.1	4.5	-$41	-$172	-$37	-$38

Table B-20: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 3 (C-Set-3) using energy-cycle emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.17	0.23	0.8	3.4	-$12	-$66	-$15	-$19
Fed. Action	0.19	0.26	0.9	3.9	-$16	-$80	-$17	-$21
OR Action	0.27	0.37	1.3	5.4	-$41	-$172	-$31	-$32

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-21 for a summary of the specific measures that are summarized by C-Set-3 and the source of each individual measure.

Table B-21: Summary of Individual Measures Included in this Measure Set C-Set-3.

Measure Name	RCI Reference Number	Source	Notes
Commercial Low Press. Dist. Complex HVAC New/Integrated Design	RCI-40	NPCC/RTF	Install high-efficiency low pressure distribution HVAC equipment as part of the integrated design of new commercial buildings.
Schools HVAC	RCI-41	NPCC/RTF	Install or upgrade to high-efficiency HVAC system.
Commercial Demand Control Ventilation New/Integrated Design	RCI-42	NPCC/RTF	Install demand control ventilation as part of the integrated design of new commercial buildings.
Commercial ECM on VAV Boxes New/Integrated Design	RCI-43	NPCC/RTF	Use electronically commutated motors on variable air volume air handling systems to control air flows while reducing electricity use
Commercial Variable Speed Chiller New/Integrated Design	RCI-44	NPCC/RTF	High-efficiency and optimized chiller systems for buildings with large cooling loads
Commercial Package Rooftop Measures New/Integrated Design	RCI-45	NPCC/RTF	Install high-efficiency rooftop HVAC system(s) as part of integrated design for new commercial buildings.
Commercial Premium HVAC New/Integrated Design	RCI-46	NPCC/RTF	Install high-efficiency HVAC system(s) as part of integrated design for new commercial buildings.
Commercial Controls Commissioning HVAC New/Integrated Design	RCI- 47	NPCC/RTF	Commission HVAC controls as part of integrated design for new commercial buildings.
Commercial Demand Control Ventilation Natural Replacement/Retrofit	RCI-53	NPCC/RTF	Install demand control ventilation.
Commercial ECM on VAV Boxes Natural Replacement/Retro	RCI-54	NPCC/RTF	Use electronically commutated motors on variable air volume air handling systems to control air flows while reducing electricity use
Commercial Variable Speed Chiller Natural Replacement/Retro	RCI-55	NPCC/RTF	Upgrade to variable speed chiller system.
Commercial Package Rooftop Measures Natural	RCI-56	NPCC/RTF	Install high-efficiency rooftop HVAC system(s).

Measure Name	RCI Reference Number	Source	Notes
Replacement/Retro			
Commercial Premium HVAC Natural Replacement/Retro	RCI-57	NPCC/RTF	Install high-efficiency HVAC system(s).
Commercial Controls Commissioning HVAC Retrofit	RCI-58	NPCC/RTF	Commission HVAC controls as part of integrated design for new commercial buildings.
Commercial Economizer Measures	RCI-78	ETO	Install and maintain economizers to mix outside air with inside air to provide cooling when appropriate.
Commercial Heating Duct Measures	RCI-81	ETO	Optimize operation of, insulate, clean, seal and perform other maintenance on commercial heating ducts.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-19) or exclude (Table B-20) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

C-Set-4: Commercial Appliances and Non-HVAC Equipment Measures

Measure Description

Improvement of the efficiency of appliances and equipment in the commercial sector can be achieved through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. These appliances and equipment have a useful life of between 10 and 30 years, and thus affect the energy use, and associated greenhouse gas emissions, for that period of time. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, equipment installer incentive programs, tax incentive programs for high-efficiency equipment purchase, and other approaches. Individual cost curve measures included in this set include:

- **Appliance technologies:** Commercial Refrigerator Improvements (RCI-60), Schools Computer/Server Improvements (RCI- 61), Commercial Cooking/Food Service Improvements (RCI-62), Commercial Wastewater Treatment improvements (RCI-63), Commercial Water Supply Improvements (RCI-64), Commercial DVC Hood (RCI-65), Commercial Fume Hood (RCI-68), Commercial Refrigerator Improvements (RCI-70), Commercial Ice-maker Improvements (RCI-71), Commercial Vending Machines (RCI-72), Commercial Clothes Washer (RCI-73)

- **Non-HVAC technologies:** Commercial Wastewater Heat Exchanger (RCI-74), Commercial Heat Pump Water Heater (RCI-76), Commercial Transformers (RCI-77)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-22 and Table B-23, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-22: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 4 (C-Set-4) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.07	0.13	0.3	1.6	-$22	-$95	-$71	-$59
Fed. Action	0.07	0.13	0.3	1.6	-$22	-$95	-$71	-$59
OR Action	0.23	0.37	0.9	5.0	-$83	-$351	-$88	-$70

Table B-23: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 4 (C-Set-4) using energy-cycle emission factors.

Scenario	GHG Reductions (MMtCO$_2$e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.08	0.16	0.4	2.0	-$22	-$95	-$60	-$49
Fed. Action	0.08	0.16	0.4	2.0	-$22	-$95	-$60	-$49
OR Action	0.26	0.45	1.1	6.0	-$83	-$351	-$74	-$58

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-24 for a summary of the specific measures that are summarized by C-Set-4 and the source of each individual measure.

Table B-24: Summary of Individual Measures Included in this Measure Set C-Set-4.

Measure Name	RCI Reference Number	Source	Notes
Commercial Refrigerator Improvements (Grocery Bundle)	RCI-60	NPCC/RTF	Upgrade to high-efficiency refrigeration systems.
Schools Computer/Server Improvements	RCI-61	NPCC/RTF	Upgrade computer / server equipment to high-efficiency models.
Commercial Cooking/Food Service Improvements	RCI-62	NPCC/RTF	Upgrade to high-efficiency cooking / food service appliances and equipment.
Commercial Wastewater Treatment improvements	RCI-63	NPCC/RTF	Optimize municipal sewage system capacity.

Measure Name	RCI Reference Number	Source	Notes
Commercial Water Supply Improvements	RCI-64	NPCC/RTF	Optimize supply system capacity.
Commercial DVC Hood	RCI-65	NPCC/RTF	Install demand-ventilation control (DVC) technologies.
Commercial Fume Hood	RCI-68	NPCC/RTF	Install high-efficiency fume hoods.
Commercial Refrigerator Improvements	RCI- 70	NPCC/RTF	Upgrade to high-efficiency refrigeration systems.
Commercial Ice-maker Improvements	RCI-71	NPCC/RTF	Install / upgrade to high-efficiency ice making equipment.
Commercial Vending Machines	RCI-72	NPCC/RTF	Install / upgrade to high-efficiency vending machines.
Commercial Clothes Washer	RCI-73	NPCC/RTF and ETO	Install high-efficiency commercial clothes washers.
Commercial Wastewater Heat Exchanger	RCI-74	ETO	Install wastewater heat exchangers to utilize the heat in wastewater to meet thermal loads.
Commercial Hot Water Efficiency Measures	RCI-75	ETO	Install / upgrade to high-efficiency hot water technologies / systems.
Commercial Heat Pump Water Heater	RCI-76	ETO	Install / upgrade to high-efficiency hot water technologies / systems.
Commercial Transformers	RCI-77	ETO	Install high-efficiency electricity transformers.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.

- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-22) or exclude (Table B-23) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

C-Set-5: Commercial Natural Gas Efficiency Measures

Measure Description

Improvement of the efficiency of heating systems, building envelope, water heating, appliances, and equipment that consume natural gas in the commercial sector can be achieved through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. These systems can include systems for building heating, water heating, building envelope / weatherization (in conjunction with natural gas heating systems), appliances, and equipment. Many of these systems are long lasting, and thus affect the energy use, and associated greenhouse gas emissions, of a home for many years to come. Often, installation of these types of measures improves occupant comfort and provides other benefits as well, while reducing energy use and expenditures. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating. Measures in this Set can be implemented through a variety of policies and programs, equipment installer incentive programs, tax incentive programs for high-efficiency equipment purchase, and other approaches. Individual cost curve measures included in this set include:

- **Heating systems:** Commercial Heat Measures--Gas (RCI-91)
- **Building envelope:** Commercial Insulation Measures--Gas Heat (RCI-89), Commercial Insulation Measures--Gas (RCI-93), Commercial Windows Measures--Gas (RCI-94)
- **Water heating technologies:** Commercial Hot Water Measure--Gas (RCI-88),
- **Appliances and equipment:** Commercial Laundry Equipment--Gas (RCI-86), Commercial Cooking Equipment--Gas (RCI-87), Commercial Heat Reclamation--Gas (RCI-90), Commercial Wastewater Heat Exchanger--Gas (RCI-92)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, weatherization installation and technical assistance providers (private and public), US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-25 and Table B-26, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-25: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 5 (C-Set-5) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.02	0.05	0.1	0.6	$3	$3	$26	$5
Fed. Action	0.02	0.06	0.1	0.7	$3	$1	$20	$2
OR Action	0.06	0.13	0.3	1.5	-$8	-$52	-$27	-$35

Table B-26: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 5 (C-Set-5) using energy-cycle emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.03	0.06	0.1	0.8	$3	$3	$21	$4
Fed. Action	0.03	0.07	0.2	0.8	$3	$1	$17	$2
OR Action	0.07	0.15	0.4	1.8	-$8	-$52	-$22	-$28

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-27 for a summary of the specific measures that are summarized by C-Set-5 and the source of each individual measure.

Table B-27: Summary of Individual Measures Included in this Measure Set C-Set-5.

Measure Name	RCI Reference Number	Source	Notes
Commercial Laundry Equipment--Gas	RCI-86	ETO	Install high-efficiency, commercial-scale natural gas laundry equipment.
Commercial Cooking Equipment--Gas	RCI-87	ETO	Install high-efficiency, commercial-scale natural gas cooking / food service equipment.
Commercial Hot Water Measures--Gas	RCI-88	ETO	Install high-efficiency, commercial-scale natural gas hot water systems.
Commercial Insulation Measures--Gas Heat	RCI-89	ETO	Install / upgrade wall, ceiling, and floor insulation.
Commercial Heat Reclamation--Gas	RCI-90	ETO	Install heat reclamation technology.
Commercial Heat Measures--Gas	RCI-91	ETO	Install / upgrade / maintain natural gas building heating systems.
Commercial Wastewater Heat Exchanger--Gas	RCI-92	ETO	Install commercial wastewater heat exchanger to utilize wastewater heat to help meet building thermal/water heating load.
Commercial Insulation Measures--Gas	RCI-93	ETO	Install spray-on wall insulation.
Commercial Windows Measures--Gas	RCI-94	ETO	Install / upgrade to high-efficiency windows.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation

units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.

- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-25) or exclude (Table B-26) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

C-Set-6: Commercial Solar PV, Solar Water Heat, CHP, and Biomass Measures

Measure Description

Installation of technologies such as solar PV electric, solar water heating, and biomass heating or technologies that significantly increase the overall efficiency with which natural gas is used such as combined heat and power (CHP) in the commercial sector displace the need for fossil fuels for both electric and thermal loads. All of these technologies are long lasting, and thus affect the energy use, and associated greenhouse gas emissions, of a business or institutional building for many years to come. Displaced fossil fuel consumption reduces the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, tax incentive programs for equipment purchase, through installers/engineering companies, and other approaches. Individual cost curve measures included in this set include:

- **Solar photovoltaic (PV) electricity generation:** Commercial Solar PV (RCI-100)
- **Solar water heating:** Commercial Solar Water Heat – Electric Back-up (RCI-80), Commercial Solar Hot Water--Gas Back-up (RCI-95)
- **Combined heat and power (CHP) technologies:** Commercial Gas-fired CHP (RCI-96)
- **Biomass heating systems:** Commercial Wood-fueled Space Heat Replacing Electric (RCI-97), Commercial Wood-fueled Space Heat Replacing Gas (RCI-98), Commercial Wood-fueled Space Heat Replacing Oil/LPG (RCI-99)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For CHP and biomass energy-related options, a variety of available sources were used to develop specific analyses. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-28 and Table B-29, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-28: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 6 (C-Set-6) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.10	0.17	0.4	2.1	$42	$132	$102	$62
Fed. Action	0.33	0.55	1.3	6.9	$127	$405	$97	$59
OR Action	0.56	0.92	2.2	11.6	$82	$119	$38	$10

Table B-29: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 6 (C-Set-6) using energy-cycle emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.12	0.21	0.5	2.6	$42	$132	$86	$52
Fed. Action	0.38	0.67	1.5	8.3	$127	$405	$83	$49
OR Action	0.64	1.13	2.6	13.9	$82	$119	$32	$9

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures, including many of the measures in this Set, were developed specifically for this project. See Table B-30 for a summary of the specific measures that are summarized by C-Set-6 and the source of each individual measure.

Table B-30: Summary of Individual measures included in this measure set C-Set-6.

Measure Name	RCI Reference Number	Source	Notes
Commercial Solar Water Heat – Electric Back-up	RCI-80	ETO	Install solar water heating systems.
Commercial Solar Hot Water--Gas Back-up	RCI-95	ETO	Install solar water heating systems.
Commercial Gas-fired CHP	RCI-96	CCS	Install gas-fired commercial-scale combined heat & power (CHP) systems.
Commercial Wood-fueled Space Heat Replacing Electric	RCI-97	CCS	Replace electric heating with wood-fueled space heating systems.
Commercial Wood-fueled Space Heat Replacing Gas	RCI-98	CCS	Replace gas heating with wood-fueled space heating systems.
Commercial Wood-fueled Space Heat Replacing Oil/LPG	RCI-99	CCS	Replace oil/LPG heating with wood-fueled space heating systems.
Commercial Solar PV	RCI-100	CCS	Install solar PV systems on commercial buildings (for example, capacity on average equal to or greater than 100kW)

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels

consumption, and either include (Table B-28) or exclude (Table B-29) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

I-Set-1: Industrial General Industry Measures

Measure Description

Improvement of the efficiency of equipment (compressors, motors, fans, and pumps), lighting and controls, materials movement, transformers, and energy management across virtually all types of firms in the industrial sector can be achieved through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. The measures in this set represent general industrial technologies that are not specific to any one industry. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, tax incentive programs for high-efficiency equipment purchase, and other approaches. Individual cost curve measures included in this set include:

- **Equipment:** Air Compressor Measures (RCI-101), Motors Measures (RCI-103), Fan Measures (RCI-104), Pump Measures (RCI-105)
- **Lighting and controls:** Lighting and Controls (RCI-102)
- **Materials movement:** Materials Movement Measures (RCI-107)
- **Transformers:** Transformers (RCI-106)
- **Energy management:** Energy Management (RCI-108)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, “Modest Effort, Continued State and Federal Policies”).

Federal Action: Moderate increase in Federal action (Scenario 2, “Moderate Increase in Federal Action”), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Industrial electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-31 and Table B-32, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-31: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 1 (I-Set-1) using direct emission factors.

Scenario	GHG Reductions (MMtCO_2e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.21	0.38	1.0	4.8	-$18	-$97	-$17	-$20
Fed. Action	0.22	0.39	1.0	4.9	-$19	-$104	-$19	-$21
OR Action	0.29	0.51	1.3	6.4	-$43	-$206	-$32	-$32

Table B-32: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 1 (I-Set-1) using energy-cycle emission factors.

Scenario	GHG Reductions (MMtCO_2e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.25	0.46	1.2	5.8	-$18	-$97	-$15	-$17
Fed. Action	0.25	0.47	1.2	5.9	-$19	-$104	-$16	-$18
OR Action	0.33	0.62	1.6	7.7	-$43	-$206	-$27	-$27

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-33 for a summary of the specific measures that are summarized by I-Set-1 and the source of each individual measure.

Table B-33: Summary of Individual Measures Included in this Measure Set I-Set-1.

Measure Name	RCI Reference Number	Source	Notes
Industrial General: Air Compressor Measures	RCI-101	NPCC/RTF	Installation of high-efficiency compressors and enhanced operations & maintenance (O&M) measures.
Industrial General: Lighting and Controls	RCI-102	NPCC/RTF	Installation of high-efficiency lighting systems and controls.
Industrial General: Motors Measures	RCI-103	NPCC/RTF	Installation of high-efficiency motors and enhanced O&M measures.
Industrial General: Fan Measures	RCI-104	NPCC/RTF	Installation of high-efficiency fans and enhanced O&M measures.
Industrial General: Pump Measures	RCI-105	NPCC/RTF	Installation of high-efficiency pumps and enhanced O&M measures.
Industrial General: Transformers	RCI-106	NPCC/RTF	Installation of high-efficiency electrical transformers.
Industrial General: Materials Movement Measures	RCI-107	NPCC/RTF	Install / upgrade to high-efficiency materials movement systems.
Industrial General: Energy Management	RCI-108	NPCC/RTF	Install integrated plant energy management technologies and systems.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels

consumption, and either include (Table B-31) or exclude (Table B-32) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

I-Set-2: Industrial Industry Specific Measures

Measure Description

Different industry sub-sectors have industry-specific equipment and processes that lend themselves to particular measures for reduction of energy use. The industry types that operate in Oregon and are considered in this measure set include: electronics chip fabrication, food processing and storage, metal foundries, wood products, and agriculture. This set also includes measures associated with streetlights and traffic signals. This measure set considers improvement of the efficiency of energy use in industry through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. The industry-specific measures have various useful lifespans, but all reduce energy use, and associated greenhouse gas emissions. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, tax incentive programs for high-efficiency equipment purchase, collaborations with industrial engineering firms and the target industries themselves, technical assistance provision, and other approaches. Individual cost curve measures included in this set include:

- **Electronics Chip Fabrication:** Industrial Electronics Chip Fab Measures (RCI-109), Industrial Electronics Clean Room Measures (RCI-110)
- **Food Processing and Storage:** Industrial Food Processing Measures (RCI-111), Industrial Cold Storage Measures (RCI-112), Industrial Fruit Storage Measures (RCI-113), Industrial Food Storage Measures (RCI-114), Industrial Grocery Distribution Measures (RCI-115)
- **Foundries:** Industrial Metals Arc Furnace (RCI-116)
- **Wood Products:** Industrial Mechanical Pulp Measures (RCI-117), Industrial Kraft Pulp Measures (RCI-118), Industrial Paper Sector Measures (RCI-119), Industrial Lumber Conveyor Replacement (RCI-120), Industrial Wood Panels Hydraulic Press (RCI-121)
- **Agriculture:** Industrial Agriculture Pump and Related Measures (RCI-122), Industrial Agriculture Irrigation Improvements (RCI-123)

- **Streetlights and Traffic Signals:** Industrial Rural Area Lighting (RCI-124), Industrial Traffic Signal Relamping (RCI-125)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B, "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-34 and B-35, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-34: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 2 (I-Set-2) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.08	0.11	0.4	1.5	-$15	-$62	-$42	-$40
Fed. Action	0.08	0.11	0.4	1.5	-$15	-$62	-$42	-$40
OR Action	0.10	0.15	0.5	2.1	-$25	-$100	-$52	-$48

Table B-35: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 2 (I-Set-2) using energy-cycle emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.09	0.14	0.4	1.9	-$15	-$62	-$35	-$33
Fed. Action	0.09	0.14	0.4	1.9	-$15	-$62	-$35	-$33
OR Action	0.12	0.18	0.6	2.5	-$25	-$100	-$43	-$40

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-36 for a summary of the specific measures that are summarized by I-Set-2 and the source of each individual measure.

Table B-36: Summary of individual measures included in this measure set I-Set-2.

Measure Name	RCI Reference Number	Source	Notes
Industrial Electronics Chip Fab Measures	RCI-109	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in chip fabrication.
Industrial Electronics Clean Room Measures	RCI-110	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in clean rooms.
Industrial Food Processing Measures	RCI-111	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in food processing.
Industrial Cold Storage Measures	RCI-112	NPCC/RTF	Includes installation / upgrade of various types of refrigeration / freezing equipment.
Industrial Fruit Storage Measures	RCI-113	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in fruit storage.
Industrial Food Storage Measures	RCI-114	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in food storage.
Industrial Grocery Distribution Measures	RCI-115	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in grocery distribution.
Industrial Metals Arc Furnace	RCI-116	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in metal foundries.
Industrial Mechanical Pulp Measures	RCI-117	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in mechanical pulping.
Industrial Kraft Pulp Measures	RCI-118	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in Kraft pulping.
Industrial Paper Sector Measures	RCI-119	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in paper production.
Industrial Lumber Conveyor Replacement	RCI-120	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in lumber production.

Measure Name	RCI Reference Number	Source	Notes
Industrial Wood Panels Hydraulic Press	RCI-121	NPCC/RTF	Includes installation / upgrade of various types of equipment and practices used in wood panel production.
Industrial Agriculture Pump and Related Measures	RCI-122	NPCC/RTF and ETO	Includes installation / upgrade of high-efficiency pumps and associated O&M improvements
Industrial Agriculture Irrigation Improvements	RCI-123	NPCC/RTF and ETO	Includes installation / upgrade of various types of equipment and practices used in agricultural irrigation.
Industrial Rural Area Lighting	RCI-124	ETO	Installation / upgrade to high-efficiency streetlights.
Industrial Traffic Signal Relamping	RCI-125	ETO	Relamping industrial traffic signals.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-34) or exclude (Table B-35) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

I-Set-3: Industrial Heating, Building Envelope, and Hot Water Measures

Measure Description

Improvement of the efficiency of heating, ventilation, and air conditioning systems (HVAC), building envelopes, and hot water systems in the industrial sector can be achieved through the installation of higher-than-standard efficiency technologies in new or natural replacement installations, and through the retrofit of existing systems with similar higher-efficiency devices. Industrial HVAC, weatherization/building envelope, and hot water systems are long lasting, and thus affect the energy use, and associated greenhouse gas emissions, of a home for many years to come. Often, installation of these types of measures improves resident comfort and provides other benefits as well, while reducing energy use and expenditures. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity and natural gas for heating. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, to low-income weatherization assistance, equipment installer incentive programs, tax incentive programs for high-efficiency equipment purchase, and other approaches. Individual cost curve measures included in this set include:

- **Heating Measures:** Industrial Boiler Measures (RCI-126), Industrial Space Heating Measures (RCI-128)
- **Building envelope/weatherization Measures:** Industrial Weatherization Measures (RCI-129)
- **Hot Water Measures:** Industrial Hot Water Measures (RCI-127)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-37 and B-38, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-37: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 3 (I-Set-3) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO_2e$)	2013-2035 CE ($/tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.03	0.07	0.2	0.9	-$14	-$60	-$85	-$69
Fed. Action	0.03	0.08	0.2	0.9	-$16	-$66	-$85	-$70
OR Action	0.04	0.09	0.2	1.1	-$18	-$75	-$85	-$70

Table B-38: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 3 (I-Set-3) using energy-cycle emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.04	0.09	0.2	1.1	-$14	-$60	-$70	-$57
Fed. Action	0.04	0.10	0.2	1.2	-$16	-$66	-$70	-$57
OR Action	0.05	0.11	0.3	1.3	-$18	-$75	-$70	-$57

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95% of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures were developed specifically for this project. See Table B-39 for a summary of the specific measures that are summarized by I-Set-3 and the source of each individual measure.

Table B-39: Summary of Individual Measures Included in this Measure Set I-Set-3.

Measure Name	RCI Reference Number	Source	Notes
Industrial Boiler Measures	RCI-126	ETO	Install / upgrade to high-efficiency boilers
Industrial Hot Water Measures	RCI-127	ETO	Install / upgrade to high-efficiency hot water systems
Industrial Space Heating Measures	RCI-128	ETO	Install / upgrade to high-efficiency space heating system
Industrial Weatherization Measures	RCI-129	ETO	Install / upgrade insulation, windows, etc.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.
- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-37) or exclude (Table B-38) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

I-Set-4: Industrial Solar PV, CHP, Process Emissions Reduction Measures

Measure Description

Installation of technologies such as solar PV electric or technologies that significantly increase the overall efficiency of natural gas use such as combined heat and power (CHP) in the industrial sector displace the need for fossil fuels for both electric and thermal loads. All of these technologies are long lasting, and thus affect the energy use, and associated greenhouse gas emissions, of a home for many years to come. Saved electricity and natural gas consumption reduce the quantity of greenhouse gas emissions from the production and combustion of fossil fuels for electricity generation at central plants, as well as natural gas and other fuels for heating and process heat. In addition to these energy generation technologies, I-Set-4 also includes measures to decrease non-energy process related greenhouse gas emissions from specific industries such as cement and electronics production. Measures in this Set can be implemented through a variety of policies and programs, ranging from utility/Energy Trust of Oregon programs, to low-income weatherization assistance, equipment installer incentive programs, tax incentive programs for high-efficiency equipment purchase, partnerships with industry, emissions regulations, and other approaches. Individual cost curve measures included in this set include:

- **Solar PV Technologies:** Industrial Solar PV (RCI-136)
- **CHP technologies:** Industrial Gas-fired CHP (RCI-130), Industrial Biomass-fired CHP (RCI-131), Industrial Digester Gas-fired CHP (RCI-132),
- **Process Emissions:** Industrial Cement Production Emissions Reduction (RCI-133), Industrial Electronics Industry Solvent Emissions Reductions (RCI-134), Industrial Halon Consumption Reduction (RCI-135)

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Continued State and Federal policies and incentives that result in reaching 60% to the maximum achievable energy efficiency potential in Oregon (Scenario 1, "Modest Effort, Continued State and Federal Policies").

Federal Action: Moderate increase in Federal action (Scenario 2, "Moderate Increase in Federal Action"), based on legislation proposed in 2011/2012, that results in a 10% increase in energy savings and a 10% reduction in cost to the state of Oregon and its citizens and businesses for applicable measures beyond what is achieved in Scenario 1.

Oregon Action + Federal Action: Assumes additional funding for ETO and other state energy efficiency programs resulting in an additional 10% energy savings beyond the level achieved in Scenario 2 (that is, 80% of achievable potential in total), but no additional cost savings for Oregon (Scenario 3, "Moderate Increase in Federal and State Action").

Note on Goals: Additional detail on the development and definition of the scenarios, and the references consulted in defining the scenarios, is presented in RCI Annex B "Assignment of Effort and Cost Variables to in the Scenarios".

Timing (Start, Phase In, End): Implementation of the measures in this set would begin in 2013 and would either be "ramped up" to a maximum annual penetration rate over a period of several years, or implemented at constant fractions (for example, 5 to 10 percent) of the estimated markets for the measures depending on variables such as the market (new/natural replacement or retrofit installations) being addressed by the measure, the lifetime of the individual measure, and other considerations. In general, for new or natural replacement installations, implementation continues through 2035, while for retrofit installations, implementation may be completed before 2035, depending on the measure and market. Where data were available, the timing and ramp-in rates for these measures were modeled consistent with approaches used by Northwest Power and Conservation Council's Regional Technical Forum (NPCC/RTF) to describe the implementation of similar measures. See the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A, "Data Source and Data Preparation Descriptions", for additional details.

Parties Involved: Retail electricity and gas customers, Energy Trust of Oregon, utilities, Oregon Department of Energy, Oregon Department of Revenue, US DOE, and others.

Data Sources and Additional Background: NPCC/RTF workbooks presenting achievable technical potential estimates; Energy Trust of Oregon; and for some scenario variables, descriptions of ongoing and proposed state/federal weatherization programs. For CHP options, a variety of available sources were used to develop specific analyses. For details see the project Excel file titled *ODOE-RCI-Options-Final.xls* and RCI Annex A: "Data Source and Data Preparation Descriptions".

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: In the Table B-40 and B-41, negative values for costs or cost effectiveness denote that net savings in direct costs to the Oregon economy accrue from the sum of the measures in the measure set.

Table B-40: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 4 (I-Set-4) using direct emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO_2e$)	2013-2035 CE ($/tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.24	0.37	0.9	4.8	$39	$85	$41	$18
Fed. Action	0.55	0.76	2.4	10.9	$120	$276	$49	$25
OR Action	1.15	1.61	5.2	23.1	$40	-$229	$8	-$10

Table B-41: Summary of Total Greenhouse Gas Marginal Abatement Cost Curve Results for RCI Measures in Set 4 (I-Set-4) using energy-cycle emission factors.

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO_2e$)	2013-2035 CE ($/tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Base	0.27	0.44	1.1	5.7	$39	$85	$36	$15
Fed. Action	0.59	0.88	2.7	12.2	$120	$276	$45	$23
OR Action	1.24	1.82	5.7	25.6	$40	-$229	$7	-$9

Quantification Methods and Results:

Detail about the background sources, assumptions, calculations, and results used in development are presented in the associated project Excel file titled *ODOE-RCI-Options-Final.xls*. In addition, the Excel workbook includes detailed results of GHG emissions, measure costs, energy savings, by year for each of 800+ individual measures as well as for all summary groupings of these measures. Underlying energy savings, measure lifetime, cost, applicable market, and market penetration data and assumptions for the majority of all of the RCI measures (over 95%

of all measures) assessed in the RCI sectors are adapted or adopted directly from two sources: the Northwest Power and Conservation Council's – Regional Technical Forum, *Energy Efficiency Measure Supply Curves in support of the 6th Power Plan*, and an Energy Trust of Oregon report titled *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010 – 2030* (prepared for ETO by Stellar Processes and Ecotope). Assessments of the remaining RCI measures, including all of the measures in this Set, were developed specifically for this project. See Table B-42 for a summary of the specific measures that are summarized by I-Set-4 and the source of each individual measure.

Table B-42: Summary of Individual Measures Included in this Measure Set I-Set-4.

Measure Name	RCI Reference Number	Source	Notes
Industrial Gas-fired CHP	RCI-130	CCS	Installation of an industrial-scale, natural gas-fired combined heat and power (CHP) system.
Industrial Biomass-fired CHP	RCI-131	CCS	Installation of an industrial-scale, biomass-fired combined heat and power (CHP) system.
Industrial Digester Gas-fired CHP	RCI-132	CCS	Installation of an industrial-scale, biogas-fired combined heat and power (CHP) system.
Industrial Cement Production Emissions Reduction	RCI-133	CCS	Substitute recycled slag for cement in concrete.
Industrial Electronics Industry Solvent Emissions Reductions	RCI-134	CCS	Install equipment and implement practices that reduce process related solvent emissions.
Industrial Halon Consumption Reduction	RCI-135	CCS	Reduce the use of and/or replace halogenated compounds in end-uses such as refrigeration, fire suppression, and others.
Industrial Solar PV	RCI-136	CCS	Installation of industrial-scale solar PV.

Key Assumptions:

- Real discount rate of 5 percent/yr.
- Current and future avoided costs of electricity estimated based on electricity avoided costs published in recent years by the two largest Oregon utilities, and current and future natural gas avoided costs estimated based on historical Oregon city-gate natural gas

prices, escalated consistent with Reference Case projections for the Northwest region included in the U.S. Department of Energy's *Annual Energy Outlook 2011*.

- Rate of technology adoption, and energy savings and costs per unit installed, as indicated above.
- Emissions avoided by reduced electricity use are assumed to be roughly consistent, in most future years, with avoiding emissions from natural gas combined-cycle generation units, factoring in an avoided rate of transmission and distribution losses of 5.7 percent of generation.
- Emission factors used to convert net impact on energy use to impact on GHG emissions include direct emissions associated with electricity generation or gas/other fuels consumption, and either include (Table B-40) or exclude (Table B-41) additional energy cycle emissions.

Key Uncertainties (including sensitivities)

Key uncertainties for this and other sets of RCI measures assessed include evolution of the costs and energy-saving performance of technologies relative to standard practice or standard units, the degree to which programs to implement measures are as effective as assumed, and changes in future gas and electricity costs in Oregon.

RCI - Annex A: Data Source and Data Preparation Descriptions

Data Sources

The majority of the Residential, Commercial and Industrial (RCI) measures included and evaluated in the preparation of the Greenhouse Gas Marginal Abatement Cost Curve Development Study are based primarily on information provided in two key data sources:

1. Northwest Power and Conservation Council – Regional Technical Forum (2009), *6th Power Plan, Conservation Supply Curve Files.* Downloaded 6/2012 from http://www.nwcouncil.org/energy/powerplan/6/supplycurves/default.htm; and
2. Stellar Processes and Ecotope on behalf of Energy Trust of Oregon (2011). *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010-2030.* Downloaded 6/2012 from http://energytrust.org/library/reports/021611_ResourceAssessment.pdf.

Brief descriptions of these key sources, and of how data from each source were interpreted to develop measure data for the Cost Curve Study, are provided below. In addition, independent estimates of costs and greenhouse gas emission impacts were prepared for a smaller number of measures not included in either of the above compendia, but of interest to Oregon.

Approaches to Data Preparation for Marginal Abatement Cost Curve Development

6th Power Plan – Conservation Supply Curves

In support of the 6th Power Plan, the Regional Technical Forum (RTF) of the Northwest Power and Conservation Council (NPCC) has prepared estimates of "achievable technical potential" costs and savings for over 1,400 detailed energy efficiency and other demand-side measures in the residential, commercial, and industrial sectors for the NPCC region (which includes Oregon, Washington, Idaho, and part of Montana). The cost and savings information developed by the RTF and NPCC is used by NPCC to develop supply curves of demand-side electricity savings (with some measures affecting gas use as well) at different levels of Total Resource Cost (TRC)-based net levelized costs. NPCC cost curves use levelized costs as a metric so as to be able to compare the costs of power purchases and the cost of new electricity supply resource development with the costs of demand-side actions. For additional information on the development of NPCC's supply curves, please see the documentation in the NPCC 6th Power plan.

The RTF/NPCC supply curves are calculated using Excel workbooks, which have been made publically available. These workbooks present the process, information sources, and assumptions used in the development of the supply curves. The information documented in these files including technical and achievable potential, measure costs, measure lifetimes, available markets for measures, market penetration assumptions, and energy savings from measure application relative to specific baseline conditions, as well as descriptions of the individual measures evaluated. The analytical structure and data provided in each of the dozens of NPCC measure workbooks varies somewhat between measures with regard to level of detail and the way that inputs are presented. Information was adopted from the RTF/NPCC workbooks for use in the development of the marginal abatement cost curves prepared for this project.

The general procedure used to adopt and adapt information from the NPCC work for use in preparing Oregon-specific measure cost and savings estimates was as follows:

1. RTF/NPCC workbooks were reviewed to determine which of the sometimes several levels of measure aggregation provided would provide sufficient detail for the ODOE cost curve work. This level of aggregation was typically the most aggregated level at which the needed cost and performance data could be obtained for RTF/NPCC measure groupings. In some cases (for example, for the four categories of commercial offices and three categories of commercial retail buildings that RTF/NPCC covers individually), CCS performed aggregation based on calculated weighted averages of key parameters so as to reduce the number of individual measures (though not the market for efficiency improvements) considered in the study.
2. For each measure, RTF/NPCC data were collected for measure lifetime, annual electricity and gas savings (or increased use) per unit of measure application, total capital and annual operating and maintenance (O&M) costs (if any) of the measure (again per application unit) and, if available and applicable, a load factor for the measure allowing the conversion of annual kWh savings to peak power demand savings. Costs were adjusted to 2010 dollars. The "units" used varied somewhat by measure, with, for example, residential sector measures typically denominated in number of households and appliances, and commercial sector measure parameters presented per 1000 square feet of floor space.
3. For most measures, RTF/NPCC included estimates of applicable measure penetration into its market, which varied depending on whether new, retrofit, natural replacement, or "integrated design" measures were considered. These estimates adopted and applied in a manner consistent with their application by RTF/NPCC.
4. To estimate the markets for each measure, the NPCC regional market forecasts were scale from the regional to the Oregon statewide level. Where NPCC data that broke down regional estimates by state were available (for example, square feet of commercial floor area by commercial building type), those data were used; in other instances, Oregon's fraction of regional population or other ratios were used to estimate future markets from NPCC market forecast.
5. RTF/NPCC included "ramp-in" assumptions for each measure that estimated how the measure would be implemented over time. For example, some measures (for example, those applying to retrofit situations) were "ramped in" at a constant 5 or 10 percent of total technical potential per year, to a maximum "achievable" value (typically 85 percent of technical potential), and others (for example, those applying to new installations) were implemented gradually to a maximum level of achievable technical potential. The ramp-in rates used by RTF/NPCC for each measure were adjusted by lagging them to start in

2013 (the assumed start year for the measures included in the analysis for ODOE) and in some cases extended the periods over which the measures were phased in through 2035.

6. Data and assumptions compiled in steps 2 through 5, above, were combined to estimate, for each measure, the net impact on electricity and gas end uses, on capital costs, and on O&M costs for each year from 2013 through 2035. In addition, capital costs were "levelized" using measure lifetime information and a discount rate of 5 percent, then combined with annual O&M costs to yield estimates of total annualized costs for each measure.
7. Based on the net impact on electricity and gas use estimated as above for each measure, estimates of net impact on retail energy costs were prepared using projections of retail electricity and gas costs for Oregon. The retail cost projections started with historical 2010 or 2011 retail rates, extrapolated based on the US Department of Energy's Energy Information Administration (USDOE EIA) Annual Energy Outlook 2011 (AEO 2011) reference case projections of energy prices by sector for the Northwest region.
8. Again based on the net impact on electricity and gas use estimated as above for each measure, estimates of net impact on avoided energy costs on an approximately a total resource cost (TRC) basis were estimated by applying annual estimates of future Oregon avoided costs to the energy use impacts. Electricity sector avoided costs were estimated by preparing a weighted average of recent avoided costs published by the two largest Oregon utilities, Pacific Power and Portland Gas and Electric. Gas avoided costs were estimated starting with the most recent available historical city-gate gas costs for Oregon, escalated based on AEO 2011 reference case projections for regional gas costs.
9. Estimates of the impacts of each measure on gas and electricity use were used to estimate avoided greenhouse gas (GHG) emissions, based both on standard "direct" emission factors and on emission factors including other "upstream" energy cycle impacts. Estimates of the GHG impacts of changes to electricity use were calculated by first adjusting for avoided electricity transmission and distribution losses (at an average of 5.7% of generation), then applying a marginal emission factor for Oregon electricity generation that varies somewhat by year through 2024, then is equal to 0.363 tCO_2/MWh, which is on the order of emissions from a natural gas combined-cycle electricity generation unit.
10. Steps 6 through 9 above were applied for each measure to calculate both technical achievable potential for each measure consistent with NPCC definitions, and also to estimate costs and GHG savings for each measure based on three implementation "scenarios" prepared for ODOE. These scenarios presume different levels of effort/support in implementing measures provided by the Federal and State of Oregon governments. This approach to scenario preparation is documented in a separate Annex B to this RCI Appendix.
11. For each measure, for both the technical achievable potential and for each of the three scenarios, results were compiled to provide estimates of GHG savings in and through the target years of 2022 and 2035, cumulative net present value costs of measures through those years, and calculated cost effectiveness (dollars per ton of carbon dioxide equivalent avoided) both through 2022 and through 2035.

12. Results from steps 6 through 11 above for individual measures (numbering over 800 in total, including measures based on NPCC, ETO, and other sources), were aggregated to a total of 136 RCI measure groupings (numbered RCI-1 through RCI-136) for assembly into overall cost curves by scenario, and aggregated further into 55 measure groupings (numbered M-RCI-1 through M-RCI-55) for input into the analysis of the macroeconomic impacts of the GHG emissions reduction measures considered under the project. Table B-42 provides the mapping of the detailed measures to the 136 RCI measure groupings for which the microeconomic analysis was completed, and the 55 measure groups included in the macroeconomic analysis.

The focus of the 6th Power Plan Supply Curves is on conservation of electricity. Certain measures evaluated by NPCC/RTF account for changes in natural gas use in those measures where measures designed to reduce electricity use affect natural gas use (for example, when lighting energy improvements reduce the heat gain into conditioned space by from lights, requiring more gas for space heating), but the NPCC Curves do not include measures focused on the efficient use of natural gas or other fuels. Also, in the period between 2009 and 2011, new technologies have emerged or become much more prevalent (for example residential LED light bulbs) that were not considered in NPCC Supply Curves. As a result, data from a recent Energy Trust of Oregon (ETO) report was used to fill in these gaps in measure coverage.

Energy Efficiency and Conservation Measure Resource Assessment for 2010-2030

This ETO report (see full reference above) also uses the NPCC Supply Curves for a portion of the measures assessed, but also includes additional electricity measures, natural gas specific measures, and renewable generation not included in the 6th Power Plan Supply Curves.

The ETO report provides information, by measure, for the residential, commercial, and industrial sectors that includes: technical and achievable potential, costs, available market and penetration, and energy savings. This information is documented in the both the main body of the report and the Appendix: Detailed Measure Descriptions. The ETO measures listed in the report were reviewed for overlap with the NPCC/RTF measures, and included in its analysis only those ETO measures that appeared not to significantly overlap with NPCC/RTF measures.

The potential in the ETO work is estimated for the ETO service area only, so adjustments are required to scale the potential to the amount available in Oregon. For electricity measures, since ETO covers only the Pacific Power and Portland General Electric service territories, ETO achievable technical potential (as reflected in applicable measure units and/or other parameters) were scaled up to cover all of Oregon based on the ratio of electricity sales by those utilities to sales in Oregon as a whole. For ETO measures affecting natural gas use, no scaling was required, as the gas utilities areas covered by ETO cover the entire state.

In general, the approach used to convert data assembled from the ETO report to input data and results used to prepare the to the marginal abatement cost curves under this project followed the steps outlined above for interpretation and use of the NPCC/RTF data. As the data presented in the ETO report were generally not as detailed as those in the NPCC/RTF sources, in some instances it was necessary to derive estimates for parameters not presented in the ETO report, including, for example, estimating implied capital costs of measures based on presented levelized costs and measure lifetimes.

Estimates for Measures Not Included in NPCC/RTF and ETO Compilations

For a total of three individual residential, five commercial, and seven industrial measures, estimates of measure costs and GHG emissions reduction were prepared based on a variety of sources. Documentation for these estimates is provided in the "Other Measures" worksheet of the "ODOE-RCI-Options-Final.xlsx" workbook.

Table B-42. Mapping of RCI Detailed Measures to Categories for the Microeconomic and Macroeconomic Impact Analyses

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
Residential Space Conditioning Measures					
R-1	Window Air Conditioners	RCI-1	Residential Cooling Appliances	M-RCI-1	Residential Cooling
R-2	Existing Manufactured Home HVAC Conversion w/ CAC	RCI-2	Manufactured Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-3	Existing Manufactured Home HVAC Conversion w/o CAC	RCI-2	Manufactured Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-4	Existing Manufactured Home HVAC Upgrade to HSPF 9.0/SEER 14 Heat Pump & w/PTCS Duct Sealing & Commissioning	RCI-2	Manufactured Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-5	Existing Single Family DHP - Convert Electric Baseboard Heat	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-6	Existing Single Family HVAC Conversion - Convert Electric FAF w/CAC to HSPF 9.0/SEER 14 Heat Pump & w/PTCS Duct Sealing & Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-7	Existing Single Family HVAC Conversion - Convert Electric FAF w/oCAC to HSPF 9.0/SEER 14 Heat Pump & w/PTCS Duct Sealing & Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-8	Existing Single Family HVAC Upgrade - Upgrade to HSPF 9.0/SEER 14 Heat Pump & w/PTCS Duct Sealing & Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-9	Existing Single Family w/Half or Full Basement HVAC Conversion - Convert Electric FAF w/CAC to HSPF 9.0/SEER 14 Heat Pump & w/Interior Ducts & PTCS Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-10	Existing Single Family w/Half or Full Basement HVAC Conversion - Convert Electric FAF w/oCAC to HSPF 9.0/SEER 14 Heat Pump & w/Interior Ducts & PTCS Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-11	Existing Single Family w/Half or Full Basement HVAC Upgrade - Upgrade to HSPF 9.0/SEER 14 Heat Pump & w/Interior HVAC & PTCS Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-12	Manufactured Home Weatherization - ATTIC R0 - ATTIC R22 Blown (Cost and Savings per square foot of component)	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-13	Manufactured Home Weatherization - ATTIC R22 Blown - ATTIC R33 Blown (Cost and Savings per square foot of component)	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-14	Manufactured Home Weatherization - DOOR R2.5 to R5 (Cost and Savings per square foot of component)	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization

Detailed Measure Category/Number		**Aggregation Assignments**		**Aggregation Assignments**	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
R-15	Manufactured Home Weatherization - FLOOR R0 - FLOOR R22 Blown (Cost and Savings per square foot of component)	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-16	Manufactured Home Weatherization - FLOOR R22 Blown - FLOOR R30 Blown (Cost and Savings per square foot of component)	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-17	Manufactured Home Weatherization - WALL R0 - WALL R11 (Cost and Savings per square foot of component)	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-18	Manufactured Home Weatherization - WINDOW CL30 Prime Window Replacement of Double Pane Base (Cost and Savings per square foot of component)	RCI-5	Manufactured Home Weatherization--Windows	M-RCI-4	Residential Windows
R-19	Manufactured Home Weatherization - WINDOW CL30 Prime Window Replacement of Single Pane Base (Cost and Savings per square foot of component)	RCI-5	Manufactured Home Weatherization--Windows	M-RCI-4	Residential Windows
R-20	Manufactured Home Weatherization - WINDOW CL30 to CL25 Upgrade (Cost and Savings per square foot of component)	RCI-5	Manufactured Home Weatherization--Windows	M-RCI-4	Residential Windows
R-21	Multifamily Weatherization - ATTIC R0 - R19 (Cost and Savings per square foot of component)	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-22	Multifamily Weatherization - ATTIC R19 - R30 (Cost and Savings per square foot of component)	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-23	Multifamily Weatherization - ATTIC R30 - R38 (Cost and Savings per square foot of component)	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-24	Multifamily Weatherization - ATTIC R38 - R49 (Cost and Savings per square foot of component)	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-25	Multifamily Weatherization - DOOR R2.5 to R5 (Cost and Savings per square foot of component)	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-26	Multifamily Weatherization - FLOOR R0 - R19 (Cost and Savings per square foot of component)	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-27	Multifamily Weatherization - FLOOR R19 - R30 (Cost and Savings per square foot of component)	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-28	Multifamily Weatherization - FLOOR R30 - R38 (Cost and Savings per square foot of component)	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-29	Multifamily Weatherization - WALL R0 - R13 (Cost and Savings per square foot of component)	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-30	Multifamily Weatherization - WINDOW CL30 Prime Window Replacement of Double Pane Base (Cost and Savings per square foot of component)	RCI-7	Multifamily Weatherization--Windows	M-RCI-4	Residential Windows

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
R-31	Multifamily Weatherization - WINDOW CL30 Prime Window Replacement of Single Pane Base (Cost and Savings per square foot of component)	RCI-7	Multifamily Weatherization--Windows	M-RCI-4	Residential Windows
R-32	Multifamily Weatherization - WINDOW CL30 to CL25 Upgrade (Cost and Savings per square foot of component)	RCI-7	Multifamily Weatherization--Windows	M-RCI-4	Residential Windows
R-33	New Manufactured Home HVAC Conversion - Convert Electric FAF w/CAC to HSPF 9.0/SEER 14 Heat Pump & w/PTCS Duct Sealing & Commissioning	RCI-2	Manufactured Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-34	New Manufactured Home HVAC Conversion - Convert Electric FAF w/oCAC to HSPF 9.0/SEER 14 Heat Pump & w/PTCS Duct Sealing & Commissioning	RCI-2	Manufactured Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-35	New Manufactured Home HVAC Upgrade - Upgrade to HSPF 9.0/SEER 14 Heat Pump & w/PTCS Duct Sealing & Commissioning	RCI-2	Manufactured Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-36	New Manufactured Home Thermal Shell - ATTIC R25 - ATTIC R30	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-37	New Manufactured Home Thermal Shell - ATTIC R30 - ATTIC R38	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-38	New Manufactured Home Thermal Shell - ATTIC R38 - ATTIC R49	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-39	New Manufactured Home Thermal Shell - DOOR R2.5 - DOOR R5	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-40	New Manufactured Home Thermal Shell - FLOOR R22 - FLOOR R33	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-41	New Manufactured Home Thermal Shell - FLOOR R33 - FLOOR R44	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-42	New Manufactured Home Thermal Shell - VAULT R25 - VAULT R30	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-43	New Manufactured Home Thermal Shell - VAULT R30 - VAULT R38	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-44	New Manufactured Home Thermal Shell - WALL R19 - WALL R21 ADV	RCI-4	Manufactured Home Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-45	New Manufactured Home Thermal Shell - WINDOW CL30 - WINDOW CL25	RCI-5	Manufactured Home Weatherization--Windows	M-RCI-4	Residential Windows
R-46	New Manufactured Home Thermal Shell - WINDOW CL35 - WINDOW CL30	RCI-5	Manufactured Home Weatherization--Windows	M-RCI-4	Residential Windows

Detailed Measure Category/Number		**Aggregation Assignments**		**Aggregation Assignments**	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
R-47	New Manufactured Home Thermal Shell - WINDOW CL50 - WINDOW CL35	RCI-5	Manufactured Home Weatherization--Windows	M-RCI-4	Residential Windows
R-48	New Multifamily Thermal Shell - ATTIC R38 STD - ATTIC R49 ADVrh	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-49	New Multifamily Thermal Shell - ATTIC R49 ADVrh - ATTIC R60 ADVrh	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-50	New Multifamily Thermal Shell - FLOOR R38 STD w/12"Truss	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-51	New Multifamily Thermal Shell - SLAB R10-2FT - SLAB R10-4FT	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-52	New Multifamily Thermal Shell - SLAB R10-4FT - SLAB R10-FULL	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-53	New Multifamily Thermal Shell - VAULT R30 HD - VAULT R38 HD	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-54	New Multifamily Thermal Shell - VAULT R38 HD - VAULT 10" SS Panel	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-55	New Multifamily Thermal Shell - WALL 8" SSPANEL - WALL R33 DBL	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-56	New Multifamily Thermal Shell - WALL R19 STD - WALL R21 INT	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-57	New Multifamily Thermal Shell - WALL R21 INT - WALL R21 INT+R5	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-58	New Multifamily Thermal Shell - WALL R21 INT+R5 - WALL 8" SSPANEL	RCI-6	Multifamily Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-59	New Multifamily Thermal Shell - WINDOW CL30 - WINDOW CL25	RCI-7	Multifamily Weatherization--Windows	M-RCI-4	Residential Windows
R-60	New Multifamily Thermal Shell - WINDOW CL35 - WINDOW CL30	RCI-7	Multifamily Weatherization--Windows	M-RCI-4	Residential Windows
R-61	New Single Family DHP - Convert Electric Baseboard Heat to HSPF 7.7/SEER 13 Ductless Heat Pump - Single Zone	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-62	New Single Family HVAC Conversion - Convert New Electric FAF w/CAC to HSPF 9.0/SEER 14 Heat Pump & w/Interior HVAC & PTCS Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-63	New Single Family HVAC Conversion - Convert New Electric FAF w/oCAC to HSPF 9.0/SEER 14 Heat Pump & w/Interior HVAC & PTCS Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-64	New Single Family HVAC Upgrade - Upgrade to HSPF 9.0/SEER 14 Heat Pump & w/Interior HVAC & Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
R-65	New Single Family Thermal Shell - ATTIC R38 STD - ATTIC R49 ADVrh	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-66	New Single Family Thermal Shell - ATTIC R49 ADVrh - ATTIC R60 ADVrh	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-67	New Single Family Thermal Shell - BGWALL R19 - BGWALL R21	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-68	New Single Family Thermal Shell - FLOOR R38 STD w/12"Truss	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-69	New Single Family Thermal Shell - INFILTRATION @ 0.20 ACH w/HRV	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-70	New Single Family Thermal Shell - SLAB R10-2FT - SLAB R10-4FT	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-71	New Single Family Thermal Shell - SLAB R10-4FT - SLAB R10-FULL	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-72	New Single Family Thermal Shell - VAULT R30 HD - VAULT R38 HD	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-73	New Single Family Thermal Shell - VAULT R38 HD - VAULT 10" SS Panel	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-74	New Single Family Thermal Shell - WALL 8" SSPANEL - WALL R33 DBL	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-75	New Single Family Thermal Shell - WALL R19 STD - WALL R21 INT	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-76	New Single Family Thermal Shell - WALL R21 INT - WALL R21 INT+R5	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-77	New Single Family Thermal Shell - WALL R21 INT+R5 - WALL 8" SSPANEL	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-78	New Single Family Thermal Shell - WINDOW CL30 - WINDOW CL22	RCI-9	Single Family Weatherization--Windows	M-RCI-4	Residential Windows
R-79	New Single Family Thermal Shell - WINDOW CL35 - WINDOW CL30	RCI-9	Single Family Weatherization--Windows	M-RCI-4	Residential Windows
R-80	New Single Family w/Half or Full Basement HVAC Conversion - Convert New Electric FAF w/CAC to HSPF 9.0/SEER 14 Heat Pump & w/Interior HVAC & Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-81	New Single Family w/Half or Full Basement HVAC Conversion - Convert New Electric FAF w/oCAC to HSPF 9.0/SEER 14 Heat Pump & w/Interior HVAC & Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-82	New Single Family w/Half or Full Basement HVAC Upgrade - Upgrade to HSPF 9.0/SEER 14 Heat Pump & w/Interior HVAC & PTCS Commissioning	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
R-83	Single Family Weatherization - ATTIC R0 - ATTIC R19 (Cost and Savings per square foot of component)	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-84	Single Family Weatherization - ATTIC R19 - ATTIC R30(Cost and Savings per square foot of component)	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-85	Single Family Weatherization - ATTIC R30 - ATTIC R38(Cost and Savings per square foot of component)	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-86	Single Family Weatherization - ATTIC R38 - ATTIC R49(Cost and Savings per square foot of component)	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-87	Single Family Weatherization - DOOR R2.5 to R5(Cost and Savings per square foot of component)	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-88	Single Family Weatherization - FLOOR R0 - FLOOR R19(Cost and Savings per square foot of component)	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-89	Single Family Weatherization - FLOOR R19 - FLOOR R25(Cost and Savings per square foot of component)	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-90	Single Family Weatherization - FLOOR R25 - FLOOR R30(Cost and Savings per square foot of component)	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-91	Single Family Weatherization - WALL R0 - WALL R13(Cost and Savings per square foot of component)	RCI-8	Single Family Weatherization--Insulation	M-RCI-3	Residential Insulation/Weatherization
R-92	Single Family Weatherization - WINDOW CL30 Prime Window Replacement of Double Pane Base(Cost and Savings per square foot of component)	RCI-9	Single Family Weatherization--Windows	M-RCI-4	Residential Windows
R-93	Single Family Weatherization - WINDOW CL30 Prime Window Replacement of Single Pane Base(Cost and Savings per square foot of component)	RCI-9	Single Family Weatherization--Windows	M-RCI-4	Residential Windows
R-94	Single Family Weatherization - WINDOW CL30 to CL25 Upgrade(Cost and Savings per square foot of component)	RCI-9	Single Family Weatherization--Windows	M-RCI-4	Residential Windows
R-95	Commissioning (HP), Z A	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-96	Commissioning (HP), Z B	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-97	Evaporative Cooling (Direct/indirect) (Z A)	RCI-1	Residential Cooling Appliances	M-RCI-1	Residential Cooling
R-98	Evaporative Cooling (Direct/indirect) (Z A)	RCI-1	Residential Cooling Appliances	M-RCI-1	Residential Cooling
R-99	Evaporative Cooling (Direct/indirect) (Z B)	RCI-1	Residential Cooling Appliances	M-RCI-1	Residential Cooling
R-100	Evaporative Cooling (Direct/indirect) (Z B)	RCI-1	Residential Cooling Appliances	M-RCI-1	Residential Cooling

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
Residential PV, Hot Water, Appliance, Lighting Measures					
R-101	Customer-side Solar PV (1 KW System), Solar Zone 1-5, Winter peak load area	RCI-10	Residential Solar Photovoltaic	M-RCI-5	Residential Solar PV
R-102	EF- 0.94 Domestic Water Heater w/50 gallon rated capacity and minimum 12 year warranty	RCI-11	Residential Electric Water Heat Efficiency	M-RCI-6	Residential Hot Water Efficiency
R-103	EF- 2.2 Domestic Heat Pump Water Heater w/50 gallon rated capacity and minimum 15 year warranty	RCI-12	Residential Heat Pump Water Heater	M-RCI-6	Residential Hot Water Efficiency
R-104	Washing Machine Energy Star - Tier 1-3 (MEF 2.0 - MEF 2.46 or higher) - Weighted Average DHW & Dryer	RCI-13	Residential Laundry Appliance Improvement	M-RCI-7	Residential Laundry Appliances
R-105	Energy Star Dishwasher (EF68 - 83 or higher) - Any Water Heater	RCI-14	Residential Dishwasher Improvement	M-RCI-8	Residential Dishwasher
R-106	Energy Star Freezer w/ Sales Weighted Average Capacity	RCI-15	Residential Refrigerator/Freezer Improvement	M-RCI-9	Residential Refrigerators/Freezers
R-107	Energy Star Lighting - Existing Dwelling Unit LPD = 0.6 W/sq.ft.	RCI-16	Residential Lighting Improvement	M-RCI-10	Residential Lighting
R-108	Energy Star Lighting - New Dwelling Unit LPD = 0.6 W/sq.ft.	RCI-16	Residential Lighting Improvement	M-RCI-10	Residential Lighting
R-109	Energy Star Refrigerator	RCI-15	Residential Refrigerator/Freezer Improvement	M-RCI-9	Residential Refrigerators/Freezers
R-110	Gravity Film Heat Exchanger in New MultiFamily Construction, Electric Resistance	RCI-17	Residential Gravity Film Heat Exchanger	M-RCI-6	Residential Hot Water Efficiency
R-111	Gravity Film Heat Exchanger in New Single Family Construction, Electric Resistance	RCI-17	Residential Gravity Film Heat Exchanger	M-RCI-6	Residential Hot Water Efficiency
R-112	Gravity Film Heat Exchanger Retrofit in Existing Single Family Residence, Electric Resistance	RCI-17	Residential Gravity Film Heat Exchanger	M-RCI-6	Residential Hot Water Efficiency
R-113	High Efficiency Dryer EF - 3.08 - 3.3	RCI-13	Residential Laundry Appliance Improvement	M-RCI-7	Residential Laundry Appliances
R-114	Microwave Oven	RCI-18	Residential Cooking Appliance Improvement	M-RCI-11	Residential Cooking Appliances
R-115	Self-Cleaning and Non Self-Cleaning Ovens	RCI-18	Residential Cooking Appliance Improvement	M-RCI-11	Residential Cooking Appliances
R-116	Showerhead Replacement in Residential Dwellings - Any Showerhead, Electric DHW	RCI-11	Residential Electric Water Heat Efficiency	M-RCI-6	Residential Hot Water Efficiency
R-117	Solar Residential Water Heater with collector area between 51 - 60 sq.ft, Solar Zone 1-5 - Winter Peaking	RCI-19	Residential Solar Water Heat--Electric Back-up	M-RCI-12	Residential Solar Hot Water
R-118	100% LED after 2020	RCI-16	Residential Lighting Improvement	M-RCI-10	Residential Lighting
R-119	50% LED after 2020	RCI-16	Residential Lighting Improvement	M-RCI-10	Residential Lighting
R-120	AC Tune - up (Z A)	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-121	AC Tune - up (Z B)	RCI-3	Single Family Home HVAC Conversion/Upgrade	M-RCI-2	Residential Heating/HVAC
R-122	Add 16 LED lamps (using CFL base) after 2015	RCI-16	Residential Lighting Improvement	M-RCI-10	Residential Lighting

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R-123	Add 16 LED lamps (using incandescent base) after 2015	RCI-16	Residential Lighting Improvement	M-RCI-10	Residential Lighting
R-124	Add 6 LED lamps (using CFL base) after 2015	RCI-16	Residential Lighting Improvement	M-RCI-10	Residential Lighting
R-125	Add 6 LED lamps (using incandescent base) aft 2015	RCI-16	Residential Lighting Improvement	M-RCI-10	Residential Lighting
R-126	All LED (from 2020 base) after 2020	RCI-16	Residential Lighting Improvement	M-RCI-10	Residential Lighting
R-127	Home Energy Monitor--New	RCI-20	Home Energy Monitor	M-RCI-13	Residential Energy Monitor
R-128	Home Energy Monitor--Replacement	RCI-20	Home Energy Monitor	M-RCI-13	Residential Energy Monitor
R-129	Hot water pipe wrap	RCI-11	Residential Electric Water Heat Efficiency	M-RCI-6	Residential Hot Water Efficiency
R-130	Refrigerator Recycle	RCI-21	Residential Refrigerator Recycle	M-RCI-9	Residential Refrigerators/Freezers
R-131	Tank wrap (in accordance with EWEB guidelines or equivalent)	RCI-11	Residential Electric Water Heat Efficiency	M-RCI-6	Residential Hot Water Efficiency
Residential Electronics Measures					
R-132	Energy Star - Weighted Average TV	RCI-22	Residential Electronics Improvements	M-RCI-14	Residential Electronics
R-133	Energy Star - Weighted Average Set Top Boxes	RCI-22	Residential Electronics Improvements	M-RCI-14	Residential Electronics
R-134	Energy Star - Weighted Average Residential Monitor	RCI-22	Residential Electronics Improvements	M-RCI-14	Residential Electronics
R-135	Energy Star - Weighted Average Residential Desktop	RCI-22	Residential Electronics Improvements	M-RCI-14	Residential Electronics
Residential Measures Addressing Gas Use					
R-136	Low Flow Shower Retro Gas	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-137	Heating upgrade (AFUE 95) (Z A)--New	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC
R-138	Heating upgrade (AFUE 95) (Z C)--New	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC
R-139	Heating upgrade (AFUE 95) (Z B)--New	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC
R-140	MF Corridor Ventilation--New	RCI-25	Multifamily HVAC--Gas Heat	M-RCI-2	Residential Heating/HVAC
R-141	AFUE 92 to condensing combo hydrocoil, Z C--New	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC
R-142	AFUE 92 to condensing combo hydrocoil, Z B--New	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC
R-143	Window, retro (U=.35), Z B	RCI-26	Residential Gas Heat Windows	M-RCI-4	Residential Windows
R-144	AFUE 92 to condensing combo hydrocoil, Z A--New	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC
R-145	Window, retro (U=.35), Z C--Retro	RCI-26	Residential Gas Heat Windows	M-RCI-4	Residential Windows
R-146	AFUE 95 Furnace, Z B--Replacement	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC
R-147	Window, retro (U=.20), Z B--Retro	RCI-26	Residential Gas Heat Windows	M-RCI-4	Residential Windows
R-148	Window, retro (U=.35), Z A--Retro	RCI-26	Residential Gas Heat Windows	M-RCI-4	Residential Windows
R-149	AFUE 95 Furnace, Z C--Replacement	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC

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R-150	Window, retro (U=.20), Z C--Retro	RCI-26	Residential Gas Heat Windows	M-RCI-4	Residential Windows
R-151	Duct Sealing, Z B--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-152	E* Insulation, Ducts, DHW, Lights (Gas Z B)--New	RCI-28	Residential Multi-Measure Gas Heat	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-153	Tankless Gas heater replace after 2015--Replacement	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-154	Tankless Gas heater after 2015--New	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-155	Solar hot water heater (50 gal) - With gas backup--New	RCI-29	Residential Solar Hot Water--Gas Back-up	M-RCI-12	Residential Solar Hot Water
R-156	Solar hot water heater (50 gal) - With gas backup--Retro	RCI-29	Residential Solar Hot Water--Gas Back-up	M-RCI-12	Residential Solar Hot Water
R-157	E* Insulation, Ducts, DHW, Lights (Gas Z C)--New	RCI-28	Residential Multi-Measure Gas Heat	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-158	E* Insulation, Ducts, DHW, Lights (Gas Z A)--New	RCI-28	Residential Multi-Measure Gas Heat	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-159	Window, retro (U=.20), Z A--Retro	RCI-26	Residential Gas Heat Windows	M-RCI-4	Residential Windows
R-160	Duct Sealing, Z C--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-161	Tankless Gas heater replace	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-162	Tankless Gas heater--New	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-163	AFUE 95 Furnace, Z A--Replacement	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC
R-164	Upgrade Gas Hearth--Replacement	RCI-24	Residential Gas Furnace Upgrade	M-RCI-2	Residential Heating/HVAC
R-165	Near Net Zero (Gas Z B)--New	RCI-28	Residential Multi-Measure Gas Heat	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-166	HRV, Z B--Retro	RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	M-RCI-2	Residential Heating/HVAC
R-167	Solar hot water heater (50 gal) - With gas aft 2015--New	RCI-29	Residential Solar Hot Water--Gas Back-up	M-RCI-12	Residential Solar Hot Water
R-168	Tank upgrade (50 gal gas)--New	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-169	Near Net Zero (Gas Z C)--New	RCI-28	Residential Multi-Measure Gas Heat	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-170	Condensing Tankless Gas heater--Replacement	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-171	Condensing Tankless Gas heater--New	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-172	Solar hot water heater (50 gal) - With gas backup aft 2015--Replacement	RCI-29	Residential Solar Hot Water--Gas Back-up	M-RCI-12	Residential Solar Hot Water
R-173	Near Net Zero (Gas Z A)--New	RCI-28	Residential Multi-Measure Gas Heat	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure

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R-174	HRV, Z C--Retro	RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	M-RCI-2	Residential Heating/HVAC
R-175	Window U=.2 (Gas Z B)--New	RCI-26	Residential Gas Heat Windows	M-RCI-4	Residential Windows
R-176	Condensing Tankless Gas heater after 2015--New	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-177	HRV, E* (Gas Z B)-New	RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	M-RCI-2	Residential Heating/HVAC
R-178	MF Corridor Ventilation--Retro	RCI-25	Multifamily HVAC--Gas Heat	M-RCI-2	Residential Heating/HVAC
R-179	Window U=.2 (Gas Z C)--New	RCI-26	Residential Gas Heat Windows	M-RCI-4	Residential Windows
R-180	Wx insulation (ceiling, floor, walls), Z B--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-181	Window U=.2 (Gas Z A)--New	RCI-26	Residential Gas Heat Windows	M-RCI-4	Residential Windows
R-182	HRV, E* (Gas Z C)--New	RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	M-RCI-2	Residential Heating/HVAC
R-183	Move Ducts Inside, E* lights , Z A--New	RCI-28	Residential Multi-Measure Gas Heat	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-184	HRV, E* (Gas Z A)--New	RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	M-RCI-2	Residential Heating/HVAC
R-185	Move Ducts Inside, E* lights , Z B--New	RCI-28	Residential Multi-Measure Gas Heat	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-186	HRV, Z A--Retro	RCI-30	Residential Heat/Energy Recovery Ventilation--Gas	M-RCI-2	Residential Heating/HVAC
R-187	Wx insulation (ceiling, floor, walls), Z C--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-188	Tank upgrade (50 gal gas) after 2015--New	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-189	Upgrade to forced draft tank--New	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-190	Duct Sealing, Z A--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-191	Move Ducts Inside, E* lights , Z C--New	RCI-28	Residential Multi-Measure Gas Heat	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-192	Wx insulation (ceiling, floor), Z B--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-193	Upgrade to forced draft tank--Replacement	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-194	Wx insulation (ceiling, floor), Z C--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-195	Wx Air Sealing, Z B--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-196	Wx Air Sealing, Z C--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure

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R-197	Wx insulation (ceiling, floor, walls), Z A--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-198	Upgrade to forced draft tank after 2015--New	RCI-23	Residential Gas Water Heat Measures	M-RCI-6	Residential Hot Water Efficiency
R-199	Wx insulation (ceiling, floor), Z A--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
R-200	Wx Air Sealing, Z A--Retro	RCI-27	Residential Gas Heat, Insulation/Ducts/Weatherization	M-RCI-15	Residential Heating Duct Sealing/Multi-Measure
Residential Combined Heat and Power and Biomass Heating					
R-201	Residential Gas-fired CHP	RCI-31	Residential CHP	M-RCI-16	Residential CHP
R-202	Residential wood-fueled space heat replacing electric resistance	RCI-32	Residential Wood-fueled Heat Replacing Electric Resistance	M-RCI-17	Residential Biomass Heating
R-203	Residential wood-fueled space heat replacing oil/LPG furnace/boiler	RCI-33	Residential Wood-fueled Heat Replacing Oil/LPG	M-RCI-17	Residential Biomass Heating
Commercial New Building Measures--Lighting					
C-1	LPD New Office	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-2	LPD New Retail	RCI-35	Schools Lighting Measures	M-RCI-18	Commercial Lighting Efficiency Measures
C-3	LPD New K-12	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-4	LPD New University	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-5	LPD New Warehouse	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-6	LPD New Supermarket	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-7	LPD New MiniMart	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-8	LPD New Restaurant	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-9	LPD New Lodging	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-10	LPD New Hospital	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-11	LPD New Other Health	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-12	LPD New Assembly	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-13	LPD New Other	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-14	Daylighting Controls New Office	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-15	Daylighting Controls New K-12	RCI-35	Schools Lighting Measures	M-RCI-19	Commercial Daylighting Measures
C-16	Daylighting Controls New University	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures

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C-17	Daylighting Controls New Other Health	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-18	Daylighting Controls New Assembly	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-19	Daylighting Controls New Other	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-20	Top Daylighting New Retail	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-21	Top Daylighting New K-12	RCI-35	Schools Lighting Measures	M-RCI-19	Commercial Daylighting Measures
C-22	Top Daylighting New Warehouse	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-23	Top Daylighting New Supermarket	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-24	Lighting Controls Interior New Office	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-25	Lighting Controls Interior New Retail	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-26	Lighting Controls Interior New K-12	RCI-35	Schools Lighting Measures	M-RCI-20	Commercial Lighting Controls Measures
C-27	Lighting Controls Interior New University	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-28	Lighting Controls Interior New Warehouse	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-29	Lighting Controls Interior New Supermarket	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-30	Lighting Controls Interior New MiniMart	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-31	Lighting Controls Interior New Restaurant	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-32	Lighting Controls Interior New Lodging	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-33	Lighting Controls Interior New Hospital	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-34	Lighting Controls Interior New Other Health	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-35	Lighting Controls Interior New Assembly	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-36	Lighting Controls Interior New Other	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
Commercial New Building Measures--Building Envelope					
C-37	Windows New Office	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-38	Windows New Retail	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures

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C-39	Windows New K-12	RCI-39	Schools Building Envelope Measures	M-RCI-21	Commercial Building Windows Measures
C-40	Windows New University	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-41	Windows New Warehouse	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-42	Windows New Supermarket	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-43	Windows New MiniMart	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-44	Windows New Restaurant	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-45	Windows New Lodging	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-46	Windows New Hospital	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-47	Windows New Other Health	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-48	Windows New Assembly	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-49	Windows New Other	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
Commercial New Building Measures--HVAC					
C-50	Low Pressure Distribution Complex HVAC New Office	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-51	Low Pressure Distribution Complex HVAC New Anchor	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-52	Low Pressure Distribution Complex HVAC New K-12	RCI-41	Schools HVAC	M-RCI-22	Commercial HVAC Control Measures
C-53	Low Pressure Distribution Complex HVAC New University	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-54	Low Pressure Distribution Complex HVAC New Other Health	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-55	Low Pressure Distribution Complex HVAC New Other	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-56	Demand Control Ventilation New Office	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-57	Demand Control Ventilation New Retail	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-58	Demand Control Ventilation New Warehouse	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-59	Demand Control Ventilation New Supermarket	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-60	Demand Control Ventilation New MiniMart	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-61	Demand Control Ventilation New Restaurant	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-62	Demand Control Ventilation New Lodging	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-63	Demand Control Ventilation New Hospital	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-64	Demand Control Ventilation New Other Health	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-65	Demand Control Ventilation New Other	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-66	ECM on VAV Boxes New Office	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-67	ECM on VAV Boxes New K-12	RCI-41	Schools HVAC	M-RCI-22	Commercial HVAC Control Measures
C-68	ECM on VAV Boxes New University	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-69	ECM on VAV Boxes New Hospital	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-70	ECM on VAV Boxes New Other Health	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-71	ECM on VAV Boxes New Assembly	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-72	ECM on VAV Boxes New Other	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-73	Variable Speed Chiller New Office	RCI-44	Commercial Variable Speed Chiller New/Integrated Design	M-RCI-23	Commercial Chillers Measures
C-74	Variable Speed Chiller New University	RCI-44	Commercial Variable Speed Chiller New/Integrated Design	M-RCI-23	Commercial Chillers Measures
C-75	Variable Speed Chiller New Lodging	RCI-44	Commercial Variable Speed Chiller New/Integrated Design	M-RCI-23	Commercial Chillers Measures
C-76	Variable Speed Chiller New Hospital	RCI-44	Commercial Variable Speed Chiller New/Integrated Design	M-RCI-23	Commercial Chillers Measures
C-77	Package Roof Top Optimization and Repair New Office	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-78	Package Roof Top Optimization and Repair New Retail	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements

Detailed Measure Category/Number		**Aggregation Assignments**		**Aggregation Assignments**	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-79	Package Roof Top Optimization and Repair New K-12	RCI-41	Schools HVAC	M-RCI-24	Commercial HVAC System Improvements
C-80	Package Roof Top Optimization and Repair New University	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-81	Package Roof Top Optimization and Repair New Warehouse	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-82	Package Roof Top Optimization and Repair New Supermarket	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-83	Package Roof Top Optimization and Repair New MiniMart	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-84	Package Roof Top Optimization and Repair New Restaurant	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-85	Package Roof Top Optimization and Repair New Lodging	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-86	Package Roof Top Optimization and Repair New Hospital	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-87	Package Roof Top Optimization and Repair New Other Health	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-88	Package Roof Top Optimization and Repair New Assembly	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-89	Package Roof Top Optimization and Repair New Other	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-90	Premium HVAC Equipment New	RCI-46	Commercial Premium HVAC New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-91	Controls Commissioning HVAC New Office	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-92	Controls Commissioning HVAC New Retail	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-93	Controls Commissioning HVAC New K-12	RCI-41	Schools HVAC	M-RCI-25	Commercial Commissioning Measures
C-94	Controls Commissioning HVAC New University	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-95	Controls Commissioning HVAC New Warehouse	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-96	Controls Commissioning HVAC New Supermarket	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-97	Controls Commissioning HVAC New MiniMart	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	Measure/Measure Group Name	Measure Category/Number for MICROeconomic Analysis		Measure Category/Number for MACROeconomic Analysis	
C-98	Controls Commissioning HVAC New Restaurant	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-99	Controls Commissioning HVAC New Lodging	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-100	Controls Commissioning HVAC New Hospital	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-101	Controls Commissioning HVAC New Other Health	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-102	Controls Commissioning HVAC New Assembly	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-103	Controls Commissioning HVAC New Other	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
Commercial Integrated Design Building Measures--Lighting					
C-104	LPD IntD Office	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-105	LPD IntD Retail	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-106	LPD IntD K-12	RCI-35	Schools Lighting Measures	M-RCI-18	Commercial Lighting Efficiency Measures
C-107	LPD IntD University	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-108	LPD IntD Warehouse	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-109	LPD IntD Supermarket	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-110	LPD IntD Restaurant	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-111	LPD IntD Lodging	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-112	LPD IntD Hospital	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-113	LPD IntD Other Health	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-114	LPD IntD Assembly	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-115	LPD IntD Other	RCI-34	Commercial LDP New/Integrated Design	M-RCI-18	Commercial Lighting Efficiency Measures
C-116	Daylighting Controls Integrated Design Office	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-117	Daylighting Controls Integrated Design K-12	RCI-35	Schools Lighting Measures	M-RCI-19	Commercial Daylighting Measures
C-118	Daylighting Controls Integrated Design University	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-119	Daylighting Controls Integrated Design Other Health	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-120	Daylighting Controls Integrated Design Assembly	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-121	Daylighting Controls Integrated Design Other	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-122	Top Daylighting Integrated Design Retail	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-123	Top Daylighting Integrated Design K-12	RCI-35	Schools Lighting Measures	M-RCI-19	Commercial Daylighting Measures
C-124	Top Daylighting Integrated Design Warehouse	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-125	Top Daylighting Integrated Design Supermarket	RCI-36	Commercial Daylighting New/Integrated Design	M-RCI-19	Commercial Daylighting Measures
C-126	Lighting Controls Interior Integrated Design Office	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-127	Lighting Controls Interior Integrated Design Retail	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-128	Lighting Controls Interior Integrated Design K-12	RCI-35	Schools Lighting Measures	M-RCI-20	Commercial Lighting Controls Measures
C-129	Lighting Controls Interior Integrated Design University	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-130	Lighting Controls Interior Integrated Design Warehouse	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-131	Lighting Controls Interior Integrated Design Supermarket	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-132	Lighting Controls Interior Integrated Design Restaurant	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-133	Lighting Controls Interior Integrated Design Lodging	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-134	Lighting Controls Interior Integrated Design Hospital	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-135	Lighting Controls Interior Integrated Design Other Health	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-136	Lighting Controls Interior Integrated Design Assembly	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-137	Lighting Controls Interior Integrated Design Other	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
Commercial Integrated Design Building Measures--Building Envelope					
C-138	Windows Integrated Design Office	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-139	Windows Integrated Design Retail	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-140	Windows Integrated Design K-12	RCI-39	Schools Building Envelope Measures	M-RCI-21	Commercial Building Windows Measures
C-141	Windows Integrated Design University	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-142	Windows Integrated Design Warehouse	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	Measure/Measure Group Name	Measure Category/Number for MICROeconomic Analysis		Measure Category/Number for MACROeconomic Analysis	
C-143	Windows Integrated Design Supermarket	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-144	Windows Integrated Design MiniMart	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-145	Windows Integrated Design Restaurant	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-146	Windows Integrated Design Lodging	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-147	Windows Integrated Design Hospital	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-148	Windows Integrated Design Other Health	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-149	Windows Integrated Design Assembly	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
C-150	Windows Integrated Design Other	RCI-38	Commercial Windows New/Integrated Design	M-RCI-21	Commercial Building Windows Measures
Commercial Integrated Design Building Measures--HVAC					
C-151	Low Pressure Distribution Complex HVAC Int. Design Office	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-152	Low Pressure Distribution Complex HVAC Int. Design Anchor	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-153	Low Pressure Distribution Complex HVAC Int. Design K-12	RCI-41	Schools HVAC	M-RCI-22	Commercial HVAC Control Measures
C-154	Low Pressure Distribution Complex HVAC Int. Design University	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-155	Low Pressure Distribution Complex HVAC Int. Design Other Health	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-156	Low Pressure Distribution Complex HVAC Int. Design Other	RCI-40	Commercial Low Press. Dist. Complex HVAC New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-157	Demand Control Ventilation Integrated Design Office	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-158	Demand Control Ventilation Integrated Design Retail	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-159	Demand Control Ventilation Integrated Design Warehouse	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-160	Demand Control Ventilation Integrated Design Supermarket	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-161	Demand Control Ventilation Integrated Design Restaurant	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-162	Demand Control Ventilation Integrated Design Lodging	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-163	Demand Control Ventilation Integrated Design Hospital	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-164	Demand Control Ventilation Integrated Design Other Health	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-165	Demand Control Ventilation Integrated Design Other	RCI-42	Commercial Demand Control Ventilation New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-166	ECM on VAV Boxes Integrated Design Office	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-167	ECM on VAV Boxes Integrated Design K-12	RCI-41	Schools HVAC	M-RCI-22	Commercial HVAC Control Measures
C-168	ECM on VAV Boxes Integrated Design University	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-169	ECM on VAV Boxes Integrated Design Hospital	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-170	ECM on VAV Boxes Integrated Design Other Health	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-171	ECM on VAV Boxes Integrated Design Assembly	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-172	ECM on VAV Boxes Integrated Design Other	RCI-43	Commercial ECM on VAV Boxes New/Integrated Design	M-RCI-22	Commercial HVAC Control Measures
C-173	Variable Speed Chiller Integrated Design Office	RCI-44	Commercial Variable Speed Chiller New/Integrated Design	M-RCI-23	Commercial Chillers Measures
C-174	Variable Speed Chiller Integrated Design University	RCI-44	Commercial Variable Speed Chiller New/Integrated Design	M-RCI-23	Commercial Chillers Measures
C-175	Variable Speed Chiller Integrated Design Lodging	RCI-44	Commercial Variable Speed Chiller New/Integrated Design	M-RCI-23	Commercial Chillers Measures
C-176	Variable Speed Chiller Integrated Design Hospital	RCI-44	Commercial Variable Speed Chiller New/Integrated Design	M-RCI-23	Commercial Chillers Measures
C-177	Package Roof Top Optimization/Repair Int. Design Office	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-178	Package Roof Top Optimization/Repair Int. Design Retail	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-179	Package Roof Top Optimization/Repair Int. Design K-12	RCI-41	Schools HVAC	M-RCI-24	Commercial HVAC System Improvements
C-180	Package Roof Top Optimization/Repair Int. Design University	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-181	Package Roof Top Optimization/Repair Int. Design Warehouse	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-182	Package Roof Top Optimization/Repair Int. Design Supermarket	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-183	Package Roof Top Optimization/Repair Int. Design Restaurant	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-184	Package Roof Top Optimization/Repair Int. Design Lodging	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-185	Package Roof Top Optimization/Repair Int. Design Hospital	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-186	Package Roof Top Optimization/Repair Int. Design Other Health	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-187	Package Roof Top Optimization/Repair Int. Design Assembly	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-188	Package Roof Top Optimization/Repair Int. Design Other	RCI-45	Commercial Package Rooftop Measures New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-189	Premium HVAC Equipment Integrated Design	RCI-46	Commercial Premium HVAC New/Integrated Design	M-RCI-24	Commercial HVAC System Improvements
C-190	Controls Commissioning HVAC Int. Design Office	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-191	Controls Commissioning HVAC Int. Design Retail	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-192	Controls Commissioning HVAC Int. Design K-12	RCI-41	Schools HVAC	M-RCI-25	Commercial Commissioning Measures
C-193	Controls Commissioning HVAC Int. Design University	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-194	Controls Commissioning HVAC Int. Design Warehouse	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-195	Controls Commissioning HVAC Int. Design Supermarket	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-196	Controls Commissioning HVAC Int. Design Restaurant	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-197	Controls Commissioning HVAC Int. Design Lodging	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-198	Controls Commissioning HVAC Int. Design Hospital	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-199	Controls Commissioning HVAC Int. Design Other Health	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-200	Controls Commissioning HVAC Int. Design Assembly	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
C-201	Controls Commissioning HVAC Int. Design Other	RCI-47	Commercial Controls Commissioning HVAC New/Integrated Design	M-RCI-25	Commercial Commissioning Measures
Commercial Natural Replacement Building Measures--Lighting					
C-202	LPD NR Office	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-203	LPD NR Retail	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures

Detailed Measure Category/Number		**Aggregation Assignments**		**Aggregation Assignments**	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for <u>MICROeconomic</u> Analysis**		**Measure Category/Number for <u>MACROeconomic</u> Analysis**	
C-204	LPD NR K-12	RCI-35	Schools Lighting Measures	M-RCI-18	Commercial Lighting Efficiency Measures
C-205	LPD NR University	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-206	LPD NR Warehouse	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-207	LPD NR Supermarket	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-208	LPD NR MiniMart	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-209	LPD NR Restaurant	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-210	LPD NR Lodging	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-211	LPD NR Hospital	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-212	LPD NR Other Health	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-213	LPD NR Assembly	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-214	LPD NR Other	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-215	Daylighting Controls Natural Replacement Office	RCI-49	Commercial Daylighting Natural Replacement/Retrofit	M-RCI-19	Commercial Daylighting Measures
C-216	Daylighting Controls Natural Replacement K-12	RCI-35	Schools Lighting Measures	M-RCI-19	Commercial Daylighting Measures
C-217	Daylighting Controls Natural Replacement University	RCI-49	Commercial Daylighting Natural Replacement/Retrofit	M-RCI-19	Commercial Daylighting Measures
C-218	Daylighting Controls Natural Replacement Other Health	RCI-49	Commercial Daylighting Natural Replacement/Retrofit	M-RCI-19	Commercial Daylighting Measures
C-219	Daylighting Controls Natural Replacement Assembly	RCI-49	Commercial Daylighting Natural Replacement/Retrofit	M-RCI-19	Commercial Daylighting Measures
C-220	Daylighting Controls Natural Replacement Other	RCI-49	Commercial Daylighting Natural Replacement/Retrofit	M-RCI-19	Commercial Daylighting Measures
C-221	Lighting Controls Interior Natural Replacement Office	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-19	Commercial Daylighting Measures
C-222	Lighting Controls Interior Natural Replacement Retail	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-19	Commercial Daylighting Measures
C-223	Lighting Controls Interior Natural Replacement K-12	RCI-35	Schools Lighting Measures	M-RCI-19	Commercial Daylighting Measures
C-224	Lighting Controls Interior Natural Replacement University	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures
C-225	Lighting Controls Interior Natural Replacement Warehouse	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-226	Lighting Controls Interior Natural Replacement Supermarket	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures
C-227	Lighting Controls Interior Natural Replacement MiniMart	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures
C-228	Lighting Controls Interior Natural Replacement Restaurant	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures
C-229	Lighting Controls Interior Natural Replacement Lodging	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures
C-230	Lighting Controls Interior Natural Replacement Hospital	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures
C-231	Lighting Controls Interior Natural Replacement Other Health	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures
C-232	Lighting Controls Interior Natural Replacement Assembly	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures
C-233	Lighting Controls Interior Natural Replacement Other	RCI-50	Commercial Lighting Controls Natural Replacement/Retrofit	M-RCI-20	Commercial Lighting Controls Measures
Commercial Natural Replacement Building Measures--Building Envelope					
C-234	Windows Natural Replacement Office	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-235	Windows Natural Replacement Retail	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-236	Windows Natural Replacement K-12	RCI-39	Schools Building Envelope Measures	M-RCI-21	Commercial Building Windows Measures
C-237	Windows Natural Replacement University	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-238	Windows Natural Replacement Warehouse	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-239	Windows Natural Replacement Supermarket	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-240	Windows Natural Replacement MiniMart	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-241	Windows Natural Replacement Restaurant	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-242	Windows Natural Replacement Lodging	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-243	Windows Natural Replacement Hospital	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-244	Windows Natural Replacement Other Health	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures

Detailed Measure Category/Number		**Aggregation Assignments**		**Aggregation Assignments**	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-245	Windows Natural Replacement Assembly	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-246	Windows Natural Replacement Other	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-247	Roof Insulation Natural Replacement Office	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-248	Roof Insulation Natural Replacement Retail	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-249	Roof Insulation Natural Replacement K-12	RCI-39	Schools Building Envelope Measures	M-RCI-26	Commercial Building Insulation Measures
C-250	Roof Insulation Natural Replacement University	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-251	Roof Insulation Natural Replacement Warehouse	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-252	Roof Insulation Natural Replacement Supermarket	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-253	Roof Insulation Natural Replacement MiniMart	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-254	Roof Insulation Natural Replacement Restaurant	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-255	Roof Insulation Natural Replacement Lodging	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-256	Roof Insulation Natural Replacement Hospital	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-257	Roof Insulation Natural Replacement Other Health	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-258	Roof Insulation Natural Replacement Assembly	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-259	Roof Insulation Natural Replacement Other	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
Commercial Natural Replacement Measures--HVAC					
C-260	Demand Control Ventilation Natural Replacement Office	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-261	Demand Control Ventilation Natural Replacement Retail	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-262	Demand Control Ventilation Natural Replacement Warehouse	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-263	Demand Control Ventilation Natural Replacement Supermarket	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-264	Demand Control Ventilation Natural Replacement MiniMart	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-265	Demand Control Ventilation Natural Replacement Restaurant	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-266	Demand Control Ventilation Natural Replacement Lodging	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-267	Demand Control Ventilation Natural Replacement Hospital	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-268	Demand Control Ventilation Natural Replacement Other Health	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-269	Demand Control Ventilation Natural Replacement Other	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-270	ECM on VAV Boxes Natural Replacement Office	RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-271	ECM on VAV Boxes Natural Replacement Anchor Retail	RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-272	ECM on VAV Boxes Natural Replacement K-12	RCI-41	Schools HVAC	M-RCI-22	Commercial HVAC Control Measures
C-273	ECM on VAV Boxes Natural Replacement University	RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-274	ECM on VAV Boxes Natural Replacement Hospital	RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-275	ECM on VAV Boxes Natural Replacement Other Health	RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-276	ECM on VAV Boxes Natural Replacement Assembly	RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-277	ECM on VAV Boxes Natural Replacement Other	RCI-54	Commercial ECM on VAV Boxes Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-278	Variable Speed Chiller Natural Replacement Office	RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	M-RCI-23	Commercial Chillers Measures
C-279	Variable Speed Chiller Natural Replacement University	RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	M-RCI-23	Commercial Chillers Measures
C-280	Variable Speed Chiller Natural Replacement Lodging	RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	M-RCI-23	Commercial Chillers Measures
C-281	Variable Speed Chiller Natural Replacement Hospital	RCI-55	Commercial Variable Speed Chiller Natural Replacement/Retro	M-RCI-23	Commercial Chillers Measures
C-282	Package Roof Top Optimization/Repair Nat. Repl. Office	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-283	Package Roof Top Optimization/Repair Nat. Repl. Retail	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-284	Package Roof Top Optimization/Repair Nat. Repl. K-12	RCI-41	Schools HVAC	M-RCI-24	Commercial HVAC System Improvements
C-285	Package Roof Top Optimization/Repair Nat. Repl. University	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-286	Package Roof Top Optimization/Repair Nat. Repl. Warehouse	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-287	Package Roof Top Optimization/Repair Nat. Repl. MiniMart	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-288	Package Roof Top Optimization/Repair Nat. Repl. Supermarket	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-289	Package Roof Top Optimization/Repair Nat. Repl. Restaurant	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-290	Package Roof Top Optimization/Repair Nat. Repl. Lodging	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-291	Package Roof Top Optimization/Repair Nat. Repl. Hospital	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-292	Package Roof Top Optimization/Repair Nat. Repl. Other Health	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-293	Package Roof Top Optimization/Repair Nat. Repl. Assembly	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-294	Package Roof Top Optimization/Repair Nat. Repl. Other	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-295	Premium HVAC Equipment Natural Replacement	RCI-57	Commercial Premium HVAC Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
Commercial Retrofit Building Measures--Lighting					
C-296	LPD Retrofit Office	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-297	LPD Retrofit Retail	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-298	LPD Retrofit K-12	RCI-35	Schools Lighting Measures	M-RCI-18	Commercial Lighting Efficiency Measures
C-299	LPD Retrofit University	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-300	LPD Retrofit Warehouse	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-301	LPD Retrofit Supermarket	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-302	LPD Retrofit MiniMart	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-303	LPD Retrofit Restaurant	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-304	LPD Retrofit Lodging	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-305	LPD Retrofit Hospital	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-306	LPD Retrofit Other Health	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-307	LPD Retrofit Assembly	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
C-308	LPD Retrofit Other	RCI-48	Commercial LDP Natural Replacement/Retrofit	M-RCI-18	Commercial Lighting Efficiency Measures
Commercial Retrofit Building Measures--Building Envelope					
C-309	Windows Retrofit Office	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-310	Windows Retrofit Retail	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-311	Windows Retrofit K-12	RCI-39	Schools Building Envelope Measures	M-RCI-21	Commercial Building Windows Measures
C-312	Windows Retrofit University	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-313	Windows Retrofit Warehouse	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-314	Windows Retrofit Supermarket	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-315	Windows Retrofit Mini Mart	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-316	Windows Retrofit Restaurant	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-317	Windows Retrofit Lodging	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-318	Windows Retrofit Hospital	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-319	Windows Retrofit Other Health	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-320	Windows Retrofit Assembly	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-321	Windows Retrofit Other	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
Commercial Retrofit Measures--HVAC					
C-322	Demand Control Ventilation Retrofit Office	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-323	Demand Control Ventilation Retrofit Retail	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-324	Demand Control Ventilation Retrofit Warehouse	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-325	Demand Control Ventilation Retrofit Supermarket	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-326	Demand Control Ventilation Retrofit MiniMart	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-327	Demand Control Ventilation Retrofit Restaurant	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-328	Demand Control Ventilation Retrofit Lodging	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-329	Demand Control Ventilation Retrofit Hospital	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-330	Demand Control Ventilation Retrofit Other Health	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-331	Demand Control Ventilation Retrofit Other	RCI-53	Commercial Demand Control Ventilation Natural Replacement/Retro	M-RCI-22	Commercial HVAC Control Measures
C-332	Package Roof Top Optimization/Repair Retrofit Office	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-333	Package Roof Top Optimization/Repair Retrofit Retail	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-334	Package Roof Top Optimization/Repair Retrofit K-12	RCI-41	Schools HVAC	M-RCI-24	Commercial HVAC System Improvements
C-335	Package Roof Top Optimization/Repair Retrofit University	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-336	Package Roof Top Optimization/Repair Retrofit Warehouse	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-337	Package Roof Top Optimization/Repair Retrofit MiniMart	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-338	Package Roof Top Optimization/Repair Retrofit Supermarket	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-339	Package Roof Top Optimization/Repair Retrofit Restaurant	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-340	Package Roof Top Optimization/Repair Retrofit Lodging	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-341	Package Roof Top Optimization/Repair Retrofit Hospital	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements

Detailed Measure Category/Number		**Aggregation Assignments**		**Aggregation Assignments**	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-342	Package Roof Top Optimization/Repair Retrofit Other Health	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-343	Package Roof Top Optimization/Repair Retrofit Assembly	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-344	Package Roof Top Optimization/Repair Retrofit Other	RCI-56	Commercial Package Rooftop Measures Natural Replacement/Retro	M-RCI-24	Commercial HVAC System Improvements
C-345	Controls Commissioning HVAC Retrofit Office	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-346	Controls Commissioning HVAC Retrofit Retail	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-347	Controls Commissioning HVAC Retrofit K-12	RCI-41	Schools HVAC	M-RCI-25	Commercial Commissioning Measures
C-348	Controls Commissioning HVAC Retrofit University	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-349	Controls Commissioning HVAC Retrofit Warehouse	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-350	Controls Commissioning HVAC Retrofit Supermarket	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-351	Controls Commissioning HVAC Retrofit MiniMart	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-352	Controls Commissioning HVAC Retrofit Restaurant	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-353	Controls Commissioning HVAC Retrofit Lodging	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-354	Controls Commissioning HVAC Retrofit Hospital	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-355	Controls Commissioning HVAC Retrofit Other Health	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-356	Controls Commissioning HVAC Retrofit Assembly	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
C-357	Controls Commissioning HVAC Retrofit Other	RCI-58	Commercial Controls Commissioning HVAC Retrofit	M-RCI-25	Commercial Commissioning Measures
Commercial Equipment Measures					
C-358	Covered Parking Lighting New	RCI-59	Commercial Parking Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-359	Surface Parking Lighting New	RCI-59	Commercial Parking Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-360	Covered Parking Lighting Natural Replacement	RCI-59	Commercial Parking Lighting	M-RCI-18	Commercial Lighting Efficiency Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-361	Surface Parking Lighting Natural Replacement	RCI-59	Commercial Parking Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-362	Grocery Store Refrigeration Bundle Retrofit	RCI-60	Commercial Refrigeration Improvements	M-RCI-27	Commercial Refrigeration Measures
C-363	Network PC Power Management	RCI-61	Commercial Computer/Server Improvements	M-RCI-29	Commercial Electronics/Transformer Measures
C-364	Computer Server Room Efficiency Retrofit	RCI-61	Commercial Computer/Server Improvements	M-RCI-29	Commercial Electronics/Transformer Measures
C-365	Pre-Rinse Valve - Code to 0.6 gpm - Food Service - Electric	RCI-62	Commercial Cooking/Food Service Improvements	M-RCI-30	Commercial Cooking Appliances Measures
C-366	Optimize Municipal Sewage ; >10 MGD Design Capacity	RCI-63	Commercial Wastewater Treatment Improvements	M-RCI-31	Commercial Water/Wastewater Measures
C-367	Optimize Municipal Sewage ; <1 MGD Design Capacity	RCI-63	Commercial Wastewater Treatment Improvements	M-RCI-31	Commercial Water/Wastewater Measures
C-368	Optimize Municipal Sewage ; 1 to 10 MGD Design Capacity	RCI-63	Commercial Wastewater Treatment Improvements	M-RCI-31	Commercial Water/Wastewater Measures
C-369	Community Water Supply Efficiency Improvements	RCI-64	Commercial Water Supply Improvements	M-RCI-31	Commercial Water/Wastewater Measures
C-370	HFHC (Wt Average Size)	RCI-62	Commercial Cooking/Food Service Improvements	M-RCI-30	Commercial Cooking Appliances Measures
C-371	Steamer (Wt Average Size)	RCI-62	Commercial Cooking/Food Service Improvements	M-RCI-30	Commercial Cooking Appliances Measures
C-372	Energy Efficient Electric Combination Oven	RCI-62	Commercial Cooking/Food Service Improvements	M-RCI-30	Commercial Cooking Appliances Measures
C-373	Energy Star Electric Convection Oven	RCI-73	Commercial Clothes Washer	M-RCI-28	Commercial Laundry Appliances Measures
C-374	DVC Hood w/ MUA 5 hp	RCI-65	Commercial DVC Hood	M-RCI-30	Commercial Cooking Appliances Measures
C-375	DVC Hood 5 hp	RCI-65	Commercial DVC Hood	M-RCI-30	Commercial Cooking Appliances Measures
C-376	LED Exit to LEC Exit New and Replacement	RCI-66	Commercial Exit Signs	M-RCI-18	Commercial Lighting Efficiency Measures
C-377	Lighted Signage New	RCI-67	Commercial Signage	M-RCI-18	Commercial Lighting Efficiency Measures
C-378	Lighted Signage Natural Replacement	RCI-67	Commercial Signage	M-RCI-18	Commercial Lighting Efficiency Measures
C-379	Premium Fume Hood-New	RCI-68	Commercial Fume Hood	M-RCI-24	Commercial HVAC System Improvements
C-380	Streetlight - HPS 100W – Group Relamp - to LED 78W - New	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-381	Streetlight - HPS 100W – Group Relamp - to LED 60W - New	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-382	Streetlight - HPS 150W – Group Relamp - to LED 117W - New	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-383	Streetlight - HPS 150W – Group Relamp - to LED 111W - New	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-384	Streetlight - HPS 100W – Tariff Relamp - to LED 78W - New	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-385	Streetlight - HPS 100W – Tariff Relamp - to LED 60W - New	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-386	Streetlight - HPS 150W – Tariff Relamp - to LED 117W - New	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-387	Streetlight - HPS 150W – Tariff Relamp - to LED 111W - New	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-388	Streetlight - HPS 100W – Group Relamp - to LED 78W - NR	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-389	Streetlight - HPS 100W – Group Relamp - to LED 60W - NR	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-390	Streetlight - HPS 150W – Group Relamp - to LED 117W - NR	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-391	Streetlight - HPS 150W – Group Relamp - to LED 111W - NR	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-392	Streetlight - HPS 100W – Tariff Relamp - to LED 78W - NR	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-393	Streetlight - HPS 100W – Tariff Relamp - to LED 60W - NR	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-394	Streetlight - HPS 150W - Tariff Relamp - to LED 117W - NR	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-395	Streetlight - HPS 150W - Tariff Relamp - to LED 111W - NR	RCI-69	Commercial Street Lighting	M-RCI-18	Commercial Lighting Efficiency Measures
C-396	Commercial Refrigerator - Vertical - No Doors - Med Temp	RCI-70	Commercial Refrigeration Improvements	M-RCI-27	Commercial Refrigeration Measures
C-397	Commercial Refrigerator - Semi vertical - No Doors - Med Temp	RCI-70	Commercial Refrigeration Improvements	M-RCI-27	Commercial Refrigeration Measures
C-398	ESTAR Commercial Refrigerator - Vertical - Solid Doors - Med Temp	RCI-70	Commercial Refrigeration Improvements	M-RCI-27	Commercial Refrigeration Measures
C-399	ESTAR Commercial Refrigerator - Vertical - Solid Doors - Low Temp	RCI-70	Commercial Refrigeration Improvements	M-RCI-27	Commercial Refrigeration Measures
C-400	ESTAR Commercial Refrigerator - Vertical - Glass Doors - Med Temp	RCI-70	Commercial Refrigeration Improvements	M-RCI-27	Commercial Refrigeration Measures
C-401	ESTAR Commercial Refrigerator - Vertical - Glass Doors - Low Temp	RCI-70	Commercial Refrigeration Improvements	M-RCI-27	Commercial Refrigeration Measures
C-402	ESTAR Commercial Refrigerator - Horizontal - Any Doors - Med Temp	RCI-70	Commercial Refrigeration Improvements	M-RCI-27	Commercial Refrigeration Measures
C-403	ESTAR Commercial Refrigerator - Horizontal - Any Doors - Low Temp	RCI-70	Commercial Refrigeration Improvements	M-RCI-27	Commercial Refrigeration Measures
C-404	ESTAR Ice-Maker - Self-Contained - < 200 lbs/day	RCI-71	Commercial Ice-Maker Improvements	M-RCI-27	Commercial Refrigeration Measures

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Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-405	ESTAR Ice-Maker - Self-Contained - > 200 lbs/day	RCI-71	Commercial Ice-Maker Improvements	M-RCI-27	Commercial Refrigeration Measures
C-406	ESTAR Ice-Maker - Not Self-Contained	RCI-71	Commercial Ice-Maker Improvements	M-RCI-27	Commercial Refrigeration Measures
C-407	CEE Tier 3 Ice-Maker - Self-Contained - < 200 lbs/day	RCI-71	Commercial Ice-Maker Improvements	M-RCI-27	Commercial Refrigeration Measures
C-408	CEE Tier 3 Ice-Maker - Self-Contained - > 200 lbs/day	RCI-71	Commercial Ice-Maker Improvements	M-RCI-27	Commercial Refrigeration Measures
C-409	CEE Tier 3 Ice-Maker - Not Self-Contained	RCI-71	Commercial Ice-Maker Improvements	M-RCI-27	Commercial Refrigeration Measures
C-410	EE Beverage Vending Machine	RCI-72	Commercial Vending Machines	M-RCI-27	Commercial Refrigeration Measures
C-411	Estar Commercial Clothes Washer--New	RCI-73	Commercial Laundry	M-RCI-28	Commercial Laundry Appliances Measures
C-412	Estar Commercial Clothes Washer--Replacement	RCI-73	Commercial Laundry	M-RCI-28	Commercial Laundry Appliances Measures
C-413	EStar Fryer	RCI-62	Commercial Cooking/Food Service Improvements	M-RCI-30	Commercial Cooking Appliances Measures
C-414	Ozone Laundry Treatment	RCI-73	Commercial Laundry	M-RCI-28	Commercial Laundry Appliances Measures
C-415	EStar Fryer	RCI-62	Commercial Cooking/Food Service Improvements	M-RCI-30	Commercial Cooking Appliances Measures
C-416	Waste Water Heat Exchanger--Retrofit	RCI-74	Commercial Wastewater Heat Exchanger	M-RCI-32	Commercial Water Heating Efficiency Measures
C-417	DHW Shower Heads	RCI-75	Commercial Hot Water Efficiency Measures	M-RCI-32	Commercial Water Heating Efficiency Measures
C-418	Heat Pump Water Heat	RCI-76	Commercial Heat Pump Water Heater	M-RCI-32	Commercial Water Heating Efficiency Measures
C-419	Transformers	RCI-77	Commercial Transformers	M-RCI-29	Commercial Electronics/Transformer Measures
C-420	Wall Insulation - BlownR11	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-421	DHW Wrap	RCI-75	Commercial Hot Water Efficiency Measures	M-RCI-32	Commercial Water Heating Efficiency Measures
C-422	Wall Insulation - Spray On for Metal Buildings	RCI-52	Commercial Insulation Natural Replacement/Retrofit	M-RCI-26	Commercial Building Insulation Measures
C-423	Computerized Water Heater Control	RCI-75	Commercial Hot Water Efficiency Measures	M-RCI-32	Commercial Water Heating Efficiency Measures
C-424	Heat Reclaim Refrigeration to Space Heating--Replacement	RCI-74	Commercial Wastewater Heat Exchanger	M-RCI-32	Commercial Water Heating Efficiency Measures
C-425	Economizer Diagnostic, Damper	RCI-	Commercial Economizer	M-RCI-	Commercial HVAC

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Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
	Repair &Reset	78	Measures	22	Control Measures
C-426	Waste Water Heat Exchanger--New	RCI-74	Commercial Wastewater Heat Exchanger	M-RCI-32	Commercial Water Heating Efficiency Measures
C-427	Heat Reclaim Refrigeration to Space Heating--New	RCI-79	Commercial Heat Reclamation Measures	M-RCI-22	Commercial HVAC Control Measures
C-428	EStar Griddle--New	RCI-62	Commercial Cooking/Food Service Improvements	M-RCI-30	Commercial Cooking Appliances Measures
C-429	Solar Hot Water--Retrofit	RCI-80	Commercial Solar Water Heat	M-RCI-33	Commercial Solar Water Heating
C-430	DHW Faucets--New	RCI-75	Commercial Hot Water Efficiency Measures	M-RCI-32	Commercial Water Heating Efficiency Measures
C-431	DHW Faucets--Retrofit	RCI-75	Commercial Hot Water Efficiency Measures	M-RCI-32	Commercial Water Heating Efficiency Measures
C-432	EStar Griddle--Replacement	RCI-62	Commercial Cooking/Food Service Improvements	M-RCI-30	Commercial Cooking Appliances Measures
C-433	Sweep Control (Lighting)--New	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-434	Computerized Water Heater Control	RCI-75	Commercial Hot Water Efficiency Measures	M-RCI-32	Commercial Water Heating Efficiency Measures
C-435	Ducts	RCI-81	Commercial Heating Duct Measures	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-436	Heat Pump Water Heat--New	RCI-76	Commercial Heat Pump Water Heater	M-RCI-32	Commercial Water Heating Efficiency Measures
C-437	DHW Pipe Insulation--New	RCI-75	Commercial Hot Water Efficiency Measures	M-RCI-32	Commercial Water Heating Efficiency Measures
C-438	EMS Retrofit for Restaurants--Retrofit	RCI-82	Commercial Energy Management Systems	M-RCI-22	Commercial HVAC Control Measures
C-439	Chiller Tower 6F approach	RCI-83	Commercial Chiller Tower 6F Approach	M-RCI-22	Commercial HVAC Control Measures
C-440	Windows - Tinted AL Code to Class 40--Replacement	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-441	Windows - Tinted AL Code to Class 45--Replacement	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-442	Rooftop Condensing Burner--New	RCI-84	Commercial Rooftop Condensing Burner	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-443	Windows - Tinted AL Code to Class 36--Replacement	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-444	Install Economizer--Retrofit	RCI-78	Commercial Economizer Measures	M-RCI-34	Commercial Heating Systems Measures--Conventional

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Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-445	Warm Up Control--Retrofit	RCI-78	Commercial Economizer Measures	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-446	Windows - Tinted AL Code to Class 36--New	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-447	Windows - Non-Tinted AL Code to Class 36--Replacement	RCI-51	Commercial Windows Natural Replacement/Retrofit	M-RCI-21	Commercial Building Windows Measures
C-448	Solar Hot Water--New	RCI-80	Commercial Solar Water Heat	M-RCI-33	Commercial Solar Water Heating
C-449	Ground Source Heat Pump - Air Source HP Base	RCI-85	Commercial Ground-source Heat Pump	M-RCI-24	Commercial HVAC System Improvements
C-450	Occupancy Sensors--New	RCI-37	Commercial Lighting Controls New/Integrated Design	M-RCI-20	Commercial Lighting Controls Measures
C-451	High Efficacy LED Display--New	RCI-67	Commercial Signage	M-RCI-18	Commercial Lighting Efficiency Measures
Commercial Measures Addressing Gas Use					
C-452	Estar Commercial Clothes Washer	RCI-86	Commercial Laundry Equipment--Gas	M-RCI-28	Commercial Laundry Appliances Measures
C-453	EStar Steam Cooker	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-454	EStar Steam Cooker	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-455	EStar Fryer	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-456	EStar Fryer	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-457	Estar Convection Oven	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-458	HW Boiler Tune	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-459	DHW Shower Heads	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-460	Hot Water Temperature Reset	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-461	Wall Insulation - BlownR11	RCI-89	Commercial Insulation Measures--Gas Heat	M-RCI-26	Commercial Building Insulation Measures
C-462	Heat Reclaim	RCI-90	Commercial Heat Reclamation--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-463	Heat Reclaim	RCI-90	Commercial Heat Reclamation--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional

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Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-464	Steam Balance	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-465	Waste Water Heat Exchanger	RCI-92	Commercial Wastewater Heat Exchanger--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-466	DHW Wrap	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-467	Wall Insulation - Spray On for Metal Buildings	RCI-93	Commercial Insulation Measures--Gas	M-RCI-26	Commercial Building Insulation Measures
C-468	Estar Convection Oven	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-469	DHW Condensing Tank (repl)	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-470	DHW Condensing Tank (new)	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-471	Computerized Water Heater Control	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-472	Windows - Add Low E to Vinyl Tint	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-473	Hot Food Holding Cabinet	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-474	Hot Food Holding Cabinet	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-475	Vent Damper	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-476	Windows - Add Low E and Argon to Vinyl Tint	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-477	EStar Griddle	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-478	EStar Griddle	RCI-87	Commercial Cooking Equipment--Gas	M-RCI-30	Commercial Cooking Appliances Measures
C-479	Waste Water Heat Exchanger	RCI-92	Commercial Wastewater Heat Exchanger--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-480	SPC Hieff Boiler Replace	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-481	DHW Hieff Boiler (repl)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-482	Combo Hieff Boiler (new)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional

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C-483	Windows - Tinted AL Code to Class 45	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-484	DHW Hieff Boiler (new)	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-485	Ducts	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-486	Combo Hieff Boiler (repl)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-487	Cond Furnace (new)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-488	Windows - Tinted AL Code to Class 40	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-489	SPC Hieff Boiler (new)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-490	DHW Recirc Controls	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-491	DHW Faucets	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-492	DHW Faucets	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-493	SPC Cond Boiler Replace	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-494	Hi Eff Unit Heater (new)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-495	DHW Cond Boiler (repl)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-496	Computerized Water Heater Control	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-497	DHW Cond Boiler (new)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-498	Power burner	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-499	SPC Cond Boiler (new)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-500	Cond Unit Heater From Power Draft (new)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional

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Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
C-501	Windows - Tinted AL Code to Class 40	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-502	DHW Pipe Ins	RCI-88	Commercial Hot Water Measures--Gas	M-RCI-32	Commercial Water Heating Efficiency Measures
C-503	Combo Cond Boiler (new)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-504	Combo Cond Boiler (repl)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-505	Rooftop Condensing Burner	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-506	Cond Unit Heater from Nat Draft (new)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-507	Hi Eff Unit Heater (replace)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-508	Windows - Tinted AL Code to Class 36	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-509	Windows - Add Argon to Vinyl Lowe	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-510	Cond Unit Heater from power draft (replace)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-511	Ozone Laundry Treatment	RCI-86	Commercial Laundry Equipment--Gas	M-RCI-28	Commercial Laundry Appliances Measures
C-512	Solar Hot Water--Retrofit	RCI-95	Commercial Solar Hot Water--Gas Back-up	M-RCI-33	Commercial Solar Water Heating
C-513	Steam Trap Maintenance	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-514	Cond Unit Heater from Nat draft (replace)	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-515	Windows - Tinted AL Code to Class 36	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-516	Windows - Non-Tinted AL Code to Class 40	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-517	Warm Up Control	RCI-91	Commercial Heating Measures--Gas	M-RCI-34	Commercial Heating Systems Measures--Conventional
C-518	Windows - Non-Tinted AL Code to Class 40	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-519	Cond Furnace (repl)	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-520	Windows - Non-Tinted AL Code to Class 36	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
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C-521	Windows - Non-Tinted AL Code to Class 45	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-522	Windows - Non-Tinted AL Code to Class 36	RCI-94	Commercial Windows Measures--Gas	M-RCI-21	Commercial Building Windows Measures
C-523	Solar Hot Water--New	RCI-95	Commercial Solar Hot Water--Gas Back-up	M-RCI-33	Commercial Solar Water Heating
Commercial Combined Heat and Power and Biomass Heating					
C-524	Commercial Gas-fired CHP	RCI-96	Commercial Gas-fired CHP	M-RCI-35	Commercial Combined Heat and Power
C-525	Commercial wood-fueled space heat Replacing electric Resistance	RCI-97	Commercial Wood-fueled Space Heat Replacing Electric	M-RCI-36	Commercial Heating Systems--Biomass/Biogas
C-526	Commercial wood-fueled space heat Replacing gas	RCI-98	Commercial Wood-fueled Space Heat Replacing Gas	M-RCI-36	Commercial Heating Systems--Biomass/Biogas
C-527	Commercial wood-fueled space heat Replacing oil or LPG	RCI-99	Commercial Wood-fueled Space Heat Replacing Oil/LPG	M-RCI-36	Commercial Heating Systems--Biomass/Biogas
C-528	Commercial Solar PV	RCI-100	Commercial Solar PV	M-RCI-37	Commercial Solar PV
Industrial Measures--All Industries					
I-1	Air Compressor Demand Reduction	RCI-101	Industrial General: Air Compressor Measures	M-RCI-38	Industrial Air Compressors
I-2	Air Compressor Equipment2	RCI-101	Industrial General: Air Compressor Measures	M-RCI-38	Industrial Air Compressors
I-3	Air Compressor Optimization	RCI-101	Industrial General: Air Compressor Measures	M-RCI-38	Industrial Air Compressors
I-4	High Bay Lighting 1 Shift	RCI-102	Industrial General: Lighting and Controls	M-RCI-39	Industrial Lighting and Control Measures
I-5	High Bay Lighting 2 Shift	RCI-102	Industrial General: Lighting and Controls	M-RCI-39	Industrial Lighting and Control Measures
I-6	High Bay Lighting 3 Shift	RCI-102	Industrial General: Lighting and Controls	M-RCI-39	Industrial Lighting and Control Measures
I-7	Efficient Lighting 1 Shift	RCI-102	Industrial General: Lighting and Controls	M-RCI-39	Industrial Lighting and Control Measures
I-8	Efficient Lighting 2 Shift	RCI-102	Industrial General: Lighting and Controls	M-RCI-39	Industrial Lighting and Control Measures
I-9	Efficient Lighting 3 Shift	RCI-102	Industrial General: Lighting and Controls	M-RCI-39	Industrial Lighting and Control Measures
I-10	Lighting Controls	RCI-102	Industrial General: Lighting and Controls	M-RCI-39	Industrial Lighting and Control Measures
I-11	Motors: Rewind 20-50 HP	RCI-103	Industrial General: Motors Measures	M-RCI-40	Industrial Motors Measures
I-12	Motors: Rewind 51-100 HP	RCI-103	Industrial General: Motors Measures	M-RCI-40	Industrial Motors Measures
I-13	Motors: Rewind 101-200 HP	RCI-103	Industrial General: Motors Measures	M-RCI-40	Industrial Motors Measures
I-14	Motors: Rewind 201-500 HP	RCI-103	Industrial General: Motors Measures	M-RCI-40	Industrial Motors Measures
I-15	Motors: Rewind 501-5000 HP	RCI-103	Industrial General: Motors Measures	M-RCI-40	Industrial Motors Measures
I-16	Efficient Centrifugal Fan	RCI-104	Industrial General: Fan Measures	M-RCI-41	Industrial Fan Efficiency Measures
I-17	Fan Energy Management	RCI-104	Industrial General: Fan Measures	M-RCI-41	Industrial Fan Efficiency Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
I-18	Fan Equipment Upgrade	RCI-104	Industrial General: Fan Measures	M-RCI-41	Industrial Fan Efficiency Measures
I-19	Fan System Optimization	RCI-104	Industrial General: Fan Measures	M-RCI-41	Industrial Fan Efficiency Measures
I-20	Pump Energy Management	RCI-105	Industrial General: Pump Measures	M-RCI-42	Industrial Pump Efficiency Measures
I-21	Pump Equipment Upgrade	RCI-105	Industrial General: Pump Measures	M-RCI-42	Industrial Pump Efficiency Measures
I-22	Pump System Optimization	RCI-105	Industrial General: Pump Measures	M-RCI-42	Industrial Pump Efficiency Measures
I-23	Transformers-Retrofit	RCI-106	Industrial General: Transformers	M-RCI-43	Industrial Transformers
I-24	Transformers-New	RCI-106	Industrial General: Transformers	M-RCI-43	Industrial Transformers
I-25	Synchronous Belts	RCI-107	Industrial General: Materials Movement Measures	M-RCI-44	Industrial Energy Management
I-26	Plant Energy Management	RCI-108	Industrial General: Energy Management	M-RCI-44	Industrial Energy Management
I-27	Energy Project Management	RCI-108	Industrial General: Energy Management	M-RCI-44	Industrial Energy Management
I-28	Integrated Plant Energy Management	RCI-108	Industrial General: Energy Management	M-RCI-44	Industrial Energy Management
I-29	Material Handling2	RCI-107	Industrial General: Materials Movement Measures	M-RCI-44	Industrial Energy Management
I-30	Material Handling VFD2	RCI-107	Industrial General: Materials Movement Measures	M-RCI-44	Industrial Energy Management
Industrial Measures--Electronic Chip Manufacture					
I-31	Elec Chip Fab: Eliminate Exhaust	RCI-109	Industrial Electronics Chip Fab Measures	M-RCI-45	Industrial Electronics Manufacturing Measures
I-32	Elec Chip Fab: Exhaust Injector	RCI-109	Industrial Electronics Chip Fab Measures	M-RCI-45	Industrial Electronics Manufacturing Measures
I-33	Elec Chip Fab: Solidstate Chiller	RCI-109	Industrial Electronics Chip Fab Measures	M-RCI-45	Industrial Electronics Manufacturing Measures
I-34	Elec Chip Fab: Reduce Gas Pressure	RCI-109	Industrial Electronics Chip Fab Measures	M-RCI-45	Industrial Electronics Manufacturing Measures
I-35	Clean Room: Change Filter Strategy	RCI-110	Industrial Electronics Clean Room Measures	M-RCI-45	Industrial Electronics Manufacturing Measures
I-36	Clean Room: Clean Room HVAC	RCI-110	Industrial Electronics Clean Room Measures	M-RCI-45	Industrial Electronics Manufacturing Measures
I-37	Clean Room: Chiller Optimize	RCI-110	Industrial Electronics Clean Room Measures	M-RCI-45	Industrial Electronics Manufacturing Measures
Industrial Measures--Food Processing/Storage Industries					
I-38	Food: Cooling and Storage	RCI-111	Industrial Food Processing Measures	M-RCI-46	Industrial Food Processing/Storage Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
I-39	Food: Refrig Storage Tuneup	RCI-111	Industrial Food Processing Measures	M-RCI-46	Industrial Food Processing/Storage Measures
I-40	Cold Storage Retrofit	RCI-112	Industrial Cold Storage Measures	M-RCI-46	Industrial Food Processing/Storage Measures
I-41	Cold Storage Tuneup	RCI-112	Industrial Cold Storage Measures	M-RCI-46	Industrial Food Processing/Storage Measures
I-42	Fruit Storage Refer Retrofit	RCI-113	Industrial Fruit Storage Measures	M-RCI-46	Industrial Food Processing/Storage Measures
I-43	CA Retrofit -- CO2 Scrub	RCI-114	Industrial Food Storage Measures	M-RCI-46	Industrial Food Processing/Storage Measures
I-44	CA Retrofit -- Membrane	RCI-114	Industrial Food Storage Measures	M-RCI-46	Industrial Food Processing/Storage Measures
I-45	Fruit Storage Tuneup	RCI-113	Industrial Fruit Storage Measures	M-RCI-46	Industrial Food Processing/Storage Measures
I-46	Groc Dist Retrofit	RCI-115	Industrial Grocery Distribution Measures	M-RCI-46	Industrial Food Processing/Storage Measures
I-47	Groc Dist Tuneup	RCI-115	Industrial Grocery Distribution Measures	M-RCI-46	Industrial Food Processing/Storage Measures
Industrial Measures--Metals Industries					
I-48	Metal: New Arc Furnace	RCI-116	Industrial Metals Arc Furnace	M-RCI-47	Industrial Arc Furnace Measures
Industrial Measures--Pulp and Paper Industries					
I-49	Mech Pulp: Refiner Replacement	RCI-117	Industrial Mechanical Pulp Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures
I-50	Mech Pulp: Premium Process	RCI-117	Industrial Mechanical Pulp Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures
I-51	Mech Pulp: Refiner Plate Improvement	RCI-117	Industrial Mechanical Pulp Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures
I-52	Kraft: Effluent Treatment System	RCI-118	Industrial Kraft Pulp Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures
I-53	Kraft: Efficient Agitator	RCI-118	Industrial Kraft Pulp Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures
I-54	Paper: Efficient Pulp Screen	RCI-119	Industrial Paper Sector Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures
I-55	Paper: Premium Fan	RCI-119	Industrial Paper Sector Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures
I-56	Paper: Material Handling	RCI-119	Industrial Paper Sector Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures
I-57	Paper: Large Material Handling	RCI-119	Industrial Paper Sector Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
I-58	Paper: Premium Control Large Material	RCI-119	Industrial Paper Sector Measures	M-RCI-48	Industrial Pulp and Paper Industry Measures
I-59	Wood: Replace Pneumatic Conveyor	RCI-120	Industrial Lumber Conveyor Replacement	M-RCI-49	Industrial Wood Products Measures
I-60	Panel: Hydraulic Press	RCI-121	Industrial Wood Panels Hydraulic Press	M-RCI-49	Industrial Wood Products Measures
Industrial Measures--Agriculture					
I-61	Pump, Nozzle & Gasket Replacement Deep Well	RCI-122	Industrial Agriculture Pump and Related Measures	M-RCI-50	Industrial Agricultural Irrigation Measures
I-62	Pump, Nozzle & Gasket Replacement Average Well	RCI-122	Industrial Agriculture Pump and Related Measures	M-RCI-50	Industrial Agricultural Irrigation Measures
I-63	Nozzle & Gasket Replacement	RCI-122	Industrial Agriculture Pump and Related Measures	M-RCI-50	Industrial Agricultural Irrigation Measures
I-64	Convert High Pressure Center Pivot to Low pressure system	RCI-123	Industrial Agriculture Irrigation Improvements	M-RCI-50	Industrial Agricultural Irrigation Measures
I-65	Convert Medium Pressure Center Pivot to Low pressure system	RCI-123	Industrial Agriculture Irrigation Improvements	M-RCI-50	Industrial Agricultural Irrigation Measures
I-66	Convert wheel line systems to low pressure systems on alfalfa acreage	RCI-123	Industrial Agriculture Irrigation Improvements	M-RCI-50	Industrial Agricultural Irrigation Measures
I-67	Convert hand line systems to low pressure systems on alfalfa acreage	RCI-123	Industrial Agriculture Irrigation Improvements	M-RCI-50	Industrial Agricultural Irrigation Measures
I-68	Irrigation: Ditch > Pipe	RCI-123	Industrial Agriculture Irrigation Improvements	M-RCI-50	Industrial Agricultural Irrigation Measures
I-69	Irrigation: Pump Systems Repair	RCI-122	Industrial Agriculture Pump and Related Measures	M-RCI-50	Industrial Agricultural Irrigation Measures
I-70	Irrigation: Pump Systems Adjust	RCI-122	Industrial Agriculture Pump and Related Measures	M-RCI-50	Industrial Agricultural Irrigation Measures
I-71	Irrigation: Water Management	RCI-123	Industrial Agriculture Irrigation Improvements	M-RCI-50	Industrial Agricultural Irrigation Measures
Industrial Measures--Rural and Traffic Lighting					
I-72	Rural Area Lights	RCI-124	Industrial Rural Area Lighting	M-RCI-51	Industrial Street and Traffic Lighting
I-73	Traffic Signals Relamping	RCI-125	Industrial Traffic Signals Relamping	M-RCI-51	Industrial Street and Traffic Lighting
Industrial Measures--Gas Savings					
I-74	Process Boiler Measures, Replacement	RCI-126	Industrial Boiler Measures	M-RCI-52	Industrial Space/Water Heating and Weatherization Measures
I-75	Process Boiler Measures, Retrofit	RCI-126	Industrial Boiler Measures	M-RCI-52	Industrial Space/Water Heating and Weatherization Measures
I-76	DHW Measures, Replacement	RCI-127	Industrial Hot Water Measures	M-RCI-52	Industrial Space/Water Heating and Weatherization Measures

Detailed Measure Category/Number		Aggregation Assignments		Aggregation Assignments	
Measure Number	**Measure/Measure Group Name**	**Measure Category/Number for MICROeconomic Analysis**		**Measure Category/Number for MACROeconomic Analysis**	
I-77	DHW Measures, Retrofit	RCI-127	Industrial Hot Water Measures	M-RCI-52	Industrial Space/Water Heating and Weatherization Measures
I-78	Space Heat Measures, Replacement	RCI-128	Industrial Space Heating Measures	M-RCI-52	Industrial Space/Water Heating and Weatherization Measures
I-79	Weatherization Measures, Retrofit	RCI-129	Industrial Weatherization Measures	M-RCI-52	Industrial Space/Water Heating and Weatherization Measures
Industrial CHP and Non-Energy GHG Reduction					
I-80	Industrial Gas-fired CHP	RCI-130	Industrial Gas-fired CHP	M-RCI-53	Industrial Combined Heat and Power
I-81	Industrial Biomass-fired CHP	RCI-131	Industrial Biomass-fired CHP	M-RCI-53	Industrial Combined Heat and Power
I-82	Industrial CHP Using Anaerobic Digesters	RCI-132	Industrial Digester Gas-fired CHP	M-RCI-53	Industrial Combined Heat and Power
I-83	Cement Production Emissions Reduction	RCI-133	Industrial Cement Production Emissions Reduction	M-RCI-54	Industrial Non-energy GHG Reduction Measures
I-84	Electronics Industry Solvent Emissions Reduction	RCI-134	Industrial Electronics Industry Solvent Emissions Reduction	M-RCI-54	Industrial Non-energy GHG Reduction Measures
I-85	Industrial Halon Consumption Reduction	RCI-135	Industrial Halon Consumption Reduction	M-RCI-54	Industrial Non-energy GHG Reduction Measures
I-86	Industrial Solar PV	RCI-136	Industrial Solar PV	M-RCI-55	Industrial Solar PV

RCI - Annex B: Assignment of Effort and Cost Variables in the Cost Curve Scenarios

As noted in RCI – Annex A ("Data Source and Data Preparation Descriptions"), the primary approach to development of costs and greenhouse gas (GHG) savings in the Residential, Commercial, and Industrial (RCI) sectors for this project was to adopt and adapt existing measure and related data to, first, prepare estimates of "achievable technical potential" for each measure in Oregon, and then, to estimate what fraction of that potential might be achieved under different scenarios of state and federal policy effort, and what impact the policy efforts assumed in the scenarios might have on the measure costs paid in Oregon. This annex describes the approach used to develop and assign "Effort" and "Cost" variables allowing costs and GHG savings estimates to be estimated for three potential future scenarios:

- Scenario 1: Modest Effort, Continued State and Federal Policies
- Scenario 2: Moderate Increase in Federal Action
- Scenario 3: Moderate Increase in Federal and State Action

The "Effort" variable indicates the fraction of "Achievable Technical Potential" that each scenario will attain. Northwest Power and Conservation Council's Regional Technical Forum (RTF) define "Achievable Technical Potential" as 85% of "Technical Potential".[1] This definition is assumed (for this work) to be equal to the maximum achievable potential in Oregon. The other major measure data compendium used in the RCI work, the 2011 volume *Energy Efficiency and Conservation Measure Resource Assessment for the Years 2010-2030* prepared for the Energy Trust of Oregon (ETO), uses effectively the same definition for achievable technical potential (and draws heavily on RTF results). In practice, assignment of effort variables scales the maximum achievable potential for each measure for each scenario. For example, an effort variable of 60% represents of 60% of the maximum achievable potential in Oregon (that is, 60% of 85% of estimated technical potential).

The "Cost" variable denotes the impact on costs to Oregon (citizens/companies/ government) of each Scenario relative to the estimated costs for each measure. This variable is expressed as the reduction in capital costs (but not operation & maintenance costs) under the scenario, relative to the cost estimate of technical potential. For example, a cost variable value of 0% indicates that the scenario is expected to have no impact on measure cost in Oregon, while a cost variable value of 50% indicates that expanded Federal or State action has the effect of reducing the capital cost of the option to those in Oregon who would pay the cost by 50%. The default setting of the "cost" variable is 0%, meaning that Federal action will have no impact on what in-Oregon actors (some combination of the State, ETO/utilities, and consumers) will pay in terms of the incremental cost of a measure. Values of the cost variable were assigned to measures in Scenarios 1 and 2/3 based on what the RCI analysis team was able to learn or, if explicit descriptions of existing or proposed programs were not available, assumed about how Federal programs for a given technology might affect costs that the State sees. The most straightforward

[1] Northwest Power & Conservation Council (2007). A Retrospective Look at the Northwest Power and Conservation Council's Conservation Planning Assumptions. Download the document at http://www.nwcouncil.org/library/2007/2007-13.htm.

example here might be extension of the 30% solar tax credit past its current sunset in 2016, which would reduce the cost of solar photovoltaic (PV) systems to in-state actors by 30% (assuming sufficient tax liability). The RCI analysis team assumed that the solar PV tax credit would sunset in Scenario 1 after 2016, as currently scheduled, but would be extended indefinitely (at least, through 2035) in Scenarios 2 and 3.

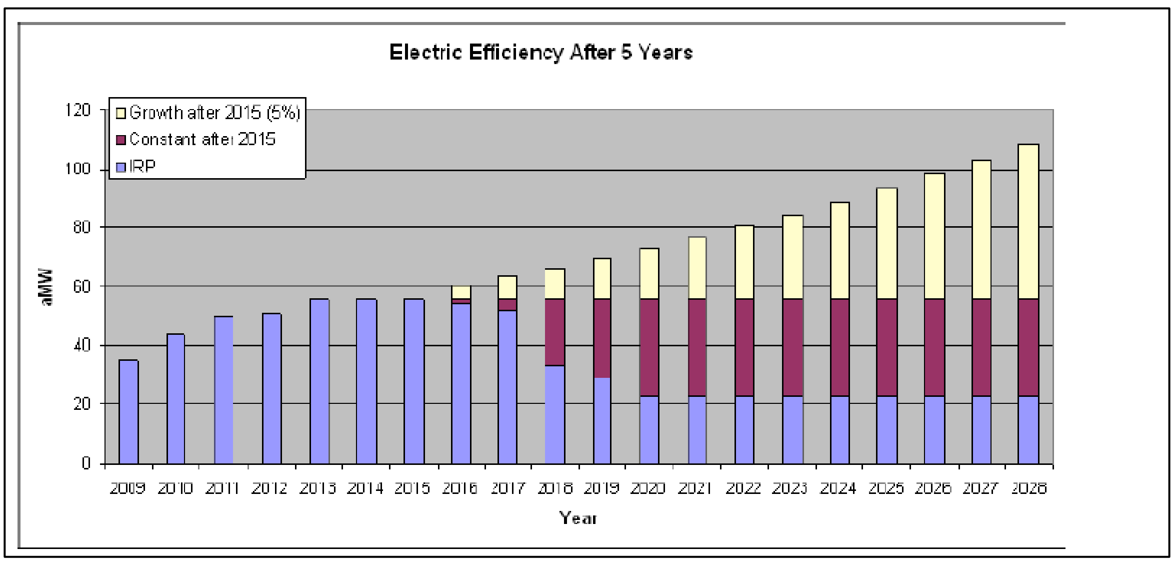
Development of the Effort and Cost Variables

Oregon is one of the leading states in terms of implementing energy efficiency measures and programs. As such, State efforts can be expected, for most technologies, to considerably outstrip Federal efforts in terms of their effects on the scenarios.

A number of resources were reviewed to inform the RCI team's assessment of the current state of energy efficiency plans and the extent to which achievable potential will be captured. These included a number of ETO reports in addition to Integrated Resource Plans (IRPs) for utilities operating in Oregon, and assessments specific to demand-side management (DSM) opportunities. Ultimately the most useful document for the intended purpose proved to be the ETO's *2010 – 2014 Strategic Plan*.[2] Figure 1 is copied from that plan. This graph presents the ETO's view of how electricity savings from the two utility areas it covers (Portland General Electric—PGE—and Pacific Power) would decrease over time if plans for State investment in energy efficiency remain as they are (the blue bars).

Based on this graphic it was calculated that on a cumulative basis what ETO labels as the "IRP" case yields about 64% of the savings of the "Constant after 2015" case. We interpret the "Constant after 2015" case to be close to what RTF and ETO describe as Achievable Potential, though, in fact the total cumulative savings under the "Constant after 2015" case is somewhat higher than the Achievable Potential cited in the more recent (2011) resource assessment done for ETO.

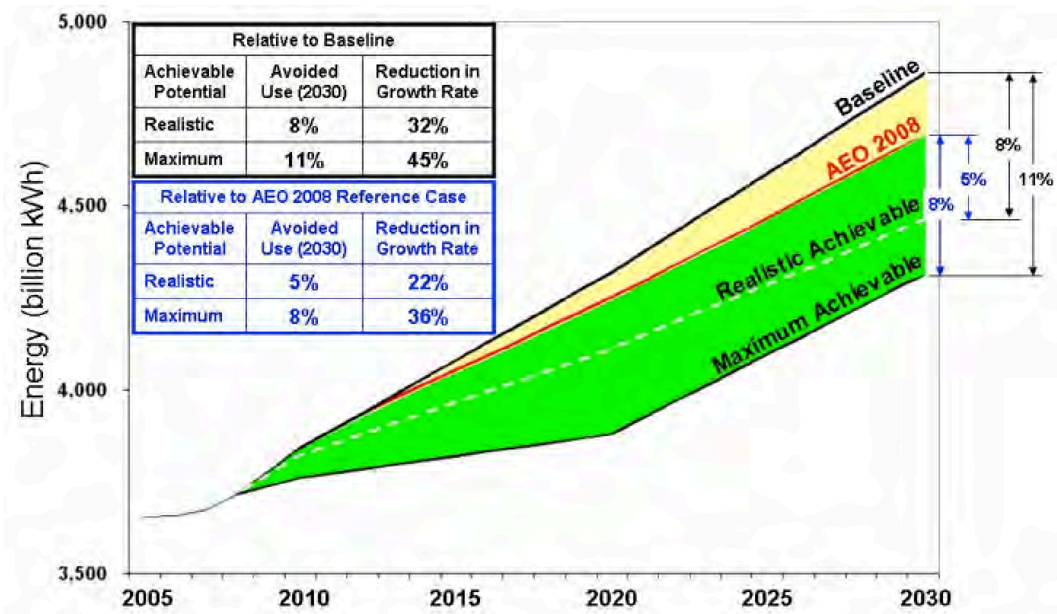
Figure B-1. ETO's estimate of electric savings through 2028 based on potential future scenarios



[2] Download a copy of the plan at energytrust.org/library/plans/2010-14_strategic_plan_approved.pdf.

Two national studies of different scenarios of effort in reducing energy demand appear to also be germane. The first, by the Electric Power Research Institute (EPRI), titled *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S. (2010–2030)*, and dated January 2009, includes the graph below. In this graph, the analog to our "Achievable Potential" is the green area, of which EPRI's "Realistic" case, which "…represents a forecast of likely customer behavior…[and] takes into account existing market, financial, political, and regulatory barriers that are likely to limit the amount of savings that might be achieved through energy-efficiency and demand-response programs", might reasonably, at least for Oregon, be considered consistent with our Scenario 1. By 2030 the "Realistic" case represents 60% of the "Maximum Achievable" case.

Figure B-2. EPRI's estimate of U.S. energy savings through 2030.



The final study cited here is the USDOE's *Annual Energy Outlook [AEO] 2012*[3], released just prior to this writing. *AEO 2012* includes, among its many scenarios, several that focus specifically on demand-side options (see Appendix D, Table D1, pages 198-199). The differences for Residential and Commercial electricity and gas consumption in 2035 (and other years) were compared for three demand scenarios: "Reference", "Integrated High Demand Technology" (including additional penetration of higher-efficiency technologies), and "Integrated Best Available Demand Technology".

This comparison found that for both residential electricity and gas use forecasts, the difference in 2035 between the Integrated High Demand Technology and Reference scenarios is 44% of the difference between the Integrated Best Available Demand Technology and Reference scenarios. For the commercial sector, the difference between scenarios is 69% for electricity use. There is relatively little difference in the level of commercial gas use in the three scenarios, because, it is assumed, the additional commercial sector use of gas for combined heat and power and/or on-

[3] Download a copy of the report at http://www.eia.gov/forecasts/aeo/pdf/0383%282012%29.pdf

site generation in the "Integrated…" cases is greater than gross savings from gas energy efficiency measure application. It is assumed that the AEO 2012 Integrated Best Available Demand Technology case roughly equates to the Achievable Technical Potential that we are deriving from ETO and RTF data.

Based on these three results, the following approach was developed to assigning the Effort and Cost variables to each scenario.

Assignment of Effort and Cost Variables to the Scenarios

Scenario 1: Modest Effort, Continued State and Federal Policies

Scenario 1 represents the continuation of state and federal policies and action at approximately current levels.

<u>Effort Variable Assignment</u>

Scenario 1, effort variables are based on current incentives programs through Energy Trust of Oregon, Oregon Department of Energy, and the Federal Government (as of July 2012). If there is an active incentive program for a given measure it is assumed that the measure will reach 60% of the achievable technical potential for electricity measures; therefore an effort variable of 60% was assigned. Natural gas measures are assigned an effort variable of 50%, recognizing that gas DSM is generally at an earlier stage than electric DSM. If there is not an existing ETO/ODOE incentive currently available for a measure in the list of RCI options considered for this study, whether the measure is designed to save electricity or natural gas, an effort variable of 0% was assigned.

<u>Cost Variable Assignment</u>

In Scenario 1, the "cost" variables applied to each measure are based on an assessment of the current availability of Federal tax credits for that measure. Federal tax credits are, currently, limited to renewable energy generation technologies in the residential and commercial sectors (e.g. solar electric and thermal, geothermal heat pumps, small-scale wind turbines, fuels cells and combined heat and power (CHP) systems). These credits are set to expire in 2016, and this analysis makes the assumption, for Scenario 1, that they will not be renewed.

Residential tax credits for energy efficiency were available during 2010 and 2011, but expired at the end of 2011 and have not been renewed or revised as of this writing. The Energy-Efficient Commercial Buildings Tax Deduction, which is set to expire at the end of 2013, is not applied to Scenario 1 due its sunset date; however this program is used as a model for increased Federal action in Scenario 2.

Scenario 2: Moderate Increase in Federal Action

Scenario 2 represents increased Federal action, relative to Scenario 1 (that is, the level of state effort remains the same as in Scenario 1). This analysis uses recently proposed legislation as models to estimate the effect of new Federal policy in Oregon.

Effort Variables

Scenario 2 represents a moderate increase in Federal action and uses the proposed U.S. Senate Legislation, Cut Energy Bills at Home (S.1914), as a model of potential future legislation in the residential sector. This proposed bill provides a tax credit to those U.S. households that reduce their energy consumption by at least 20%. The tax credit equals 20% of all capital and installation costs up to $2,000. An additional 5% tax credit is given for each additional 5% energy savings up to 30% for a tax credit of $3,000. The tax credit is scaled based on baseline consumption (i.e. the greater the initial consumption, the larger the tax credit) but will not exceed a $5,000 tax credit for 30% energy savings.

Maximum electricity and natural gas savings for Oregon as a result of this program were estimated based on the number of retail electricity customers and the average annual Oregon household energy use. These maximum savings were scaled by the number of Oregon households that have a tax liability greater than $3,000 per year. The number of households with this tax obligation was determined using data from the U.S. Census Bureau and an online Federal tax calculator. It was determined that households with annual income greater than $60,000 could utilize these tax credits. In Oregon, roughly 400,000 households[4] have this level of income, or about 25% of the total retail electricity customers in the state. It is assumed that 40% of the electric retail customers with this income level will claim the tax credit, or about 10% of retail customers.

For the commercial and industrial sectors in Scenario 2, The Energy-Efficient Commercial Buildings Tax Deduction, which sunsets at the end of 2013, is used as a model for increased Federal action. In other words, it is assumed that this program will be renewed. This program provides tax credits per square foot of building area ($0.30 - $1.80 / square foot) depending on the scale and type of efficiency measures undertaken. Applicable measures for this program include: building envelope, lighting, and HVAC.

The program is limited to existing buildings, but does not impose a building age requirement. Each measure category (envelope, lighting, and HVAC) earns $0.60 of the total $1.80 per square foot maximum tax credit. It is assumed that this program represents an increase of 10% for the effort variables associated with the measures to which it is applicable, in addition to the values of the effort variable assigned to those measures under Scenario 1.

Cost Variables

This model program is assumed to increase the cost variable by 10% for applicable measures (that is, retrofit and natural replacement building envelope, lighting, HVAC measures in the commercial and industrial sector), meaning that it will reduce the cost paid by in-state actors for those measures.

[4] U.S. Census Bureau.

Scenario 3: Moderate Increase in Federal and State Action

Scenario 3 represents a moderate increase in both Federal and State programs, relative to Scenario 1 and Scenario 2.

Effort Variables

For Scenario 3, effort variables for most measures are set at 80% (of achievable technical potential) for electricity and 75% for gas efficiency options, effectively assuming that ETO funding will be higher than in Scenarios 1 and 2, and thus effective savings will also be higher, but will not quite reach the maximum achievable potential level.

Cost Variables

The Cost variables in Scenario 3 are identical to those assigned in Scenario 2, because only the levels of state programs increase in this scenario relative to Scenario 2, and state programs do not influence the cost variable.

Appendix C: Transportation and Land Use (TLU) Measure Descriptions and Related Materials

To produce the data estimate results for the transportation and land use (TLU) sector, four sets of options and four general streams of data were used. The four (4) streams of work and data include:

(1) Transit and Land Use (TL), which produced data for options TLU 1-8, which also correspond to TL1-8. The strategies analyzed are consistent with the scenarios for transit and land use change developed as part of the larger statewide planning process. For further information about these options and data, please refer to the reports and data produced by the Oregon Department of Transportation (ODOT) as part of the Oregon Sustainable Transportation Initiative (OSTI) project, and the associated Statewide Transportation Strategy (STS).

(2) Low Carbon Fuel Standard (LCFS), which produced data for options TLU 9-21, which also correspond to LCFS1-13. For further information about these options and data, please refer to the reports and data produced by the Oregon Department of Environmental Quality (ODEQ) as part of the Oregon Low Carbon Fuel Standard development process.

(3) Freight and Heavy Duty Vehicle (FR), which produced data for options TLU 22-27, which also correspond to FR 1-6. For further information about these options and data, please refer to the reports and data produced by the Oregon Department of Transportation (ODOT) as part of the Oregon Sustainable Transportation Initiative (OSTI) project, and the associated Statewide Transportation Strategy (STS).

(4) Light Duty Vehicle (LD) travel options , which relied upon the ODOT GREENSTEP modeling tool, and produced data for options TLU 28-37, which also correspond to LD 1-10. For further information about these options and data, please refer to the reports and data produced by the Oregon Department of Transportation (ODOT) as part of the Oregon Sustainable Transportation Initiative (OSTI) project, and the associated Statewide Transportation Strategy (STS).

Table. TLU Measure Categories in Four Major Groups

Major Groups of Measures	Measure Number	Measure Category for Microeconomic Analysis
(1) Transit and Land Use Major Group		
TLU-1-8	**TLU-1**	TL1 -- TriMet - Rail
	TLU-2	TL2 -- TriMet - Bus
	TLU-3	TL3 -- Lane Transit District
	TLU-4	TL4 -- Salem Area Mass Transit District
	TLU-5	TL5 -- Rogue Valley Transportation District
	TLU-6	TL6 -- Bend Area Transit
	TLU-7	TL7 -- City of Corvallis
	TLU-8	TL8 -- Land Use
(2) Low Carbon Fuels Major Group		

Major Groups of Measures	Measure Number	Measure Category for Microeconomic Analysis
TLU-9-21	**TLU-9**	LCFS1 -- MW Corn Ethanol
	TLU-10	LCFS2 -- OR Corn Ethanol
	TLU-11	LCFS3 -- Imported Cellulosic Ethanol
	TLU-12	LCFS4 -- Oregon Wheat Straw Ethanol
	TLU-13	LCFS5 -- Brazil Sugar Cane Ethanol
	TLU-14	LCFS6 -- Low Carbon MW Corn
	TLU-15	LCFS7 -- OR Cellulosic Ethanol
	TLU-16	LCFS8 – Cellulosic
	TLU-17	LCFS9 -- CNG from biogas
	TLU-18	LCFS10 -- Camelian RD
	TLU-19	LCFS 11 -- NW Canola
	TLU-20	LCFS 12 -- Waste Oil
	TLU-21	LCFS 13 -- MW Soybean
(3) Freight and Heavy Duty Vehicles Major Group		
TLU-22-27	**TLU-22**	FR1 -- Land Use Policy Changes
	TLU-23	FR2 -- Urban Traffic Congestion Relief
	TLU-24	FR3 -- Idle Reduction Strategies
	TLU-25	FR4 -- More Energy Efficient Transporter Operations
	TLU-26	FR5 -- Mode Shift of Freight in Response to Higher Fees
	TLU-27	FR6 --Low Carbon Fuels
(4) Light Duty Vehicles Travel Options Major Group		
TLU-28-37	**TLU-28**	LD1 -- Transit Growth
	TLU-29	LD2 -- Walk/Bike Short SOV mode shift
	TLU-30	LD3 -- ITS &Operations
	TLU-31	LD4 -- PAYD
	TLU-32	LD5 -- TDM
	TLU-33	LD6 -- EcoDrive
	TLU-34	LD7 -- Parking Management
	TLU-35	LD8 -- Externality Taxes
	TLU-36	LD9 -- Congestion Charges
	TLU-37	LD10 -- Carsharing

TLU – 1-8 / TL 1-8 – Transit and Land Use Options

The strategies analyzed are consistent with the scenarios for transit and land use change developed as part of the larger statewide planning process. For further information about these options and data, please refer to the reports and data produced by the Oregon Department of Transportation (ODOT) as part of the Oregon Sustainable Transportation Initiative (OSTI) project, and the associated Statewide Transportation Strategy (STS).

Measure Number	Measure Category for Microeconomic Analysis
TLU-1	TL1 -- TriMet - Rail
TLU-2	TL2 -- TriMet - Bus
TLU-3	TL3 -- Lane Transit District
TLU-4	TL4 -- Salem Area Mass Transit District
TLU-5	TL5 -- Rogue Valley Transportation District
TLU-6	TL6 -- Bend Area Transit
TLU-7	TL7 -- City of Corvallis
TLU-8	TL8 -- Land Use

TLU – 1 / TL 1 – Portland Region Rail Transit

Measure Description

An important strategy in reducing GHG emissions produced from transportation sources is reducing the growth rate in per-capita VMT. Providing alternatives to the SOV has been shown to reduce the number of trips and VMT on the highway system. Modal alternatives can include bus transit and paratransit, rail transit, ridesharing, and vanpools (in addition to bicycling and walking, which are not addressed here).

Increased transit use is an important element to achieving the goal of reducing the growth rate of VMT. A higher rate of transit use can be achieved by improving transit's competitiveness with other modes, expanding transit services, ensuring the safety and security of transit systems, and educating the public about transit options available in their community. Transit's competitiveness will be enhanced by providing the livable, walkable, complete streets context in which transit can be cost-effective.

Rail transit management and infrastructure strategies are intended to make public transit a practical transportation choice for people in Oregon. Increased use of rail transit that reduces reliance on private automobile travel can achieve a net reduction in transportation related energy demand and greenhouse gas (GHG) emissions. Public transportation improvements are essential to reduce GHG emissions associated with transportation. This analysis focuses on strategies to increase rail transit passenger miles.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Passenger miles on rail transit increase at Oregon's projected population growth rate for different regions.

Low Federal Action: The Federal Government provides 100 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 0 percent of the funding for these capital investments. This scenario achieves 33 percent of the increase in rail transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal Action: The Federal Government provides 90 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 10 percent of the funding for these capital investments. This scenario achieves 66 percent of the increase in rail transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal and State Action: The Federal Government provides 50 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 50 percent of the funding for these capital investments. This scenario assumes rail transit passenger miles in Oregon increases by a factor of 2.12 between 2010 and 2035.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2035.

Parties Involved: Portland's Tri-County Metropolitan Transportation District of Oregon (TriMet) and the Oregon Department of Department.

Data Sources and Additional Background: The estimates of projected increases in rail transit passenger miles were derived from the Oregon Department of Transportation's Statewide Transportation Strategy (2012). Current levels of rail transit passenger miles and service region population estimates for the Portland metropolitan area were derived from the National Transit Database. Transit agency costs per passenger revenue mile were calculated based on cost data published in TriMet's FY2011 financial reports. TriMet provided estimates of their projected future capital and operating expenditures.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV	2013-2022 CE	2013-2035 CE
	2022	2035	Total	Total				

			(2013-2022)	(2013-2035)		($MM2010)	($/$tCO_2e$)	($/$tCO_2e$)
#1: Low Federal Action	0.0057	0.0115	0.0663	0.1525	$19.37	$44.55	$292.07	$292.07
#2: Moderate Federal Action	0.0115	0.0230	0.1326	0.3051	$144.66	$113.47	$1,090.59	$1,090.59
#3: Moderate Federal and State Action	0.0174	0.0349	0.1323	0.4623	$130.39	$319.57	$985.22	$691.33

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0086	0.0173	0.0995	0.2288	$19.37	$44.55	$194.71	$194.71
#2: Moderate Federal Action	0.0172	0.0346	0.0346	0.4576	$49.33	$113.47	$247.95	$247.95
#3: Moderate Federal and State Action	0.0260	0.0524	0.1985	0.6934	$130.39	$319.57	$656.82	$460.89

Quantification Methods and Results:

Using the strategy goal, the associated GHG emission reductions were estimated using analytical methods developed by the American Public Transportation Association (APTA).[1] According to APTA, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are

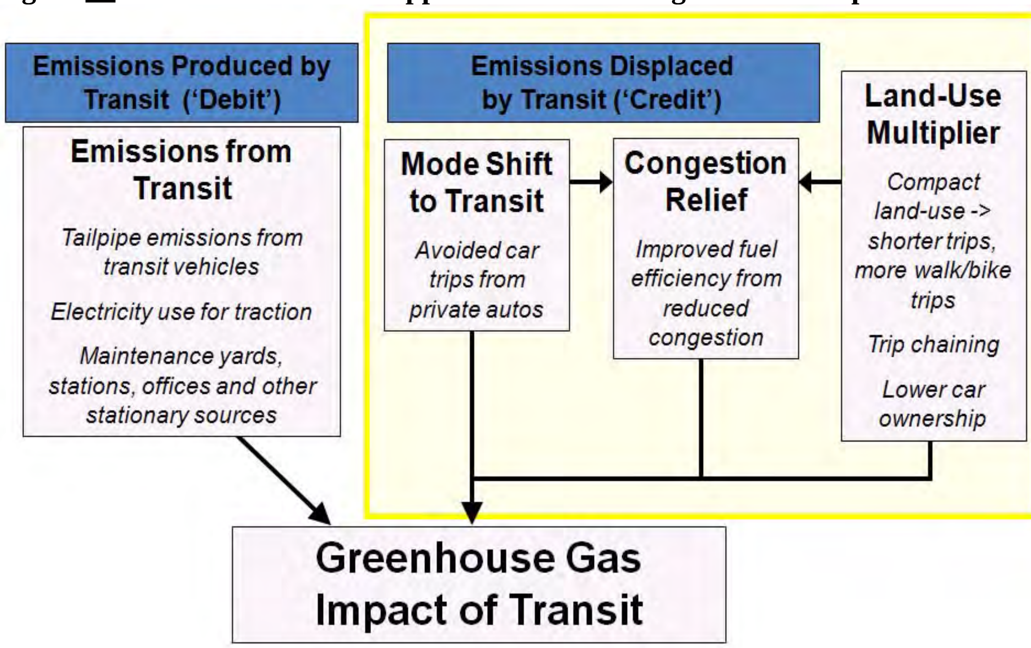
[1] APTA. 2009. Quantifying Greenhouse Gas Emissions from Transit.

used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

The analysis was performed using Jack Faucett Associates' TARGGET (Transit Associated Reduced Greenhouse Gas Emissions Tool) program. TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit agency passenger revenue miles and service area population and density. This allows the analysis to develop Oregon-specific estimates.

The rail transit analysis uses the American Public Transportation Association's (APTA) guidance on measuring transit's impacts on community wide greenhouse gas emissions. The title of the APTA guidance document is "Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit" (2010). The analysis performed for Oregon focuses on the greenhouse gas impacts related to mode shift and congestion relief associated with rail transit service.

Figure __. Overview of APTA Approach to Estimating the GHG Impacts of Public Transit



The methodology of our analysis comes from APTA's 2009 report, "Quantifying Greenhouse Gas Emissions from Transit." This report outlines how to quantify the displaced greenhouse gas emissions, in metric tons of CO2-equivalent, based on mode shifting, congestion relief, and the land-use multiplier. APTA provides several different methods of calculating these displaced emissions. Some are very time and resource intensive, requiring onsite surveys and regional analysis. However, APTA also propose methods that require only basic information regarding the transit service region, such as service region population, density, and transit use. For many transit systems this information can be found in the National Transit Database (NTD). Using transit agency specific data from the NTD avoided fuel use and greenhouse gas emissions facilitated by transit can be easily estimated for hundreds of transit agencies across the country.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA).[2] Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is also used to estimate gallons of fuel saved and the associated reduction in GHG emissions. The capital costs of the transit management and infrastructure were estimated using GHG emission reduction strategy cost estimates in the *Moving Cooler* report and a joint product cost allocation estimate.[3]

APTA's methodology uses population, population density, and passenger revenue miles for a given transit service region in order to assess the community-wide fuel and greenhouse gas emissions savings facilitated by transit. The estimates are calculated through a multistep process. To calculate the effect of mode shifting, a mode shift factor must be calculated. This factor, when multiplied by passenger revenue miles determines how many VMT are displaced by the transit system. To determine a mode shift factor, APTA conducted national surveys of commuters to determine how they would commute in the absence of public transportation. The mode shift factor is the percentage of people that would drive plus those that would take a taxi, divided by 2.5 times the amount of people who would ride with somebody else. These results were then bracketed based on population into small, medium and large cities, with the mode shift factor rising from 0.34 in small cities to 0.455 in large cities. This number multiplied by the passenger revenue miles estimates the VMT reduced due to public transit use. VMT reductions can be converted to fuel savings estimates based on average fuel economy. Fuel savings can be converted to CO2-e savings estimates.

Transit reduces (displaces) Scope 3 GHG emissions in three ways:

1. Mode shift(transit riders take less private vehicle trips)
2. Congestion relief
3. Land use changes (i.e. land use multiplier)

APTA provides guidance on how to estimate each of these GHG reduction mechanisms at the transit agency level.

Key Assumptions:

Rail transit passenger miles will increase at the rate projected in each scenario.Rail transit agency capital and operating costs per passenger revenue mile will not change substantially during the

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[2] FTA. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/ntdprogram/.

[3] Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.

period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

Key Uncertainties (including sensitivities)

This analysis assumes certain projections, all of which are sensitive to a number of exogenous forces: Rail transit passenger miles will increase at the rate projected in each scenario. Rail transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

TLU – 2 / TL 2 - Portland Region Bus Transit

Measure Description

An important strategy in reducing GHG emissions produced from transportation sources is reducing the growth rate in per-capita VMT. Providing alternatives to the SOV has been shown to reduce the number of trips and VMT on the highway system. Modal alternatives can include bus transit and paratransit, rail transit, ridesharing, and vanpools (in addition to bicycling and walking, which are not addressed here).

Increased transit use is key to reducing the growth rate of VMT. A higher rate of transit use can be achieved by improving transit's competitiveness with other modes, expanding transit services, ensuring the safety and security of transit systems, and educating the public about transit options available in their community. Transit's competitiveness will be enhanced by providing the livable, walkable, complete streets context in which transit can be cost-effective.

Bus transit management and infrastructure strategies are intended to make public transit a practical transportation choice for people in Oregon. Increased use of bus transit that reduces reliance on private automobile travel can achieve a net reduction in transportation related energy demand and greenhouse gas (GHG) emissions. According to the U.S. Department of Transportation (DOT), the national average carbon dioxide (CO_2) emissions per passenger-mile for bus transit are only two-thirds of that for private automobile. When buses operate with all seats occupied, that fraction is reduced to less than one-fifth. Therefore, public transportation improvements are essential to reduce GHG emissions associated with transportation. This analysis focuses on strategies to increase bus transit passenger miles.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Passenger miles on transit buses increase at Oregon's projected population growth rate for different regions.

Low Federal Action: The Federal Government provides 100 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 0 percent of the funding for these capital investments. This scenario achieves 33 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal Action: The Federal Government provides 90 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 10 percent of the funding for these capital investments. This scenario achieves 66 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal and State Action: The Federal Government provides 50 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 50 percent of the funding for these capital investments. This scenario

achieves the following metro region increases in the amount of transit passenger miles between 2010 and 2035: Portland (2.12), Eugene (2.12), Salem (1.76), Medford (3.10), Bend (4.98), and Corvallis (2.21).

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2035 for all relevant transit agencies.

Parties Involved: Oregon transit agencies and the Oregon Department of Department.

Data Sources and Additional Background: The estimates of projected increases in passenger miles by transit agency were derived from the Oregon Department of Transportation's Statewide Transportation Strategy (2012). Current levels of transit passenger miles and service region population estimates for Oregon transit agencies were derived from the National Transit Database. Transit agency costs per passenger revenue mile were calculated based on cost data published in the annual financial reports of Oregon transit agencies. Officials from Portland's Tri-County Metropolitan Transportation District of Oregon (TriMet) and Eugene's Lane Transit District helped develop transit service and cost estimates. These officials also helped estimate the future capital and operating expenditures for each relevant transit agency.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0063	0.0126	0.0727	0.1672	$81.27	$186.93	$1,118.31	$1,118.31
#2: Moderate Federal Action	0.0126	0.0253	0.1454	0.3343	$219.22	$386.90	$1,508.22	$1,508.22
#3: Moderate Federal and State Action	0.0190	0.0383	0.1247	0.5065	$245.89	$665.21	$1,972.36	$1,313.27

Full Energy-Cycle

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0094	0.0189	0.1090	0.2507	$81.27	$186.93	$745.54	$745.54
#2: Moderate Federal Action	0.0188	0.0379	0.0379	0.5015	$168.22	$386.90	$771.54	$771.54
#3: Moderate Federal and State Action	0.0285	0.0574	0.1870	0.7598	$245.89	$665.21	$1,314.90	$875.51

Quantification Methods and Results:

Using the strategy goal, the associated GHG emission reductions were estimated using analytical methods developed by the American Public Transportation Association (APTA).[4] According to APTA, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

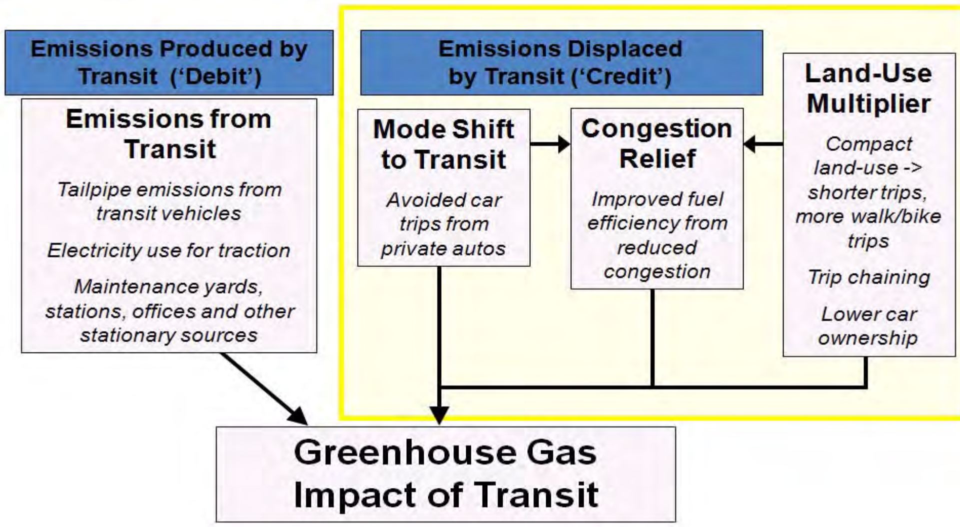
The analysis was performed using Jack Faucett Associates' TARGGET (Transit Associated Reduced Greenhouse Gas Emissions Tool) program. TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit agency passenger revenue miles and service area population and density. This allows the analysis to develop Oregon-specific estimates.

The transit analysis uses the American Public Transportation Association's (APTA) guidance on measuring transit's impacts on community wide greenhouse gas emissions. The title of the

[4] APTA. 2009. Quantifying Greenhouse Gas Emissions from Transit.

APTA guidance document is "Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit" (2010). The analysis performed for Oregon focuses on the greenhouse gas impacts related to mode shift and congestion relief associated with transit service.

Figure __. Overview of APTA Approach to Estimating the GHG Impacts of Public Transit



The methodology of our analysis comes from APTA's 2009 report, "Quantifying Greenhouse Gas Emissions from Transit." This report outlines how to quantify the displaced greenhouse gas emissions, in metric tons of CO2-equivalent, based on mode shifting, congestion relief, and the land-use multiplier. APTA provides several different methods of calculating these displaced emissions. Some are very time and resource intensive, requiring onsite surveys and regional analysis. However, APTA also propose methods that require only basic information regarding the transit service region, such as service region population, density, and transit use. For many transit systems this information can be found in the National Transit Database (NTD). Using transit agency specific data from the NTD avoided fuel use and greenhouse gas emissions facilitated by transit can be easily estimated for hundreds of transit agencies across the country.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA).[5] Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is also used to estimate gallons of fuel saved and the associated reduction in GHG emissions. The capital costs of the transit management and infrastructure were estimated using GHG emission reduction strategy cost estimates in the *Moving Cooler* report and a joint product cost allocation estimate.[6]

[5] FTA. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/ntdprogram/.

[6] Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.

APTA's methodology uses population, population density, and passenger revenue miles for a given transit service region in order to assess the community-wide fuel and greenhouse gas emissions savings facilitated by transit. The estimates are calculated through a multistep process. To calculate the effect of mode shifting, a mode shift factor must be calculated. This factor, when multiplied by passenger revenue miles determines how many VMT are displaced by the transit system. To determine a mode shift factor, APTA conducted national surveys of commuters to determine how they would commute in the absence of public transportation. The mode shift factor is the percentage of people that would drive plus those that would take a taxi, divided by 2.5 times the amount of people who would ride with somebody else. These results were then bracketed based on population into small, medium and large cities, with the mode shift factor rising from 0.34 in small cities to 0.455 in large cities. This number multiplied by the passenger revenue miles estimates the VMT reduced due to public transit use. VMT reductions can be converted to fuel savings estimates based on average fuel economy. Fuel savings can be converted to CO2-e savings estimates.

Transit reduces (displaces) Scope 3 GHG emissions in three ways:

1. Mode shift(transit riders take less private vehicle trips)
2. Congestion relief
3. Land use changes (i.e. land use multiplier)

APTA provides guidance on how to estimate each of these GHG reduction mechanisms at the transit agency level.

Key Assumptions:

Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

Key Uncertainties (including sensitivities)

This analysis assumes certain projections, all of which are sensitive to a number of exogenous forces: Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

TLU – 3 / TL 3 - Lane Transit District Region Bus Transit

Measure Description

An important strategy in reducing GHG emissions produced from transportation sources is reducing the growth rate in per-capita VMT. Providing alternatives to the SOV has been shown to reduce the number of trips and VMT on the highway system. Modal alternatives can include bus transit and paratransit, rail transit, ridesharing, and vanpools (in addition to bicycling and walking, which are not addressed here).

Increased transit use is key to reducing the growth rate of VMT. A higher rate of transit use can be achieved by improving transit's competitiveness with other modes, expanding transit services, ensuring the safety and security of transit systems, and educating the public about transit options available in their community. Transit's competitiveness will be enhanced by providing the livable, walkable, complete streets context in which transit can be cost-effective.

Bus transit management and infrastructure strategies are intended to make public transit a practical transportation choice for people in Oregon. Increased use of bus transit that reduces reliance on private automobile travel can achieve a net reduction in transportation related energy demand and greenhouse gas (GHG) emissions. According to the U.S. Department of Transportation (DOT), the national average carbon dioxide (CO2) emissions per passenger-mile for bus transit are only two-thirds of that for private automobile. When buses operate with all seats occupied, that fraction is reduced to less than one-fifth. Therefore, public transportation improvements are essential to reduce GHG emissions associated with transportation. This analysis focuses on strategies to increase bus transit passenger miles.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Passenger miles on transit buses increase at Oregon's projected population growth rate for different regions.

Low Federal Action: The Federal Government provides 100 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 0 percent of the funding for these capital investments. This scenario achieves 33 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal Action: The Federal Government provides 90 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 10 percent of the funding for these capital investments. This scenario achieves 66 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal and State Action: The Federal Government provides 50 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 50 percent of the funding for these capital investments. This scenario

achieves the following metro region increases in the amount of transit passenger miles between 2010 and 2035: Portland (2.12), Eugene (2.12), Salem (1.76), Medford (3.10), Bend (4.98), and Corvallis (2.21).

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2035 for all relevant transit agencies.

Parties Involved: Oregon transit agencies and the Oregon Department of Department.

Data Sources and Additional Background: The estimates of projected increases in passenger miles by transit agency were derived from the Oregon Department of Transportation's Statewide Transportation Strategy (2012). Current levels of transit passenger miles and service region population estimates for Oregon transit agencies were derived from the National Transit Database. Transit agency costs per passenger revenue mile were calculated based on cost data published in the annual financial reports of Oregon transit agencies. Officials from Portland's Tri-County Metropolitan Transportation District of Oregon (TriMet) and Eugene's Lane Transit District helped develop transit service and cost estimates. These officials also helped estimate the future capital and operating expenditures for each relevant transit agency.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO2e)	2013-2035 CE ($/tCO2e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0009	0.0018	0.0103	0.0238	$15.54	$35.75	$1,502.14	$1,502.14
#2: Moderate Federal Action	0.0018	0.0036	0.0207	0.0476	$48.70	$75.54	$2,353.45	$2,353.45
#3: Moderate Federal and State Action	0.0027	0.0055	0.0176	0.0721	$62.76	$139.02	$3,570.15	$1,927.80

Full Energy-Cycle

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0013	0.0027	0.0155	0.0357	$15.54	$35.75	$1,001.43	$1,001.43
#2: Moderate Federal Action	0.0027	0.0054	0.0054	0.0714	$32.85	$75.54	$1,058.18	$1,058.18
#3: Moderate Federal and State Action	0.0041	0.0082	0.0264	0.1082	$62.76	$139.02	$2,380.10	$1,285.20

Quantification Methods and Results:

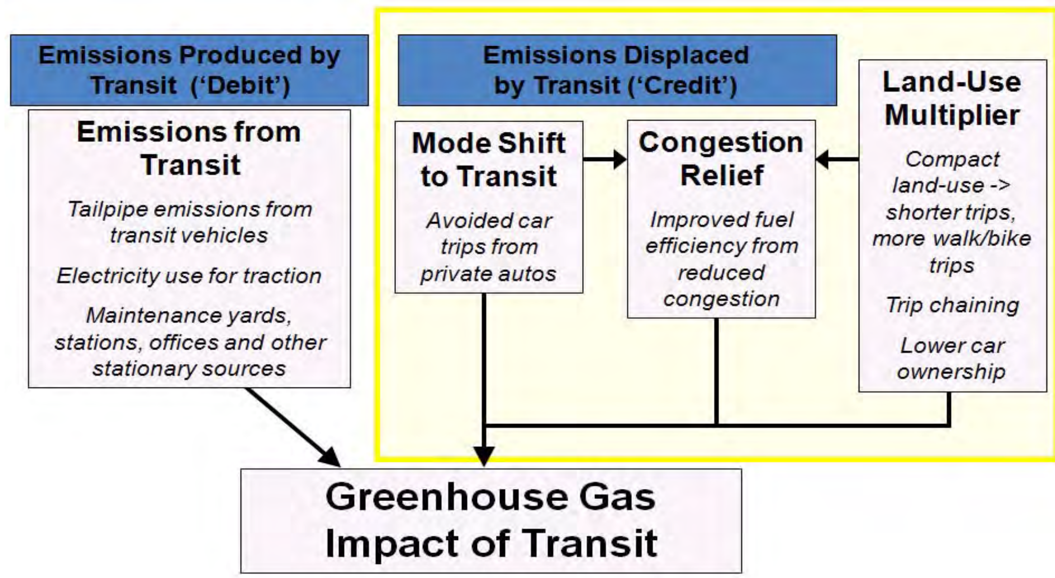
Using the strategy goal, the associated GHG emission reductions were estimated using analytical methods developed by the American Public Transportation Association (APTA).[7] According to APTA, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

The analysis was performed using Jack Faucett Associates' TARGGET (Transit Associated Reduced Greenhouse Gas Emissions Tool) program. TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit agency passenger revenue miles and service area population and density. This allows the analysis to develop Oregon-specific estimates.

[7] APTA. 2009. Quantifying Greenhouse Gas Emissions from Transit.

The transit analysis uses the American Public Transportation Association's (APTA) guidance on measuring transit's impacts on community wide greenhouse gas emissions. The title of the APTA guidance document is "Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit" (2010). The analysis performed for Oregon focuses on the greenhouse gas impacts related to mode shift and congestion relief associated with transit service.

Figure __. Overview of APTA Approach to Estimating the GHG Impacts of Public Transit



The methodology of our analysis comes from APTA's 2009 report, "Quantifying Greenhouse Gas Emissions from Transit." This report outlines how to quantify the displaced greenhouse gas emissions, in metric tons of CO2-equivalent, based on mode shifting, congestion relief, and the land-use multiplier. APTA provides several different methods of calculating these displaced emissions. Some are very time and resource intensive, requiring onsite surveys and regional analysis. However, APTA also propose methods that require only basic information regarding the transit service region, such as service region population, density, and transit use. For many transit systems this information can be found in the National Transit Database (NTD). Using transit agency specific data from the NTD avoided fuel use and greenhouse gas emissions facilitated by transit can be easily estimated for hundreds of transit agencies across the country.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA).[8] Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is also used to estimate gallons of fuel saved and the associated reduction in GHG emissions. The capital costs of the transit management and infrastructure were estimated using GHG emission

[8] FTA. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/ntdprogram/.

reduction strategy cost estimates in the *Moving Cooler* report and a joint product cost allocation estimate.[9]

APTA's methodology uses population, population density, and passenger revenue miles for a given transit service region in order to assess the community-wide fuel and greenhouse gas emissions savings facilitated by transit. The estimates are calculated through a multistep process. To calculate the effect of mode shifting, a mode shift factor must be calculated. This factor, when multiplied by passenger revenue miles determines how many VMT are displaced by the transit system. To determine a mode shift factor, APTA conducted national surveys of commuters to determine how they would commute in the absence of public transportation. The mode shift factor is the percentage of people that would drive plus those that would take a taxi, divided by 2.5 times the amount of people who would ride with somebody else. These results were then bracketed based on population into small, medium and large cities, with the mode shift factor rising from 0.34 in small cities to 0.455 in large cities. This number multiplied by the passenger revenue miles estimates the VMT reduced due to public transit use. VMT reductions can be converted to fuel savings estimates based on average fuel economy. Fuel savings can be converted to CO2-e savings estimates.

Transit reduces (displaces) Scope 3 GHG emissions in three ways:

1. Mode shift(transit riders take less private vehicle trips)
2. Congestion relief
3. Land use changes (i.e. land use multiplier)

APTA provides guidance on how to estimate each of these GHG reduction mechanisms at the transit agency level.

Key Assumptions:

Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

Key Uncertainties (including sensitivities)

This analysis assumes certain projections, all of which are sensitive to a number of exogenous forces: Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

[9] Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.

TLU – 4 / TL 4 - Salem Area Region Bus Transit

Measure Description

An important strategy in reducing GHG emissions produced from transportation sources is reducing the growth rate in per-capita VMT. Providing alternatives to the SOV has been shown to reduce the number of trips and VMT on the highway system. Modal alternatives can include bus transit and paratransit, rail transit, ridesharing, and vanpools (in addition to bicycling and walking, which are not addressed here).

Increased transit use is key to reducing the growth rate of VMT. A higher rate of transit use can be achieved by improving transit's competitiveness with other modes, expanding transit services, ensuring the safety and security of transit systems, and educating the public about transit options available in their community. Transit's competitiveness will be enhanced by providing the livable, walkable, complete streets context in which transit can be cost-effective.

Bus transit management and infrastructure strategies are intended to make public transit a practical transportation choice for people in Oregon. Increased use of bus transit that reduces reliance on private automobile travel can achieve a net reduction in transportation related energy demand and greenhouse gas (GHG) emissions. According to the U.S. Department of Transportation (DOT), the national average carbon dioxide (CO2) emissions per passenger-mile for bus transit are only two-thirds of that for private automobile. When buses operate with all seats occupied, that fraction is reduced to less than one-fifth. Therefore, public transportation improvements are essential to reduce GHG emissions associated with transportation. This analysis focuses on strategies to increase bus transit passenger miles.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Passenger miles on transit buses increase at Oregon's projected population growth rate for different regions.

Low Federal Action: The Federal Government provides 100 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 0 percent of the funding for these capital investments. This scenario achieves 33 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal Action: The Federal Government provides 90 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 10 percent of the funding for these capital investments. This scenario achieves 66 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal and State Action: The Federal Government provides 50 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 50 percent of the funding for these capital investments. This scenario

achieves the following metro region increases in the amount of transit passenger miles between 2010 and 2035: Portland (2.12), Eugene (2.12), Salem (1.76), Medford (3.10), Bend (4.98), and Corvallis (2.21).

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2035 for all relevant transit agencies.

Parties Involved: Oregon transit agencies and the Oregon Department of Department.

Data Sources and Additional Background: The estimates of projected increases in passenger miles by transit agency were derived from the Oregon Department of Transportation's Statewide Transportation Strategy (2012). Current levels of transit passenger miles and service region population estimates for Oregon transit agencies were derived from the National Transit Database. Transit agency costs per passenger revenue mile were calculated based on cost data published in the annual financial reports of Oregon transit agencies. Officials from Portland's Tri-County Metropolitan Transportation District of Oregon (TriMet) and Eugene's Lane Transit District helped develop transit service and cost estimates. These officials also helped estimate the future capital and operating expenditures for each relevant transit agency.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Point-of-combustion Results:

	GHG Reductions (MMtCO$_2$e)							
Scenario	2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
#1: Low Federal Action	0.0001	0.0002	0.0010	0.0024	$0.88	$2.03	$862.53	$862.53
#2: Moderate Federal Action	0.0002	0.0004	0.0021	0.0047	$2.32	$4.19	$1,132.25	$1,132.25
#3: Moderate Federal and State Action	0.0003	0.0005	0.0027	0.0071	$17.81	$7.13	$6,654.85	$997.39

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0001	0.0003	0.0015	0.0035	$0.88	$2.03	$575.02	$575.02
#2: Moderate Federal Action	0.0003	0.0005	0.0005	0.0071	$1.82	$4.19	$593.00	$593.00
#3: Moderate Federal and State Action	0.0004	0.0008	0.0040	0.0107	$17.81	$7.13	$4,436.57	$664.93

Quantification Methods and Results:

Using the strategy goal, the associated GHG emission reductions were estimated using analytical methods developed by the American Public Transportation Association (APTA).[10] According to APTA, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

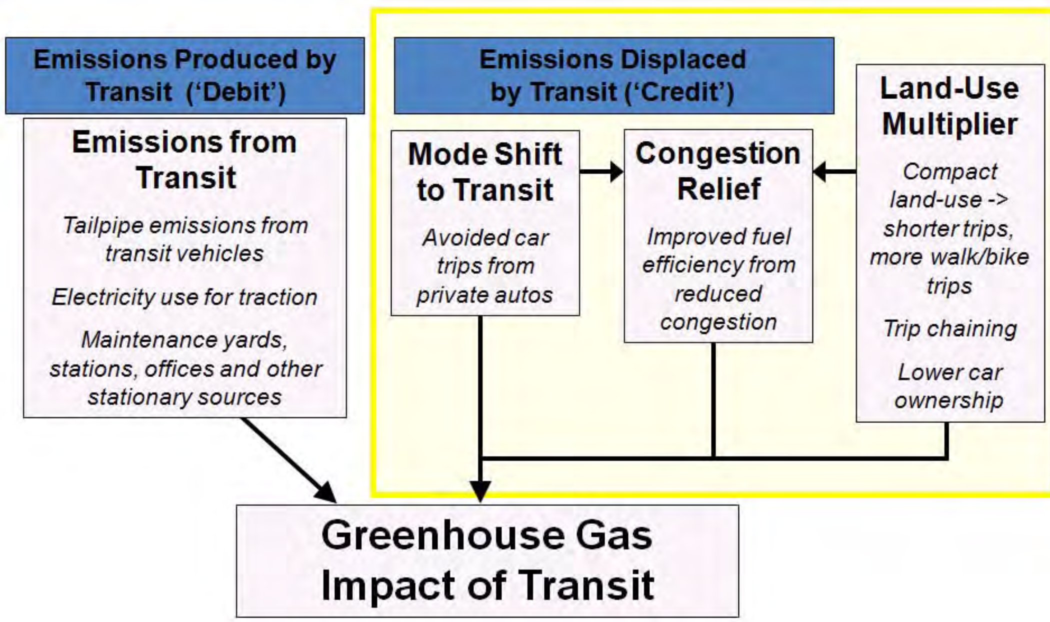
The analysis was performed using Jack Faucett Associates' TARGGET (Transit Associated Reduced Greenhouse Gas Emissions Tool) program. TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit

[10] APTA. 2009. Quantifying Greenhouse Gas Emissions from Transit.

agency passenger revenue miles and service area population and density. This allows the analysis to develop Oregon-specific estimates.

The transit analysis uses the American Public Transportation Association's (APTA) guidance on measuring transit's impacts on community wide greenhouse gas emissions. The title of the APTA guidance document is "Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit" (2010). The analysis performed for Oregon focuses on the greenhouse gas impacts related to mode shift and congestion relief associated with transit service.

Figure __. Overview of APTA Approach to Estimating the GHG Impacts of Public Transit



The methodology of our analysis comes from APTA's 2009 report, "Quantifying Greenhouse Gas Emissions from Transit." This report outlines how to quantify the displaced greenhouse gas emissions, in metric tons of CO2-equivalent, based on mode shifting, congestion relief, and the land-use multiplier. APTA provides several different methods of calculating these displaced emissions. Some are very time and resource intensive, requiring onsite surveys and regional analysis. However, APTA also propose methods that require only basic information regarding the transit service region, such as service region population, density, and transit use. For many transit systems this information can be found in the National Transit Database (NTD). Using transit agency specific data from the NTD avoided fuel use and greenhouse gas emissions facilitated by transit can be easily estimated for hundreds of transit agencies across the country.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA).[11] Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is

[11] FTA. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/ntdprogram/.

also used to estimate gallons of fuel saved and the associated reduction in GHG emissions. The capital costs of the transit management and infrastructure were estimated using GHG emission reduction strategy cost estimates in the *Moving Cooler* report and a joint product cost allocation estimate.[12]

APTA's methodology uses population, population density, and passenger revenue miles for a given transit service region in order to assess the community-wide fuel and greenhouse gas emissions savings facilitated by transit. The estimates are calculated through a multistep process. To calculate the effect of mode shifting, a mode shift factor must be calculated. This factor, when multiplied by passenger revenue miles determines how many VMT are displaced by the transit system. To determine a mode shift factor, APTA conducted national surveys of commuters to determine how they would commute in the absence of public transportation. The mode shift factor is the percentage of people that would drive plus those that would take a taxi, divided by 2.5 times the amount of people who would ride with somebody else. These results were then bracketed based on population into small, medium and large cities, with the mode shift factor rising from 0.34 in small cities to 0.455 in large cities. This number multiplied by the passenger revenue miles estimates the VMT reduced due to public transit use. VMT reductions can be converted to fuel savings estimates based on average fuel economy. Fuel savings can be converted to CO2-e savings estimates.

Transit reduces (displaces) Scope 3 GHG emissions in three ways:

1. Mode shift(transit riders take less private vehicle trips)
2. Congestion relief
3. Land use changes (i.e. land use multiplier)

APTA provides guidance on how to estimate each of these GHG reduction mechanisms at the transit agency level.

Key Assumptions:

Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

Key Uncertainties (including sensitivities)

This analysis assumes certain projections, all of which are sensitive to a number of exogenous forces: Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

[12] Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.

TLU – 5 / TL 5 - Rogue Valley Region Bus Transit

Measure Description

An important strategy in reducing GHG emissions produced from transportation sources is reducing the growth rate in per-capita VMT. Providing alternatives to the SOV has been shown to reduce the number of trips and VMT on the highway system. Modal alternatives can include bus transit and paratransit, rail transit, ridesharing, and vanpools (in addition to bicycling and walking, which are not addressed here).

Increased transit use is key to reducing the growth rate of VMT. A higher rate of transit use can be achieved by improving transit's competitiveness with other modes, expanding transit services, ensuring the safety and security of transit systems, and educating the public about transit options available in their community. Transit's competitiveness will be enhanced by providing the livable, walkable, complete streets context in which transit can be cost-effective.

Bus transit management and infrastructure strategies are intended to make public transit a practical transportation choice for people in Oregon. Increased use of bus transit that reduces reliance on private automobile travel can achieve a net reduction in transportation related energy demand and greenhouse gas (GHG) emissions. According to the U.S. Department of Transportation (DOT), the national average carbon dioxide (CO2) emissions per passenger-mile for bus transit are only two-thirds of that for private automobile. When buses operate with all seats occupied, that fraction is reduced to less than one-fifth. Therefore, public transportation improvements are essential to reduce GHG emissions associated with transportation. This analysis focuses on strategies to increase bus transit passenger miles.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Passenger miles on transit buses increase at Oregon's projected population growth rate for different regions.

Low Federal Action: The Federal Government provides 100 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 0 percent of the funding for these capital investments. This scenario achieves 33 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal Action: The Federal Government provides 90 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 10 percent of the funding for these capital investments. This scenario achieves 66 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal and State Action: The Federal Government provides 50 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 50 percent of the funding for these capital investments. This scenario

achieves the following metro region increases in the amount of transit passenger miles between 2010 and 2035: Portland (2.12), Eugene (2.12), Salem (1.76), Medford (3.10), Bend (4.98), and Corvallis (2.21).

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2035 for all relevant transit agencies.

Parties Involved: Oregon transit agencies and the Oregon Department of Department.

Data Sources and Additional Background: The estimates of projected increases in passenger miles by transit agency were derived from the Oregon Department of Transportation's Statewide Transportation Strategy (2012). Current levels of transit passenger miles and service region population estimates for Oregon transit agencies were derived from the National Transit Database. Transit agency costs per passenger revenue mile were calculated based on cost data published in the annual financial reports of Oregon transit agencies. Officials from Portland's Tri-County Metropolitan Transportation District of Oregon (TriMet) and Eugene's Lane Transit District helped develop transit service and cost estimates. These officials also helped estimate the future capital and operating expenditures for each relevant transit agency.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO_2e$)	2013-2035 CE ($/tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0002	0.0004	0.0024	0.0056	$3.03	$6.96	$1,235.82	$1,235.82
#2: Moderate Federal Action	0.0004	0.0008	0.0049	0.0113	$8.38	$14.46	$1,710.57	$1,710.57
#3: Moderate Federal and State Action	0.0006	0.0013	0.0041	0.0171	$12.30	$25.14	$2,965.82	$1,473.20

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0003	0.0006	0.0037	0.0084	$3.03	$6.96	$823.88	$823.88
#2: Moderate Federal Action	0.0006	0.0013	0.0013	0.0169	$6.29	$14.46	$855.53	$855.53
#3: Moderate Federal and State Action	0.0010	0.0019	0.0062	0.0256	$12.30	$25.14	$1,977.22	$982.13

Quantification Methods and Results:

Using the strategy goal, the associated GHG emission reductions were estimated using analytical methods developed by the American Public Transportation Association (APTA).[13] According to APTA, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

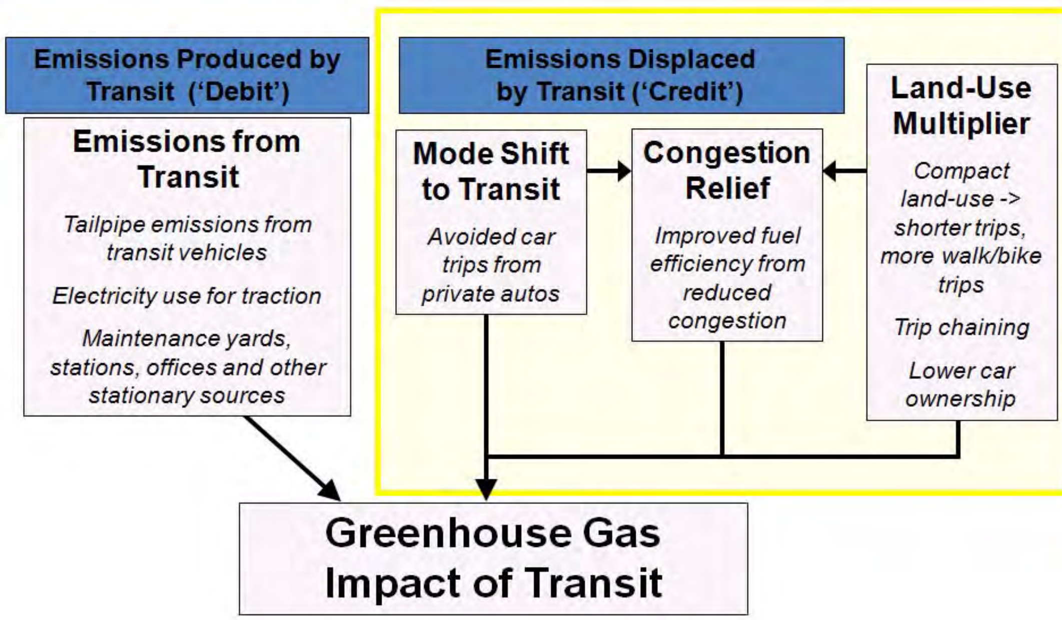
The analysis was performed using Jack Faucett Associates' TARGGET (Transit Associated Reduced Greenhouse Gas Emissions Tool) program. TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit

[13] APTA. 2009. Quantifying Greenhouse Gas Emissions from Transit.

agency passenger revenue miles and service area population and density. This allows the analysis to develop Oregon-specific estimates.

The transit analysis uses the American Public Transportation Association's (APTA) guidance on measuring transit's impacts on community wide greenhouse gas emissions. The title of the APTA guidance document is "Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit" (2010). The analysis performed for Oregon focuses on the greenhouse gas impacts related to mode shift and congestion relief associated with transit service.

Figure __. Overview of APTA Approach to Estimating the GHG Impacts of Public Transit



The methodology of our analysis comes from APTA's 2009 report, "Quantifying Greenhouse Gas Emissions from Transit." This report outlines how to quantify the displaced greenhouse gas emissions, in metric tons of CO2-equivalent, based on mode shifting, congestion relief, and the land-use multiplier. APTA provides several different methods of calculating these displaced emissions. Some are very time and resource intensive, requiring onsite surveys and regional analysis. However, APTA also propose methods that require only basic information regarding the transit service region, such as service region population, density, and transit use. For many transit systems this information can be found in the National Transit Database (NTD). Using transit agency specific data from the NTD avoided fuel use and greenhouse gas emissions facilitated by transit can be easily estimated for hundreds of transit agencies across the country.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA).[14] Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is

[14] FTA. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/ntdprogram/.

also used to estimate gallons of fuel saved and the associated reduction in GHG emissions. The capital costs of the transit management and infrastructure were estimated using GHG emission reduction strategy cost estimates in the *Moving Cooler* report and a joint product cost allocation estimate.[15]

APTA's methodology uses population, population density, and passenger revenue miles for a given transit service region in order to assess the community-wide fuel and greenhouse gas emissions savings facilitated by transit. The estimates are calculated through a multistep process. To calculate the effect of mode shifting, a mode shift factor must be calculated. This factor, when multiplied by passenger revenue miles determines how many VMT are displaced by the transit system. To determine a mode shift factor, APTA conducted national surveys of commuters to determine how they would commute in the absence of public transportation. The mode shift factor is the percentage of people that would drive plus those that would take a taxi, divided by 2.5 times the amount of people who would ride with somebody else. These results were then bracketed based on population into small, medium and large cities, with the mode shift factor rising from 0.34 in small cities to 0.455 in large cities. This number multiplied by the passenger revenue miles estimates the VMT reduced due to public transit use. VMT reductions can be converted to fuel savings estimates based on average fuel economy. Fuel savings can be converted to CO2-e savings estimates.

Transit reduces (displaces) Scope 3 GHG emissions in three ways:

1. Mode shift(transit riders take less private vehicle trips)
2. Congestion relief
3. Land use changes (i.e. land use multiplier)

APTA provides guidance on how to estimate each of these GHG reduction mechanisms at the transit agency level.

Key Assumptions:

Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

Key Uncertainties (including sensitivities)

This analysis assumes certain projections, all of which are sensitive to a number of exogenous forces: Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

[15] Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.

TLU – 6 / TL 6 - Bend Area Region Bus Transit

Measure Description

An important strategy in reducing GHG emissions produced from transportation sources is reducing the growth rate in per-capita VMT. Providing alternatives to the SOV has been shown to reduce the number of trips and VMT on the highway system. Modal alternatives can include bus transit and paratransit, rail transit, ridesharing, and vanpools (in addition to bicycling and walking, which are not addressed here).

Increased transit use is key to reducing the growth rate of VMT. A higher rate of transit use can be achieved by improving transit's competitiveness with other modes, expanding transit services, ensuring the safety and security of transit systems, and educating the public about transit options available in their community. Transit's competitiveness will be enhanced by providing the livable, walkable, complete streets context in which transit can be cost-effective.

Bus transit management and infrastructure strategies are intended to make public transit a practical transportation choice for people in Oregon. Increased use of bus transit that reduces reliance on private automobile travel can achieve a net reduction in transportation related energy demand and greenhouse gas (GHG) emissions. According to the U.S. Department of Transportation (DOT), the national average carbon dioxide (CO2) emissions per passenger-mile for bus transit are only two-thirds of that for private automobile. When buses operate with all seats occupied, that fraction is reduced to less than one-fifth. Therefore, public transportation improvements are essential to reduce GHG emissions associated with transportation. This analysis focuses on strategies to increase bus transit passenger miles.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Passenger miles on transit buses increase at Oregon's projected population growth rate for different regions.

Low Federal Action: The Federal Government provides 100 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 0 percent of the funding for these capital investments. This scenario achieves 33 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal Action: The Federal Government provides 90 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 10 percent of the funding for these capital investments. This scenario achieves 66 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal and State Action: The Federal Government provides 50 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 50 percent of the funding for these capital investments. This scenario

achieves the following metro region increases in the amount of transit passenger miles between 2010 and 2035: Portland (2.12), Eugene (2.12), Salem (1.76), Medford (3.10), Bend (4.98), and Corvallis (2.21).

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2035 for all relevant transit agencies.

Parties Involved: Oregon transit agencies and the Oregon Department of Department.

Data Sources and Additional Background: The estimates of projected increases in passenger miles by transit agency were derived from the Oregon Department of Transportation's Statewide Transportation Strategy (2012). Current levels of transit passenger miles and service region population estimates for Oregon transit agencies were derived from the National Transit Database. Transit agency costs per passenger revenue mile were calculated based on cost data published in the annual financial reports of Oregon transit agencies. Officials from Portland's Tri-County Metropolitan Transportation District of Oregon (TriMet) and Eugene's Lane Transit District helped develop transit service and cost estimates. These officials also helped estimate the future capital and operating expenditures for each relevant transit agency.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Point-of-combustion Results:

	GHG Reductions ($MMtCO_2e$)							
Scenario	2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0004	0.0008	0.0044	0.0100	$3.12	$7.18	$715.86	$715.86
#2: Moderate Federal Action	0.0008	0.0015	0.0087	0.0201	$8.02	$14.77	$919.20	$919.20
#3: Moderate Federal and State Action	0.0011	0.0023	0.0074	0.0304	$13.47	$24.86	$1,831.20	$817.53

Full Energy-Cycle Results:

Scenario	GHG Reductions (MMtCO2e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO2e)	2013-2035 CE ($/tCO2e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0006	0.0011	0.0065	0.0151	$3.12	$7.18	$477.24	$477.24
#2: Moderate Federal Action	0.0011	0.0023	0.0023	0.0301	$6.42	$14.77	$490.80	$490.80
#3: Moderate Federal and State Action	0.0017	0.0034	0.0110	0.0456	$13.47	$24.86	$1,220.80	$545.02

Quantification Methods and Results:

Using the strategy goal, the associated GHG emission reductions were estimated using analytical methods developed by the American Public Transportation Association (APTA).[16] According to APTA, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

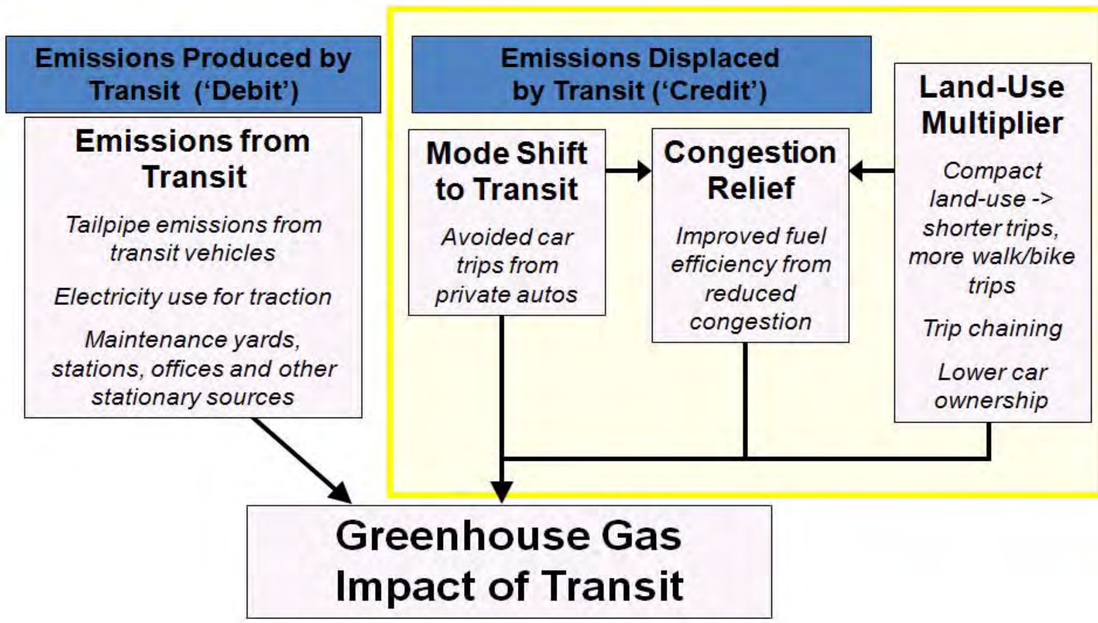
The analysis was performed using Jack Faucett Associates' TARGGET (Transit Associated Reduced Greenhouse Gas Emissions Tool) program. TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit agency passenger revenue miles and service area population and density. This allows the analysis to develop Oregon-specific estimates.

The transit analysis uses the American Public Transportation Association's (APTA) guidance on measuring transit's impacts on community wide greenhouse gas emissions. The title of the

[16] APTA. 2009. Quantifying Greenhouse Gas Emissions from Transit.

APTA guidance document is "Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit" (2010). The analysis performed for Oregon focuses on the greenhouse gas impacts related to mode shift and congestion relief associated with transit service.

Figure __. Overview of APTA Approach to Estimating the GHG Impacts of Public Transit



The methodology of our analysis comes from APTA's 2009 report, "Quantifying Greenhouse Gas Emissions from Transit." This report outlines how to quantify the displaced greenhouse gas emissions, in metric tons of CO2-equivalent, based on mode shifting, congestion relief, and the land-use multiplier. APTA provides several different methods of calculating these displaced emissions. Some are very time and resource intensive, requiring onsite surveys and regional analysis. However, APTA also propose methods that require only basic information regarding the transit service region, such as service region population, density, and transit use. For many transit systems this information can be found in the National Transit Database (NTD). Using transit agency specific data from the NTD avoided fuel use and greenhouse gas emissions facilitated by transit can be easily estimated for hundreds of transit agencies across the country.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA).[17] Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is also used to estimate gallons of fuel saved and the associated reduction in GHG emissions. The capital costs of the transit management and infrastructure were estimated using GHG emission

[17] FTA. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/ntdprogram/.

reduction strategy cost estimates in the *Moving Cooler* report and a joint product cost allocation estimate.[18]

APTA's methodology uses population, population density, and passenger revenue miles for a given transit service region in order to assess the community-wide fuel and greenhouse gas emissions savings facilitated by transit. The estimates are calculated through a multistep process. To calculate the effect of mode shifting, a mode shift factor must be calculated. This factor, when multiplied by passenger revenue miles determines how many VMT are displaced by the transit system. To determine a mode shift factor, APTA conducted national surveys of commuters to determine how they would commute in the absence of public transportation. The mode shift factor is the percentage of people that would drive plus those that would take a taxi, divided by 2.5 times the amount of people who would ride with somebody else. These results were then bracketed based on population into small, medium and large cities, with the mode shift factor rising from 0.34 in small cities to 0.455 in large cities. This number multiplied by the passenger revenue miles estimates the VMT reduced due to public transit use. VMT reductions can be converted to fuel savings estimates based on average fuel economy. Fuel savings can be converted to CO2-e savings estimates.

Transit reduces (displaces) Scope 3 GHG emissions in three ways:

1. Mode shift(transit riders take less private vehicle trips)
2. Congestion relief
3. Land use changes (i.e. land use multiplier)

APTA provides guidance on how to estimate each of these GHG reduction mechanisms at the transit agency level.

Key Assumptions:

Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

Key Uncertainties (including sensitivities)

This analysis assumes certain projections, all of which are sensitive to a number of exogenous forces: Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

[18] Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.

TLU – 7 / TL 7 - Corvallis Region Bus Transit

Measure Description

An important strategy in reducing GHG emissions produced from transportation sources is reducing the growth rate in per-capita VMT. Providing alternatives to the SOV has been shown to reduce the number of trips and VMT on the highway system. Modal alternatives can include bus transit and paratransit, rail transit, ridesharing, and vanpools (in addition to bicycling and walking, which are not addressed here).

Increased transit use is key to reducing the growth rate of VMT. A higher rate of transit use can be achieved by improving transit's competitiveness with other modes, expanding transit services, ensuring the safety and security of transit systems, and educating the public about transit options available in their community. Transit's competitiveness will be enhanced by providing the livable, walkable, complete streets context in which transit can be cost-effective.

Bus transit management and infrastructure strategies are intended to make public transit a practical transportation choice for people in Oregon. Increased use of bus transit that reduces reliance on private automobile travel can achieve a net reduction in transportation related energy demand and greenhouse gas (GHG) emissions. According to the U.S. Department of Transportation (DOT), the national average carbon dioxide (CO2) emissions per passenger-mile for bus transit are only two-thirds of that for private automobile. When buses operate with all seats occupied, that fraction is reduced to less than one-fifth. Therefore, public transportation improvements are essential to reduce GHG emissions associated with transportation. This analysis focuses on strategies to increase bus transit passenger miles.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Passenger miles on transit buses increase at Oregon's projected population growth rate for different regions.

Low Federal Action: The Federal Government provides 100 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 0 percent of the funding for these capital investments. This scenario achieves 33 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal Action: The Federal Government provides 90 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 10 percent of the funding for these capital investments. This scenario achieves 66 percent of the increase in bus transit passenger miles achieved in the Moderate Federal and State Action scenario.

Moderate Federal and State Action: The Federal Government provides 50 percent of future capital investments to expand transit ridership at Oregon transit agencies. The State Government provides 50 percent of the funding for these capital investments. This scenario

achieves the following metro region increases in the amount of transit passenger miles between 2010 and 2035: Portland (2.12), Eugene (2.12), Salem (1.76), Medford (3.10), Bend (4.98), and Corvallis (2.21).

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2035 for all relevant transit agencies.

Parties Involved: Oregon transit agencies and the Oregon Department of Department.

Data Sources and Additional Background: The estimates of projected increases in passenger miles by transit agency were derived from the Oregon Department of Transportation's Statewide Transportation Strategy (2012). Current levels of transit passenger miles and service region population estimates for Oregon transit agencies were derived from the National Transit Database. Transit agency costs per passenger revenue mile were calculated based on cost data published in the annual financial reports of Oregon transit agencies. Officials from Portland's Tri-County Metropolitan Transportation District of Oregon (TriMet) and Eugene's Lane Transit District helped develop transit service and cost estimates. These officials also helped estimate the future capital and operating expenditures for each relevant transit agency.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0001	0.0002	0.0010	0.0024	$0.88	$2.03	$862.53	$862.53
#2: Moderate Federal Action	0.0002	0.0004	0.0021	0.0047	$2.32	$4.19	$1,132.25	$1,132.25
#3: Moderate Federal and State Action	0.0003	0.0005	0.0017	0.0071	$3.20	$7.13	$1,843.37	$997.39

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)	2013-2022			

	2022	2035	Total (2013-2022)	Total (2013-2035)	NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
#1: Low Federal Action	0.0001	0.0003	0.0015	0.0035	$0.88	$2.03	$575.02	$575.02
#2: Moderate Federal Action	0.0003	0.0005	0.0005	0.0071	$1.82	$4.19	$593.00	$593.00
#3: Moderate Federal and State Action	0.0004	0.0008	0.0026	0.0107	$3.20	$7.13	$1,228.92	$664.93

Quantification Methods and Results:

Using the strategy goal, the associated GHG emission reductions were estimated using analytical methods developed by the American Public Transportation Association (APTA).[19] According to APTA, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

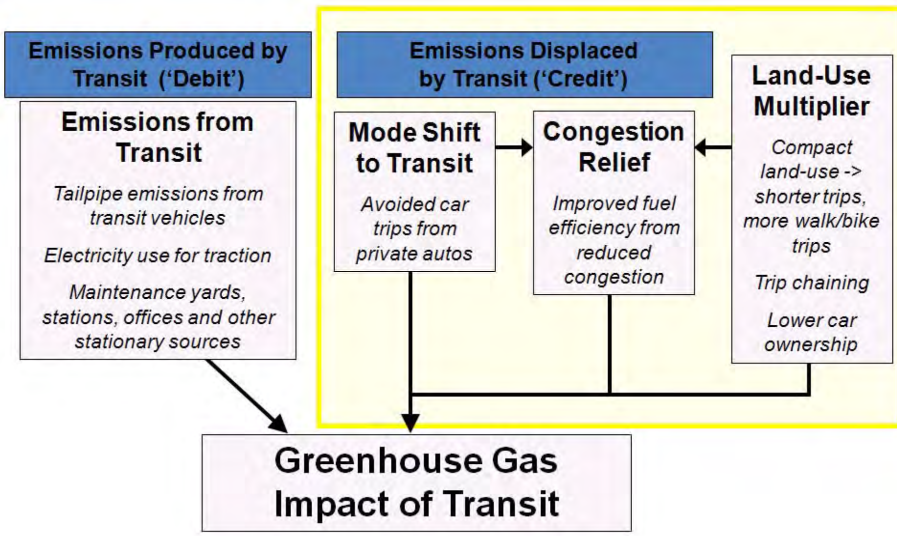
The analysis was performed using Jack Faucett Associates' TARGGET (Transit Associated Reduced Greenhouse Gas Emissions Tool) program. TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit agency passenger revenue miles and service area population and density. This allows the analysis to develop Oregon-specific estimates.

The transit analysis uses the American Public Transportation Association's (APTA) guidance on measuring transit's impacts on community wide greenhouse gas emissions. The title of the APTA guidance document is "Recommended Practice for Quantifying Greenhouse Gas

[19] APTA. 2009. Quantifying Greenhouse Gas Emissions from Transit.

Emissions from Transit" (2010). The analysis performed for Oregon focuses on the greenhouse gas impacts related to mode shift and congestion relief associated with transit service.

Figure __. Overview of APTA Approach to Estimating the GHG Impacts of Public Transit



The methodology of our analysis comes from APTA's 2009 report, "Quantifying Greenhouse Gas Emissions from Transit." This report outlines how to quantify the displaced greenhouse gas emissions, in metric tons of CO2-equivalent, based on mode shifting, congestion relief, and the land-use multiplier. APTA provides several different methods of calculating these displaced emissions. Some are very time and resource intensive, requiring onsite surveys and regional analysis. However, APTA also propose methods that require only basic information regarding the transit service region, such as service region population, density, and transit use. For many transit systems this information can be found in the National Transit Database (NTD). Using transit agency specific data from the NTD avoided fuel use and greenhouse gas emissions facilitated by transit can be easily estimated for hundreds of transit agencies across the country.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA).[20] Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is also used to estimate gallons of fuel saved and the associated reduction in GHG emissions. The capital costs of the transit management and infrastructure were estimated using GHG emission reduction strategy cost estimates in the *Moving Cooler* report and a joint product cost allocation estimate.[21]

[20] FTA. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/ntdprogram/.

[21] Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.

APTA's methodology uses population, population density, and passenger revenue miles for a given transit service region in order to assess the community-wide fuel and greenhouse gas emissions savings facilitated by transit. The estimates are calculated through a multistep process. To calculate the effect of mode shifting, a mode shift factor must be calculated. This factor, when multiplied by passenger revenue miles determines how many VMT are displaced by the transit system. To determine a mode shift factor, APTA conducted national surveys of commuters to determine how they would commute in the absence of public transportation. The mode shift factor is the percentage of people that would drive plus those that would take a taxi, divided by 2.5 times the amount of people who would ride with somebody else. These results were then bracketed based on population into small, medium and large cities, with the mode shift factor rising from 0.34 in small cities to 0.455 in large cities. This number multiplied by the passenger revenue miles estimates the VMT reduced due to public transit use. VMT reductions can be converted to fuel savings estimates based on average fuel economy. Fuel savings can be converted to CO2-e savings estimates.

Transit reduces (displaces) Scope 3 GHG emissions in three ways:

1. Mode shift(transit riders take less private vehicle trips)
2. Congestion relief
3. Land use changes (i.e. land use multiplier)

APTA provides guidance on how to estimate each of these GHG reduction mechanisms at the transit agency level.

Key Assumptions:

Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

Key Uncertainties (including sensitivities)

This analysis assumes certain projections, all of which are sensitive to a number of exogenous forces: Transit passenger miles will increase at the rate projected in each scenario. Transit agency capital and operating costs per passenger revenue mile will not change substantially during the period of analysis. Future transit agency capital and operating costs will not change substantially during the period of analysis.

TLU – 8 / TL 8 - Land Use

Measure Description

Land Use Strategies include multiple methods for optimizing the consumption of land and the distribution of a growing population. Specific strategies include transit-oriented and mixed-use development, infill and brownfield redevelopment, and funding for mixed-income and affordable housing.

This strategy focuses on transit-oriented development (TOD), the creation of compact, mixed-use commercial or residential communities designed to maximize access to public transit and create a community attractive to pedestrians and bicyclists. Policies that support TOD provide economic incentives, reformed zoning, land-use restrictions, and permit streamlining to encourage dense mixed-use development of properties in proximity to transit stations or facilities. They can promote overall targeted infrastructure investment section toward priority growth centers by providing funding, grant programs, and tax cuts to promote the creation of priority growth centers.

Infill and brownfield redevelopment is the repurposing of previously underutilized land to increase density, manage sprawl or revitalize neighborhoods. Land use strategies might provide economic incentives, reformed zoning, and land-use restrictions, and permit streamlining to encourage development of empty or underutilized industrial facilities and derelict properties in urban areas that includes urban-like areas within suburbs. Public-Private Partnerships can be considered as a funding source. In addition, this option is likely to consider the concept of adaptive reuse and include building maintenance. Redevelopment in urban areas can be a key factor in urban revitalization, providing new centrally located areas for residential, commercial, or mixed-use development. There are a number of public incentives for encouraging development and redevelopment near transit.

This policy is intended to increase the number of walkable, bikable, compact, and mixed-use communities, provide incentives for their development, and to extend these concepts in Oregon. This policy encourages an increase in transit-supported dense communities.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Transit-supported communities observe land use related greenhouse gas emission savings that increase annually at the population growth rate for individual regions.

Low Federal Action: The Federal Government provides 100 percent of future land use associated capital investments related to transit. The State Government provides 0 percent of the funding for these capital investments. This scenario achieves 33 percent of the greenhouse gas emission savings in the Moderate Federal and State Action scenario.

Moderate Federal Action: The Federal Government provides 90 percent of future land use associated capital investments related to transit. The State Government provides 10 percent of the funding for these capital investments. This scenario achieves 66 percent of the greenhouse gas emission savings in the Moderate Federal and State Action scenario.

Moderate Federal and State Action: The Federal Government provides 50 percent of future land use associated capital investments related to transit. The State Government provides 50 percent of the funding for these capital investments.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2035.

Parties Involved: Oregon Department of Department.

Data Sources and Additional Background: The estimates of projected increases in land use related greenhouse gas emissions were derived from the Oregon Department of Transportation's Statewide Transportation Strategy (2012). Land use related regional transit patterns were derived from the National Transit Database.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0375	0.0823	0.4468	1.0276	($104.30)	($239.89)	($233.46)	($233.46)
#2: Moderate Federal Action	0.0742	0.1822	0.9370	2.1552	-$45.12	($487.59)	($48.16)	($48.16)
#3: Moderate Federal and State Action	0.1186	0.2924	0.7145	3.4628	($16.85)	($598.40)	($23.58)	($172.81)

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0562	0.1235	0.6702	1.5414	($104.30)	($239.89)	($155.64)	($155.64)

#2: Moderate Federal Action	0.1112	0.2733	0.2733	3.2328	($212.00)	($487.59)	($150.83)	($150.83)
#3: Moderate Federal and State Action	0.1779	0.4386	1.0717	5.1942	($16.85)	($598.40)	($15.72)	($115.21)

Quantification Methods and Results:

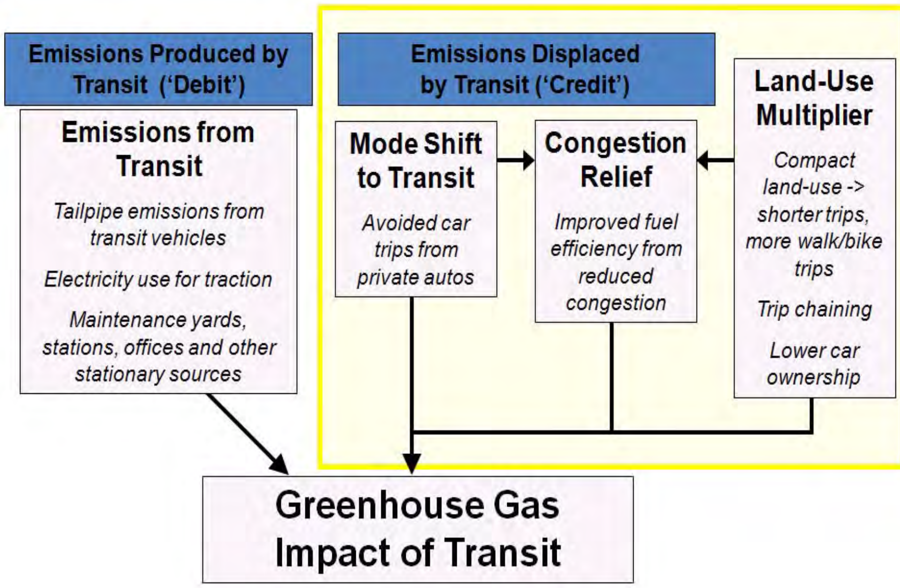
Using the strategy goal, the associated GHG emission reductions were estimated using analytical methods developed by the American Public Transportation Association (APTA).[22] According to APTA, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

The analysis was performed using Jack Faucett Associates' TARGGET (Transit Associated Reduced Greenhouse Gas Emissions Tool) program. TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit agency passenger revenue miles and service area population and density. This allows the analysis to develop Oregon-specific estimates.

The transit analysis uses the American Public Transportation Association's (APTA) guidance on measuring transit's impacts on community wide greenhouse gas emissions. The title of the APTA guidance document is "Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit" (2010). The analysis performed for Oregon focuses on the greenhouse gas impacts related to mode shift and congestion relief associated with transit service.

Figure __. Overview of APTA Approach to Estimating the GHG Impacts of Public Transit

[22] APTA. 2009. Quantifying Greenhouse Gas Emissions from Transit.



The methodology of our analysis comes from APTA's 2009 report, "Quantifying Greenhouse Gas Emissions from Transit." This report outlines how to quantify the displaced greenhouse gas emissions, in metric tons of CO2-equivalent, based on mode shifting, congestion relief, and the land-use multiplier. APTA provides several different methods of calculating these displaced emissions. Some are very time and resource intensive, requiring onsite surveys and regional analysis. However, APTA also propose methods that require only basic information regarding the transit service region, such as service region population, density, and transit use. For many transit systems this information can be found in the National Transit Database (NTD). Using transit agency specific data from the NTD avoided fuel use and greenhouse gas emissions facilitated by transit can be easily estimated for hundreds of transit agencies across the country.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA).[23] Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is also used to estimate gallons of fuel saved and the associated reduction in GHG emissions. The capital costs of the transit management and infrastructure were estimated using GHG emission reduction strategy cost estimates in the *Moving Cooler* report and a joint product cost allocation estimate.[24]

APTA's methodology uses population, population density, and passenger revenue miles for a given transit service region in order to assess the community-wide fuel and greenhouse gas emissions savings facilitated by transit. The estimates are calculated through a multistep process. To calculate the effect of mode shifting, a mode shift factor must be calculated. This factor, when multiplied by passenger revenue miles determines how many VMT are displaced by the

[23] FTA. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/ntdprogram/.

[24] Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.

transit system. To determine a mode shift factor, APTA conducted national surveys of commuters to determine how they would commute in the absence of public transportation. The mode shift factor is the percentage of people that would drive plus those that would take a taxi, divided by 2.5 times the amount of people who would ride with somebody else. These results were then bracketed based on population into small, medium and large cities, with the mode shift factor rising from 0.34 in small cities to 0.455 in large cities. This number multiplied by the passenger revenue miles estimates the VMT reduced due to public transit use. VMT reductions can be converted to fuel savings estimates based on average fuel economy. Fuel savings can be converted to CO2-e savings estimates.

Transit reduces (displaces) Scope 3 GHG emissions in three ways:

1. Mode shift(transit riders take less private vehicle trips)
2. Congestion relief
3. Land use changes (i.e. land use multiplier)

APTA provides guidance on how to estimate each of these GHG reduction mechanisms at the transit agency level.

The APTA equations can effectively estimate the effects of mode shifting and congestion relief, however, they do make major assumptions when calculating the effects of the land-use multiplier. When local analyses are too costly or resource intensive, they simply suggest using the default national average land-use multiplier of 1.9, as calculated by the ICF. This produces results that suggest a far more uniform effect of public transit on fuel consumption and greenhouse gas emissions than studies have shown. In order to account for regional variation and more accurately determine the regional land-use multipliers, a typology based on local demographics and transit use could be developed. Similar to APTA's calculations for the mode shift factor, which increases in scale based on tiered population levels, a typology for the land-use multiplier could provide a more specific estimation based on easily attainable demographics such as population.

In the development of a land-use multiplier typology, a logical starting place is to account for local population, population density, and passenger revenue miles. These factors are the primary ones in the other APTA calculations, so the data is readily available. Also, these are factors that have been shown to have a widespread effect on transit leverage. Population is a major factor as it frames the size of an urban region, and generally, the larger the city, the more opportunities become available with increased transportation. Population density has been found in several studies to be a major factor in transit leverage, as discussed in earlier sections. Density allows urban infrastructure to be accessed by many more people, conducive to commercial centers and job clusters. (Holtzclaw, 1991; Newman and Kenworthy, 1999). Finally, passenger revenue miles provides insight into the scale and effect of a transit system on local commuters. A populous region low passenger revenue miles, such as Los Angeles, will likely have a low land-use multiplier, as the public transit system is not a major means of transportation. However, high passenger revenue miles suggest that the system is of great importance to a regions commuters and the absence of such a system would have much greater effects on congestion and alternative transit.

During the transit analyses of the Los Angeles Southern California metropolitan region, Jack Faucett Associates developed a typology to more accurately calculate the land-use multiplier. The typology uses data from the National Transit Database to classify a land-use multiplier based on population, population density, and passenger revenue miles. The typology was calibrated based on the past research in order to maintain consistency with empirical evidence that has placed the land-use multiplier, largely between 1 and 9.

Key Assumptions:

Oregon's population by major metropolitan region will increase at the rate projected based on the Oregon Department of Transportation's Statewide Transportation Strategy (2012).

Key Uncertainties (including sensitivities)

This analysis assumes that Oregon's population by major metropolitan region will increase at the rate projected based on the Oregon Department of Transportation's Statewide Transportation Strategy (2012).

TLU – 9-21 / LCFS 1-13 – Low Carbon Fuels Options

The strategies analyzed are consistent with the scenarios for lower carbon transportation fuels developed as part of the larger statewide planning process. For further information about these options and data, please refer to the reports and data produced by the Oregon Department of Environmental Quality (ODEQ) as part of the Oregon Low Carbon Fuel Standard development process.

Measure Number	Measure Category for Microeconomic Analysis
TLU-9	LCFS1 -- MW Corn Ethanol
TLU-10	LCFS2 -- OR Corn Ethanol
TLU-11	LCFS3 -- Imported Cellulosic Ethanol
TLU-12	LCFS4 -- Oregon Wheat Straw Ethanol
TLU-13	LCFS5 -- Brazil Sugar Cane Ethanol
TLU-14	LCFS6 -- Low Carbon MW Corn
TLU-15	LCFS7 -- OR Cellulosic Ethanol
TLU-16	LCFS8 -- Cellulosic
TLU-17	LCFS9 -- CNG from biogas
TLU-18	LCFS10 -- Camelian RD
TLU-19	LCFS 11 -- NW Canola
TLU-20	LCFS 12 -- Waste Oil
TLU-21	LCFS 13 -- MW Soybean

This section presents the results of macroeconomic analyses of multiple scenarios seeking to model possible responses to a low-carbon fuel standard (LCFS) policy in the state of Oregon. While not all LCFS policies are equal, they are generally characterized by a focus on the intensity of emissions from fuel consumed, rather than on the exact type of fuel consumed. Unlike mandates to displace gasoline with ethanol or electricity, or to displace diesel with biodiesel, an LCFS strategy simply establishes an overall emissions standard for the fuel supply.

This approach seeks to create flexibility, allowing regulated parties to identify the most cost-effective path to compliance. There are many different fuels available to the transportation sector, including natural gas, electricity, and a wide variety of biofuels feed stocks, each with its own cost and its own greenhouse gas emissions intensity. This variety produces many different options for achievement of a lower-carbon fuel mix.

California was the first to enact an LCFS. This rule, which requires a 10% reduction in the carbon intensity of fuels by the year 2020, contains reduction targets for each year between 2011 and 2020. Oregon's proposed LCFS has the same intermediate requirements by which the fuel supply must meet progressively stricter standards over a ten-year span from 2012 through 2022. Improvements are mandated starting in 2013 and the final target is to be reached in the tenth year.

LCFS Bundles

The State of Oregon has proposed to adopt a Low Carbon Fuel Standard, a performance based program that has the goal of reducing greenhouse gas emissions from transportation fuels. This paper estimates Greenhouse Gas Emissions Reductions Potentials and costs that are associated with potential implementation scenarios for the program. Such policies mandate no specific fuel requirement, either by type or by volume of fuel. Instead, they only mandate an average carbon intensity standard for the fuel supply.

The State of Oregon has proposed to adopt a Low Carbon Fuel Standard, a performance based program that has the goal of reducing greenhouse gas emissions from transportation fuels. This paper estimates Greenhouse Gas Emissions Reductions Potentials and costs that are associated with potential implementation scenarios for the program. LCFS policies require that the fuel supply used become ten percent less carbon-intense over ten years. Such policies mandate no specific fuel requirement, either by type or by volume of fuel. Instead, they only mandate an average carbon intensity standard for the fuel supply. Such policies have been praised as economically beneficial because they could drive a shift from imported fuels to domestic fuels, but have been criticized because mandates may conflict with supply limitations, potentially driving up fuel prices and transportation costs. Scenarios considered include increased use of in-state biofuels, out-of-state or foreign biofuels, or natural gas and electrification.

OPTIONS FOR LCFS COMPLIANCE

Biofuels

The combustion of biofuels, a category which includes ethanol and biodiesel, generally emits less greenhouse gases per unit of energy than combustion of gasoline and diesel, when analyzed on a life cycle basis. Displacing conventional gas and diesel with biofuels, therefore, reduces the overall carbon intensity of the fuel mix and thus achieves progress toward LCFS targets.[25]

Electricity and Hybridization

By virtue of their comparative efficiency when compared against conventional fuels, electric vehicles are also beneficial to reaching an LCFS target. Electric vehicles and plug-in hybrid electric vehicles use an electric motor (either independently or in combination with a conventional engine) to achieve lower-carbon transportation.

These are included in LCFS strategies even though electricity from coal is actually significantly more carbon-intensive than gasoline or diesel, when measured per unit of energy. Electrification remains an option, however, because vehicular efficiency (how far the vehicle can go on the same amount of energy) is projected to be so much greater for these vehicles than for

[25] The carbon intensities discussed here are estimated on a "Life cycle" basis. Life cycle carbon intensities measure not only the greenhouse gases contained in the fuel and emitted from the tailpipe upon combustion, but also the emissions required to grow, harvest, refine and transport the fuels to market. Cellulosic fuels gain an advantage over corn primarily in these "upstream" phases – they require less energy to grow and refine than corn typically does, or are made from waste products. Calculations of life cycle greenhouse gas emissions are generated by DEQ and its contractor, TIAX LLC, using a model developed by DOE and can be independently assessed through the GREET emissions measurement tool, available at http://greet.es.anl.gov/. Oregon and TIAX have customized this GREET model to reflect Oregon-specific conditions.

conventional vehicles that it overwhelms the higher carbon intensity of electricity from fossil fuels. In Oregon, the future of electricity generation will become less carbon-intense due to a state renewable portfolio standard and the closure of its only coal-fired power plant.

Natural gas and biogas

The combustion of natural gas, either in compressed (CNG) or liquefied (LNG) form, generally emits less greenhouse gases per unit of energy than combustion of gasoline and diesel, when analyzed on a life cycle basis. Displacing conventional gas and diesel with natural gas, therefore, reduces the overall carbon intensity of the fuel mix and thus achieves progress toward LCFS targets. This is true despite adjustment for the fact that liquefied natural gas contains less energy per gallon than diesel, and consequently permits fewer miles of travel per gallon.

Unlike petroleum, most of which is imported, most natural gas is domestically produced, allowing the positive economic and employment benefits from production, processing, distribution and sale to be captured within the US economy. Also, a natural-gas distribution infrastructure already exists in the form of pipeline networks serving the utilities sector. Along with low projected costs of extraction, this produces a very low retail price (projected to be only around 60% of petroleum fuels).

Hydrogen

Hydrogen fuel is yet another alternative fuel offering lower carbon emissions per mile of vehicle travel. Hydrogen technology is, however, in its infancy, and expansion of a hydrogen transportation industry is viewed as unrealistic over the period of analysis considered in this project.

SCENARIO DEVELOPMENT

All impact analyses require an explicit or implicit model that explains how the economy is affected by a variety of factors determined outside the control of private decision makers. In order to complete the analysis of the Oregon LCFS scenarios, the project team created a baseline that includes not only the fuel mix today, but the mix in each year between the current year and a forecast year without the potential Oregon LCFS. The end year for this analysis is 2022. This baseline is developed from the US Department of Energy Annual Energy Outlook with major modifications based on discussions with the Low Carbon Fuel Advisory Committee and TIAX.

Many issues must be considered in the baseline, including the underlying growth in Oregon population and economic activity. The most recent Oregon Economic Review and Forecast[26] expects annual employment growth over the next decade to be between one and two percent with annual growth in per capita income of about three percent. This growth in income and employment will include expected growth in demand for gasoline and diesel fuel to power transportation. Because of the State of Oregon and City of Portland renewable fuel standards, similar growth is expected for biofuels. These expectations are in the baseline scenario. The baseline scenario changes will proceed in a dynamic fashion, the pace of which will be crucial in defining the impact and viability of a less carbon-intense-fuel-driven Oregon economy. There

[26] http://www.oregon.gov/DAS/OEA/economic.shtml#Most_Recent_Forecast

are both microeconomic and macroeconomic baseline considerations. As such, both the VISION (vehicle inventory and use) and REMI PI+ (Input-Output, Computable General Equilibrium, and economic Geography models) tools must generate a baseline from which scenarios under consideration can be evaluated in later steps.

Scenario Analysis

For this analysis, individual life-cycle carbon intensities and end-user costs were developed for the following fuel options:

- Midwest corn ethanol, refined in Midwestern refineries and imported to Oregon
    - Conventional varieties
    - Lower-carbon varieties
- Midwest corn ethanol, made with midwest corn but refined in Oregon
- Cellulosic ethanol from waste food
- Out-of-state cellulosic ethanol
- Imported sugarcane ethanol from Brazil
- Cellulosic ethanol from forest residue and from grass waste
- Cellulosic ethanol from wheat straw
- Cellulosic ethanol from farmed trees
- Midwest-produced biodiesel from soybean stock
- Northwest-produced biodiesel from canola
- Northwest-produced biodiesel from waste yellow grease
- Northwest-produced renewable diesel from camelina
- Cellulosic diesel
- Compressed natural gas from waste biogas
- Electricity from the Grid
- Natural gas from existing infrastructure

The Oregon Department of Environmental Quality (DEQ), working with the low carbon fuel advisory committee and TIAX, developed a set of compliance scenarios that are believed to bracket the range of potential fuel supply options. Additional scenarios were developed to test the importance of fuel prices, the importance of in-state production, and the consideration of indirect land-use change. All of the selected scenarios achieve the LCFS goal. Scenario analyses were conducted for changes to light- and heavy-duty fleets, both separately and in a single fuel pool. The scenarios analyzed were as follows:[27]

- Scenario A – Cellulosic Ethanol and biodiesel, with Indirect Land Use Change
- Scenario B – A mix of cellulosic and corn ethanol and conventional biodiesel, with Indirect Land Use Change
- Scenario C – A mix of cellulosic and corn ethanol and conventional biodiesel, without Indirect Land Use Change

[27] Full descriptions of scenario assumptions are available within the full report to the Oregon DEQ, available at http://www.deq.state.or.us/aq/committees/docs/lcfs/appendixDeconimpact.pdf

- Scenario D – Electricity and cellulosic ethanol for light vehicles and CNG and cellulosic biodiesel for heavy vehicles, with Indirect Land Use Change
- Scenario E – One pool of multiple fuel sources, allowing heavy vehicle to achieve most compliance
- Scenario F – Same as Scenario C, but assuming higher oil prices
- Scenario G – Same as Scenario C, but assuming lower oil prices
- Scenario H – Cellulosic ethanol and biodiesel, all from out-of-state sources, with Indirect Land Use Change

The following sections provide summary descriptive of each of the scenarios analyzed in the LCFS analysis for the OR DEQ study. For the OR DOE study, only Scenario B and Scenario D were selected for further analysis for GHG reduction estimation and cost effectiveness analysis. While Scenario B and Scenario D were selected for further analysis, as described in a later section on the 'decomposition analysis,' it is also important to consider the possibility that the future compliance of LCFS may be closer to other feasible scenarios.

MICROECONOMIC IMPACT METHODOLOGY AND RESULTS

The VISION Model, developed by Argonne National Laboratories, is a spreadsheet-based tool that seeks to measure energy and greenhouse gas emissions from the entire US on-road vehicle fleet. It relies on perpetual inventories of 22 classes of light-duty vehicles and six classes of heavy-duty vehicles. The tool allows extensive customization of the assumptions underlying the types of fuel used, the types of vehicles entering the market, the carbon intensities of each type of fuel, and the extent to which various fuels are blended together.

The standard tool was extensively modified to reflect Oregon, rather than the entire US, before any analyses were completed. The vehicle fleet was adjusted in both size and composition to reflect state rather than national data. Fuel price data and projections were adjusted to reflect projections for the Pacific region, rather than national average projections.

For each scenario, analysts developed a detailed picture of the exact sources from which various fuel supplies would be obtained. The model was expanded to reflect this detailed picture of the scenario's fuel supply, and the carbon intensities used were adjusted to reflect the scenario's unique mix as well.

Key assumptions in the VISION analyses, beyond those related to developing the LCFS scenarios, are as follows:

- Fleet composition
- Fuel efficiency
- Fuel and Vehicle prices
- Carbon intensity
- Vehicle duration and scrappage

To provide custom inputs, analysts (with input from the Low Carbon Fuel Standards Advisory Committee) developed estimates for a number of direct expenditures expected as part of each scenario. These inputs included the following for each scenario (where appropriate):

- retail fuel-spending changes (using US DOE, Argonne National Laboratories and DEQ price forecasts)
- new vehicle purchase cost changes (electrics assumed over 60% more expensive; plug-in hybrids 40% more expensive)
- importation, permitting and installation of charging stations for electric and plug-in hybrid vehicles ($1000-$2000 per station)
- capital, labor and infrastructure costs for expanding natural-gas consumption
- capital, labor, permitting, feedstock and operating costs for new ethanol and/or biodiesel plants in the state of Oregon
- transportation and storage costs, as well as capital and labor for fueling stations, for additional ethanol, regardless of presence or absence of new refining capacity

Fuel Spending

The projected changes in fuel spending in the state of Oregon from each scenario are shown in the graph below. These numbers represent the net spending change; in each case, reductions in conventional fuel purchase offset increases in spending on lower-carbon fuels. All scenarios showed some reduction in fuel expenditure, though in most cases the savings is well below 1% of the baseline expenditure of $86 billion. In Scenario D, which emphasized a switch to electricity and natural gas (both of which offered significant savings per mile traveled), the fuel savings approached 2% of the baseline.

Capital Spending

Scenarios are also characterized by changes in the capital spending, either on new fuels refining and fueling capacity or on electric charging infrastructure. In Scenario D, which produced a dramatic $1.6-billion savings on fuel costs, the analysis projected an increase of almost exactly the same volume in additional spending on new vehicles, along with an additional cost of around $300 million for new charging equipment.

In most scenarios (all but Scenario H), two or three ethanol plants costing approximately $226 million each were assumed to be required. Production of cellulosic biodiesel required in Scenario A was assumed to require an additional plant, with a total cost of nearly $355 million.

Because the macroeconomic modeling relies on cash flows, the timing of these costs is significant. Most of the economic impacts in this analysis were projected to occur in the later years, after 2017. New fuels refining capacity was assumed to require time for site selection, permitting and a two-year construction period, meaning that most local fuel supply would come online only the last two or three years of the period. A notable exception was the expenditure on charging infrastructure and new vehicles in scenario D, which was assumed to begin immediately and continue throughout the ten-year period.

GHG Reduction by Adopting Substitutes from Different Feedstocks for Gasoline& Diesel

For the OR DOE project, JFA undertook a decomposition analysis

1. First, we undertook a decomposition analysis of individual gasoline and diesel substitutes from various feedstocks in terms of GHG emission reduction in Scenario B (run 2 +run 7) and Scenario D (run 4 +run9).

2. Second, we undertook a decomposition analysis of overall GHG emission difference for individual gasoline & diesel substitutes between 2012 and 2022 in Scenario B and Scenario D

3. Third and finally, we conducted a decomposition cost analysis for biofuels in Scenario B and Scenario D with regards to GHG emission reduction in this ten year period.

As a result of the decomposition analysis, JFA estimated values for GHG reduction potential and cost effectiveness for the following thirteen (13) fuel types or 'feedstocks'

- TLU 9 /LCFS1 -- MW Corn Ethanol
- TLU 10/LCFS2 -- OR Corn Ethanol
- TLU 11/LCFS3 -- Imported Cellulosic Ethanol
- TLU 12/LCFS4 -- Oregon Wheat Straw Ethanol
- TLU 13/LCFS5 -- Brazil Sugar Cane Ethanol
- TLU 14/LCFS6 -- Low Carbon MW Corn
- TLU 15/LCFS7 -- OR Cellulosic Ethanol
- TLU 16/LCFS8 -- Cellulosic
- TLU 17/LCFS9 -- CNG from biogas
- TLU 18/LCFS10 -- Camelian RD
- TLU 19/LCFS 11 -- NW Canola
- TLU 20/LCFS 12 -- Waste Oil
- TLU 21/LCFS 13 -- MW Soybean

LCFS-B: Mixed Biofuels Adjusted for Indirect Land Use Change

Measure Description

Low-Carbon Fuel Standard (LCFS) policies set a standard for the carbon intensity of the overall fuel mix utilized by the on-road fleet, but do not mandate the use of any one particular fuel over another. This type of rule seeks economic efficiency by allowing consumers and producers to make their own decisions about which blend of conventional and alternative fuels they prefer in meeting the standard. The analysis of LCFS led by Oregon's Department of Environmental Quality took into account the market-oriented nature of LCFS policies by considering eight alternative scenarios, which sought to bracket the range of potential market responses to such a rule. Those eight responses are identified as Scenarios A through H. These scenarios cover a wide range of potential fuel types (conventional and cellulosic biofuels, natural gas, and electricity) and production locations (in-state, around the US, and international). The scenarios also model the differences in responses to the LCFS standard depending on whether or not fuel carbon content of biofuels is adjusted for emissions generated by Indirect Land Use Change (ILUC).

Scenario B envisioned a market response which relied on a blend of different ethanol feedstocks, including Northwest corn, Midwest corn, waste biomass, imported sugarcane and Oregon cellulosic crops. The location of the crop source is taken into account because the transportation of fuels to the Oregon market affects their overall life-cycle carbon intensity. This scenario took into account ILUC, which increases the estimated carbon content of certain biofuels in order to reflect the anticipated clearing of additional land for farming.

For the heavy-duty sector, Scenario B envisioned a market response which relied on a blend of different biodiesel feedstocks, including in-state cellulosic and waste-oil-based biodiesel, out-of-state biodiesel from camelina crops, and canola biodiesel from both in-state and out-of-state sources. The location of the crop source is taken into account because the transportation of fuels to the Oregon market affects their overall life-cycle carbon intensity. This scenario took into account ILUC, which increases the estimated carbon content of certain biofuels in order to reflect the anticipated clearing of additional land for farming.

This section provides summary descriptive of each of the scenarios analyzed in the LCFS analysis for the OR DEQ study. For the OR DOE study, only Scenario B and Scenario D were selected for further analysis for GHG reduction estimation and cost effectiveness analysis. While Scenario B and Scenario D were selected for further analysis, as described in a later section on the 'decomposition analysis,' it is also important to consider the possibility that the future compliance of LCFS may be closer to other feasible scenarios.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Low Federal Action: Initial planning completed but little follow-through; fuel blend becomes somewhat less carbon-intensive by 2022 but achieves only a third of the effect expected of the full 10% reduction target. Production and investment tax credits for alternative fuels or advanced technologies are either not renewed or maintained at only marginally effective levels.

Moderate Federal Action: Federal government supports alternative fuels and alternative technologies through production and investment tax credits, and through continuation of subsidies such as the electric-vehicle tax credit. These are effective at inducing investment in fuels and charging infrastructure, improving uptake of cleaner fuels. Demand reaches approximately two thirds of that necessary to meet full 10% emissions-intensity reduction target. This level of demand is maintained through 2050.

Moderate Federal and State Action: Oregon supports federal action with sufficient communications, outreach, and incentive programs to enable full investment on the production side, as well as full adoption of new technologies and fuels on the consumer side. The full LCFS target is met in 2022, and maintained through 2050.

Timing (Start, Phase In, End): Adoption of out-of-state biofuels would begin immediately in 2013, though adoption of significant domestically-produced biofuels would begin only after 2020, when the first newly-constructed ethanol and biodiesel plants would achieve operation. In those scenarios where electric vehicles are anticipated to grow significantly (D and E), adoption of vehicles and charging infrastructure would begin immediately and would occur incrementally. Significant capital investment stops in 2022 when the target (or share of the target) is reached, but vehicle and fuel purchases will remain different from the business-as-usual scenario throughout the period until 2050.

Parties Involved: Federal transportation and energy agencies, Oregon Department of Energy (DOE), Department of Transportation (DOT) and Department of Environmental Quality (DEQ), fuel industry retailers and producers, ethanol crop growers, vehicle manufacturers, the driving public.

Data Sources and Additional Background: Assumptions for all LCFS analyses are described in detail by the Oregon DEQ-commissioned study on the economic impacts of an LCFS policy in the state. Scenario details and extensive data on assumptions and inputs may all be found on the DEQ website.

Estimated Net GHG Reductions and Net Financial Costs or Savings

For the OR DOE study, only Scenario B and Scenario D were selected for further analysis for GHG reduction estimation and cost effectiveness analysis.

<u>GHG Reduction by Adopting Substitutes from Different Feedstocks for Gasoline& Diesel</u>

For the OR DOE project, JFA undertook a decomposition analysis

4. First, we undertook a decomposition analysis of individual gasoline and diesel substitutes from various feedstocks in terms of GHG emission reduction in Scenario B (run 2 +run 7) and Scenario D (run 4 +run9).

5. Second, we undertook a decomposition analysis of overall GHG emission difference for individual gasoline & diesel substitutes between 2012 and 2022 in Scenario B and Scenario D

6. Third and finally, we conducted a decomposition cost analysis for biofuels in Scenario B and Scenario D with regards to GHG emission reduction in this ten year period.

As a result of the decomposition analysis, JFA estimated values for GHG reduction potential and cost effectiveness for the following thirteen (13) fuel types or 'feedstocks'

- TLU 9 /LCFS1 -- MW Corn Ethanol
- TLU 10/LCFS2 -- OR Corn Ethanol
- TLU 11/LCFS3 -- Imported Cellulosic Ethanol
- TLU 12/LCFS4 -- Oregon Wheat Straw Ethanol
- TLU 13/LCFS5 -- Brazil Sugar Cane Ethanol
- TLU 14/LCFS6 -- Low Carbon MW Corn
- TLU 15/LCFS7 -- OR Cellulosic Ethanol
- TLU 16/LCFS8 -- Cellulosic
- TLU 17/LCFS9 -- CNG from biogas
- TLU 18/LCFS10 -- Camelian RD
- TLU 19/LCFS 11 -- NW Canola
- TLU 20/LCFS 12 -- Waste Oil
- TLU 21/LCFS 13 -- MW Soybean

TLU - 9 LCFS1 -- MW Corn Ethanol

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
#1: Low Federal Action	0.0000	0.0000	-0.0962	-0.2212	($16.85)	($132.12)	$597.27	$597.27

#2: Moderate Federal Action	0.0000	0.0000	-0.0962	-0.2212	($16.85)	($132.12)	$597.27	$597.27
#3: Moderate Federal and State Action	0.0000	0.0000	-0.0962	-0.2212	($16.85)	($132.12)	$597.27	$597.27

TLU -10 LCFS2 -- OR Corn Ethanol

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0075	0.0172	0.0841	0.1934	$50.23	$115.52	$597.27	$597.27
#2: Moderate Federal Action	0.0075	0.0172	0.0841	0.1934	$50.23	$115.52	$597.27	$597.27
#3: Moderate Federal and State Action	0.0075	0.0172	0.0841	0.1934	$50.23	$115.52	$597.27	$597.27

TLU -11 LCFS3 -- Imported Cellulosic Ethanol

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0078	0.0178	0.0078	0.0178	$0.33	$0.76	$42.46	$42.46

#2: Moderate Federal Action	0.0078	0.0178	0.0078	0.0178	$0.33	$0.76	$42.46	$42.46
#3: Moderate Federal and State Action	0.0078	0.0178	0.0078	0.0178	$50.23	$0.76	$42.46	$42.46

TLU -12 LCFS4 -- Oregon Wheat Straw Ethanol

Point-of-combustion

Results:

	GHG Reductions ($MMtCO_2e$)							
Scenario	2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.2167	0.4984	0.2581	0.5937	$10.96	$25.21	$42.46	$42.46
#2: Moderate Federal Action	0.2167	0.4984	0.2581	0.5937	$10.96	$25.21	$42.46	$42.46
#3: Moderate Federal and State Action	0.2167	0.4984	0.2581	0.5937	$0.33	$25.21	$42.46	$42.46

TLU -13 LCFS5 -- Brazil Sugar Cane Ethanol

Point-of-combustion

Results:

	GHG Reductions ($MMtCO_2e$)							
Scenario	2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)

#1: Low Federal Action	0.0697	0.1602	0.3929	0.9037	$60.77	$139.78	$154.68	$154.68
#2: Moderate Federal Action	0.0697	0.1602	0.3929	0.9037	$60.77	$139.78	$154.68	$154.68
#3: Moderate Federal and State Action	0.0697	0.1602	0.3929	0.9037	$10.96	$139.78	$154.68	$154.68

TLU -14 LCFS6 -- Low Carbon MW Corn

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0571	0.1312	0.4407	1.0137	$87.70	$201.72	$198.99	$198.99
#2: Moderate Federal Action	0.0571	0.1312	0.4407	1.0137	$87.70	$201.72	$198.99	$198.99
#3: Moderate Federal and State Action	0.0571	0.1312	0.4407	1.0137	$60.77	$201.72	$198.99	$198.99

TLU -15 LCFS7 -- OR Cellulosic Ethanol

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV	2013-2022 CE	2013-2035 CE
	2022	2035	Total	Total				

			(2013-2022)	(2013-2035)		($MM2010)	($/tCO₂e)	($/tCO₂e)
#1: Low Federal Action	0.7358	1.6924	3.0368	6.9846	$140.53	$323.21	$46.27	$46.27
#2: Moderate Federal Action	0.7358	1.6924	3.0368	6.9846	$140.53	$323.21	$46.27	$46.27
#3: Moderate Federal and State Action	0.7358	1.6924	3.0368	6.9846	$87.70	$323.21	$46.27	$46.27

TLU -16 LCFS8 -- Cellulosic

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.1168	0.2686	0.1168	0.2686	$7.36	$16.93	$63.03	$63.03
#2: Moderate Federal Action	0.1168	0.2686	0.1168	0.2686	$7.36	$16.93	$63.03	$63.03
#3: Moderate Federal and State Action	0.1168	0.2686	0.1168	0.2686	$140.53	$16.93	$63.03	$63.03

TLU -17 LCFS9 -- CNG from biogas

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)

#1: Low Federal Action	0.1141	0.2625	0.2240	0.5151	$9.45	$21.73	$42.18	$42.18
#2: Moderate Federal Action	0.1141	0.2625	0.2240	0.5151	$9.45	$21.73	$42.18	$42.18
#3: Moderate Federal and State Action	0.1141	0.2625	0.2240	0.5151	$7.36	$21.73	$42.18	$42.18

TLU -18 LCFS10 -- Camelian RD

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
#1: Low Federal Action	0.2216	0.5096	0.9366	2.1543	$249.60	$574.08	$266.48	$266.48
#2: Moderate Federal Action	0.2216	0.5096	0.9366	2.1543	$249.60	$574.08	$266.48	$266.48
#3: Moderate Federal and State Action	0.2216	0.5096	0.9366	2.1543	$9.45	$574.08	$266.48	$266.48

TLU -19 LCFS 11 -- NW Canola

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
#1: Low Federal Action	0.0229	0.0526	0.1581	0.3636	$48.96	$112.60	$309.65	$309.65

#2: Moderate Federal Action	0.0229	0.0526	0.1581	0.3636	$48.96	$112.60	$309.65	$309.65
#3: Moderate Federal and State Action	0.0229	0.0526	0.1581	0.3636	$249.60	$112.60	$309.65	$309.65

TLU -20 LCFS 12 -- Waste Oil

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO_2e)	2013-2035 CE ($/tCO_2e)
#1: Low Federal Action	0.1105	0.2540	1.0533	2.4225	$47.83	$110.01	$45.41	$45.41
#2: Moderate Federal Action	0.1105	0.2540	1.0533	2.4225	$47.83	$110.01	$45.41	$45.41
#3: Moderate Federal and State Action	0.1105	0.2540	1.0533	2.4225	$48.96	$110.01	$45.41	$45.41

TLU -21 LCFS 13 -- MW Soybean

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO_2e)	2013-2035 CE ($/tCO_2e)
#1: Low Federal Action	0.0000	0.0000	0.1397	0.3212	$52.59	$120.97	$376.56	$376.56

#2: Moderate Federal Action	0.0000	0.0000	0.1397	0.3212	$52.59	$120.97	$376.56	$376.56
#3: Moderate Federal and State Action	0.0000	0.0000	0.1397	0.3212	$47.83	$120.97	$376.56	$376.56

TLU - 9 LCFS1 -- MW Corn Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0000	0.0000	-0.1443	-0.3318	($86.16)	($198.17)	$597.27	$597.27
#2: Moderate Federal Action	0.0000	0.0000	-0.1443	-0.3318	($86.16)	($198.17)	$597.27	$597.27
#3: Moderate Federal and State Action	0.0000	0.0000	-0.1443	-0.3318	($86.16)	($198.17)	$597.27	$597.27

TLU -10 LCFS2 -- OR Corn Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0112	0.0258	0.1261	0.2901	$75.34	$173.28	$597.27	$597.27

#2: Moderate Federal Action	0.0112	0.0258	0.1261	0.2901	$75.34	$173.28	$597.27	$597.27
#3: Moderate Federal and State Action	0.0112	0.0258	0.1261	0.2901	$75.34	$173.28	$597.27	$597.27

TLU -11 LCFS3 -- Imported Cellulosic Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0116	0.0267	0.0116	0.0267	$0.49	$1.14	$42.46	$42.46
#2: Moderate Federal Action	0.0116	0.0267	0.0116	0.0267	$0.49	$1.14	$42.46	$42.46
#3: Moderate Federal and State Action	0.0116	0.0267	0.0116	0.0267	$0.49	$1.14	$42.46	$42.46

TLU -12 LCFS4 -- Oregon Wheat Straw Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.3250	0.7476	0.3872	0.8906	$16.44	$37.81	$42.46	$42.46

#2: Moderate Federal Action	0.3250	0.7476	0.3872	0.8906	$16.44	$37.81	$42.46	$42.46
#3: Moderate Federal and State Action	0.3250	0.7476	0.3872	0.8906	$16.44	$37.81	$42.46	$42.46

TLU -13 LCFS5 -- Brazil Sugar Cane Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.1045	0.2403	0.5893	1.3555	$91.16	$209.67	$154.68	$154.68
#2: Moderate Federal Action	0.1045	0.2403	0.5893	1.3555	$91.16	$209.67	$154.68	$154.68
#3: Moderate Federal and State Action	0.1045	0.2403	0.5893	1.3555	$91.16	$209.67	$154.68	$154.68

TLU -14 LCFS6 -- Low Carbon MW Corn

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0856	0.1968	0.6611	1.5205	$131.56	$302.58	$198.99	$198.99

#2: Moderate Federal Action	0.0856	0.1968	0.6611	1.5205	$131.56	$302.58	$198.99	$198.99
#3: Moderate Federal and State Action	0.0856	0.1968	0.6611	1.5205	$131.56	$302.58	$198.99	$198.99

TLU -15 LCFS7 -- OR Cellulosic Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	1.1037	2.5386	4.5552	10.477	$210.79	$484.82	$46.27	$46.27
#2: Moderate Federal Action	1.1037	2.5386	4.5552	10.477	$210.79	$484.82	$46.27	$46.27
#3: Moderate Federal and State Action	1.1037	2.5386	4.5552	10.477	$210.79	$484.82	$46.27	$46.27

TLU -16 LCFS8 -- Cellulosic

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.1751	0.4028	0.1751	0.4028	$11.04	$25.39	$63.03	$63.03

#2: Moderate Federal Action	0.1751	0.4028	0.1751	0.4028	$11.04	$25.39	$63.03	$63.03
#3: Moderate Federal and State Action	0.1751	0.4028	0.1751	0.4028	$11.04	$25.39	$63.03	$63.03

TLU -17 LCFS9 -- CNG from biogas

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.1712	0.3938	0.3360	0.7727	$14.17	$32.59	$42.18	$42.18
#2: Moderate Federal Action	0.1712	0.3938	0.3360	0.7727	$14.17	$32.59	$42.18	$42.18
#3: Moderate Federal and State Action	0.1712	0.3938	0.3360	0.7727	$14.17	$32.59	$42.18	$42.18

TLU -18 LCFS10 -- Camelian RD

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.3323	0.7643	1.4050	3.2314	$374.40	$861.12	$266.48	$266.48

#2: Moderate Federal Action	0.3323	0.7643	1.4050	3.2314	$374.40	$861.12	$266.48	$266.48
#3: Moderate Federal and State Action	0.3323	0.7643	1.4050	3.2314	$374.40	$861.12	$266.48	$266.48

TLU -19 LCFS 11 -- NW Canola

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0343	0.0789	0.2371	0.5454	$73.43	$168.90	$309.65	$309.65
#2: Moderate Federal Action	0.0343	0.0789	0.2371	0.5454	$73.43	$168.90	$309.65	$309.65
#3: Moderate Federal and State Action	0.0343	0.0789	0.2371	0.5454	$73.43	$168.90	$309.65	$309.65

TLU -20 LCFS 12 -- Waste Oil

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.1657	0.3811	1.5799	3.6338	$71.75	$165.02	$45.41	$45.41

#2: Moderate Federal Action	0.1657	0.3811	1.5799	3.6338	$71.75	$165.02	$45.41	$45.41
#3: Moderate Federal and State Action	0.1657	0.3811	1.5799	3.6338	$71.75	$165.02	$45.41	$45.41

TLU -21 LCFS 13 -- MW Soybean

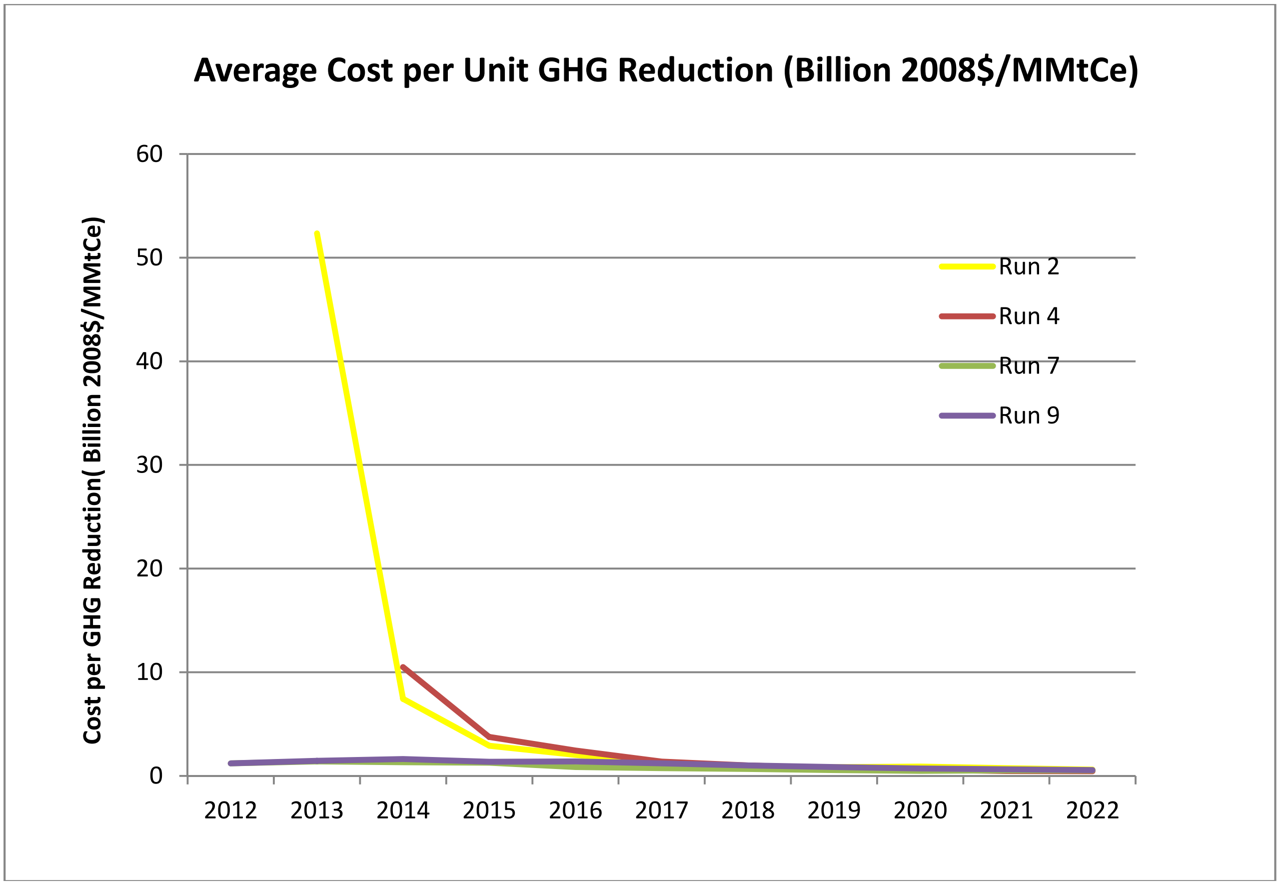
Full Energy-Cycle Results:

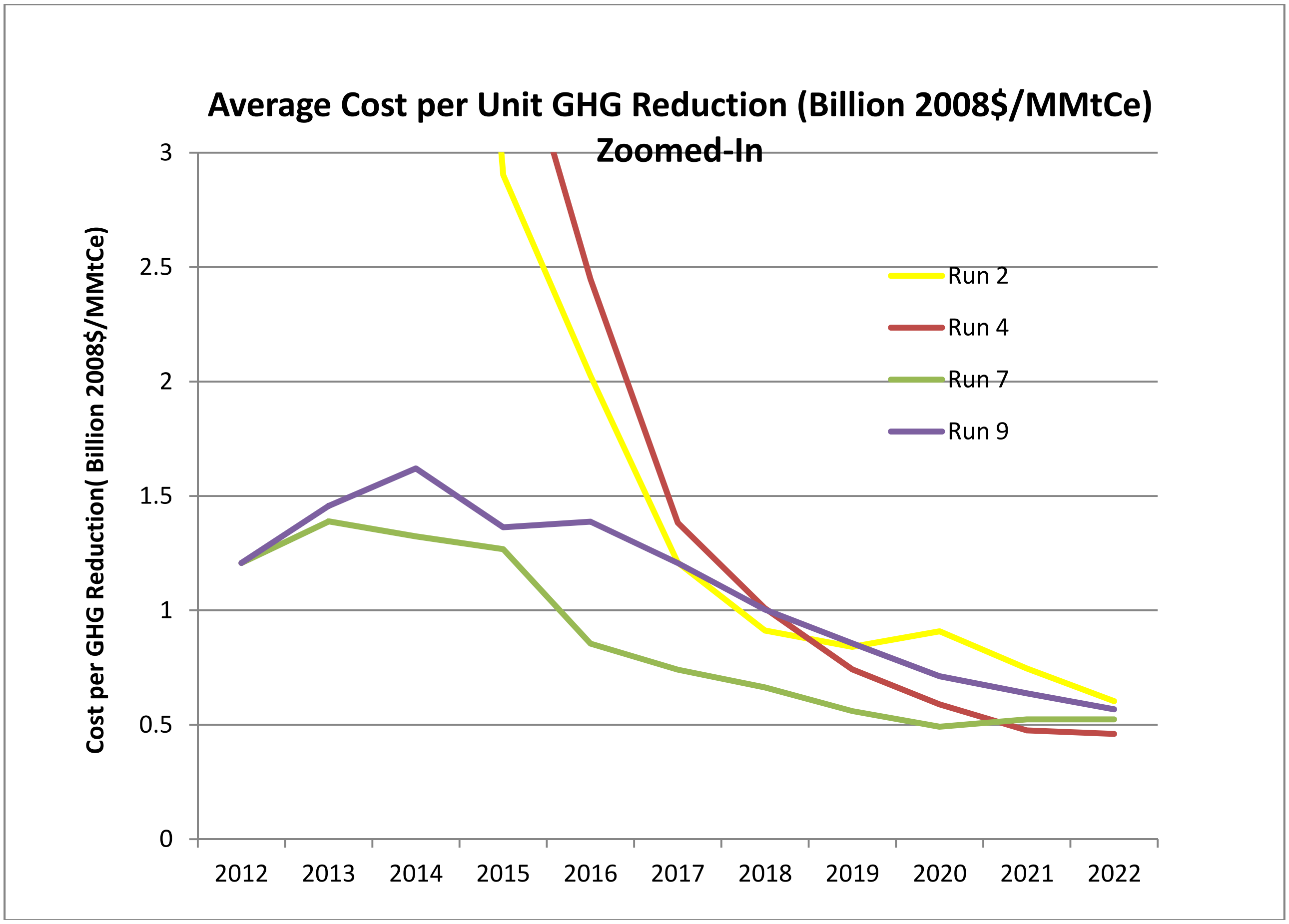
Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
#1: Low Federal Action	0.0000	0.0000	0.2095	0.4819	$78.89	$181.45	$376.56	$376.56
#2: Moderate Federal Action	0.0000	0.0000	0.2095	0.4819	$78.89	$181.45	$376.56	$376.56
#3: Moderate Federal and State Action	0.0000	0.0000	0.2095	0.4819	$78.89	$181.45	$376.56	$376.56

Overview

In order to reduce greenhouse gas (GHG) emission during the next ten years, biofuels will be adopted. While GHG emission can be reduced in all scenarios by using biofuels as substitutes for gasoline and diesel respectively, we are interested in decomposing biofuels from individual feedstocks in terms of GHG emission reduction and cost per unit GHG emission reduction in the period between year 2012 and 2022. Specifically, Scenario B (run 2 + run 4) and Scenario D (run 7 + run 9) are examined.

The average cost per unit GHG reduction for run 2 and run 4 is the highest in the first few years of this period, starting as high as over 50 billion (2008$) dollars per million metric tons of carbon dioxide equivalent (MMtCe) for run 2 in 2013 and 10 billion (2008$) dollars per MMtCe for run 4 in 2014, due to the relatively small amount of GHG reduction in these years with adoption of less efficient biofuels. However, with the usage of increasing amount of biofuels of low carbon intensity, the average cost per unit GHG reduction is reduced to approximately 0.5 billion (2008$) dollars per MMtCe in 2022 for all runs in Scenario B and Scenario D.

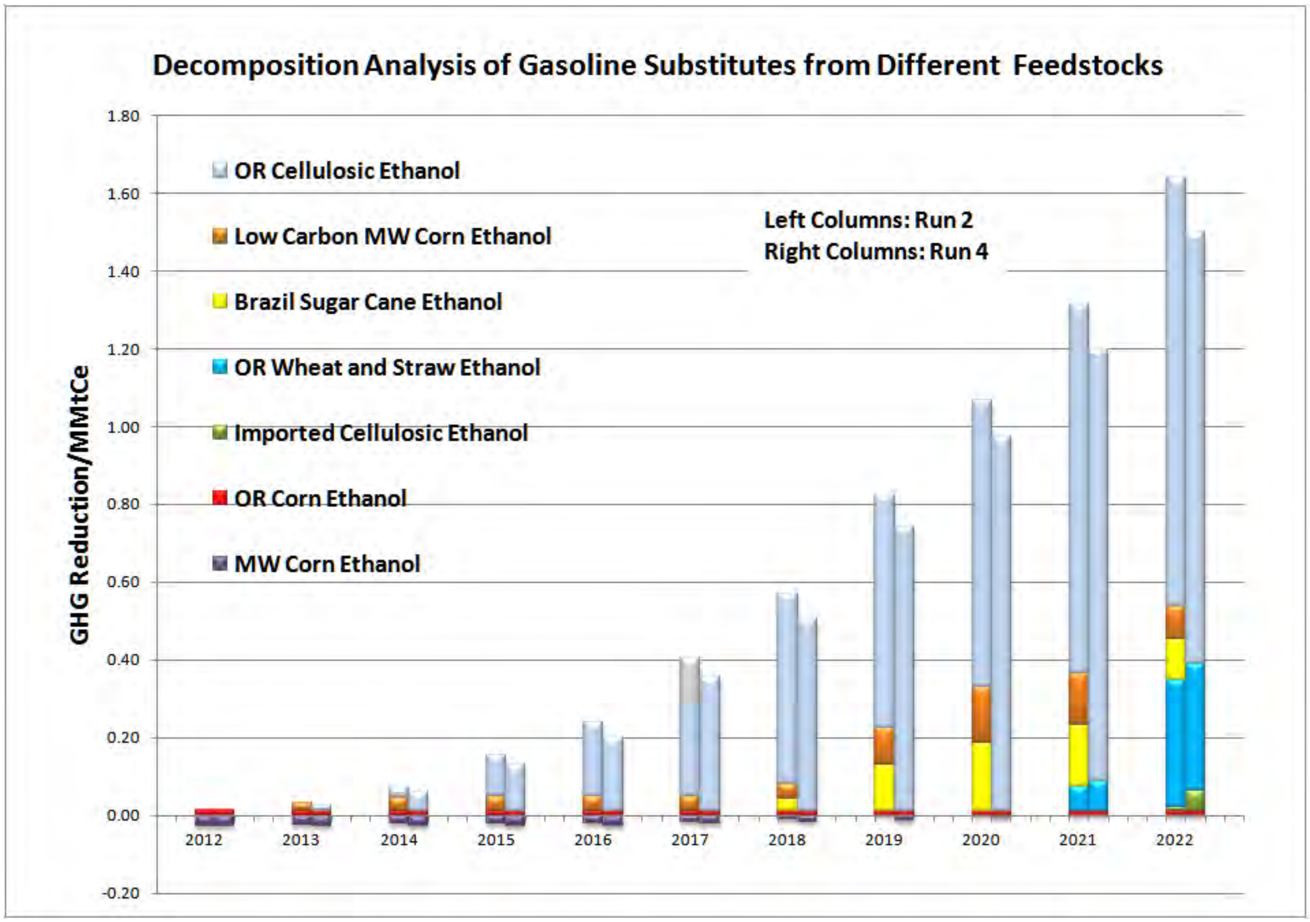

Average Cost per Unit GHG Reduction (Billion 2008$/MMtCe)
Cost per GHG Reduction(Billion 2008$/MMtCe)
60
50
40
30
20
10
0
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Run 2
Run 4
Run 7
Run 9



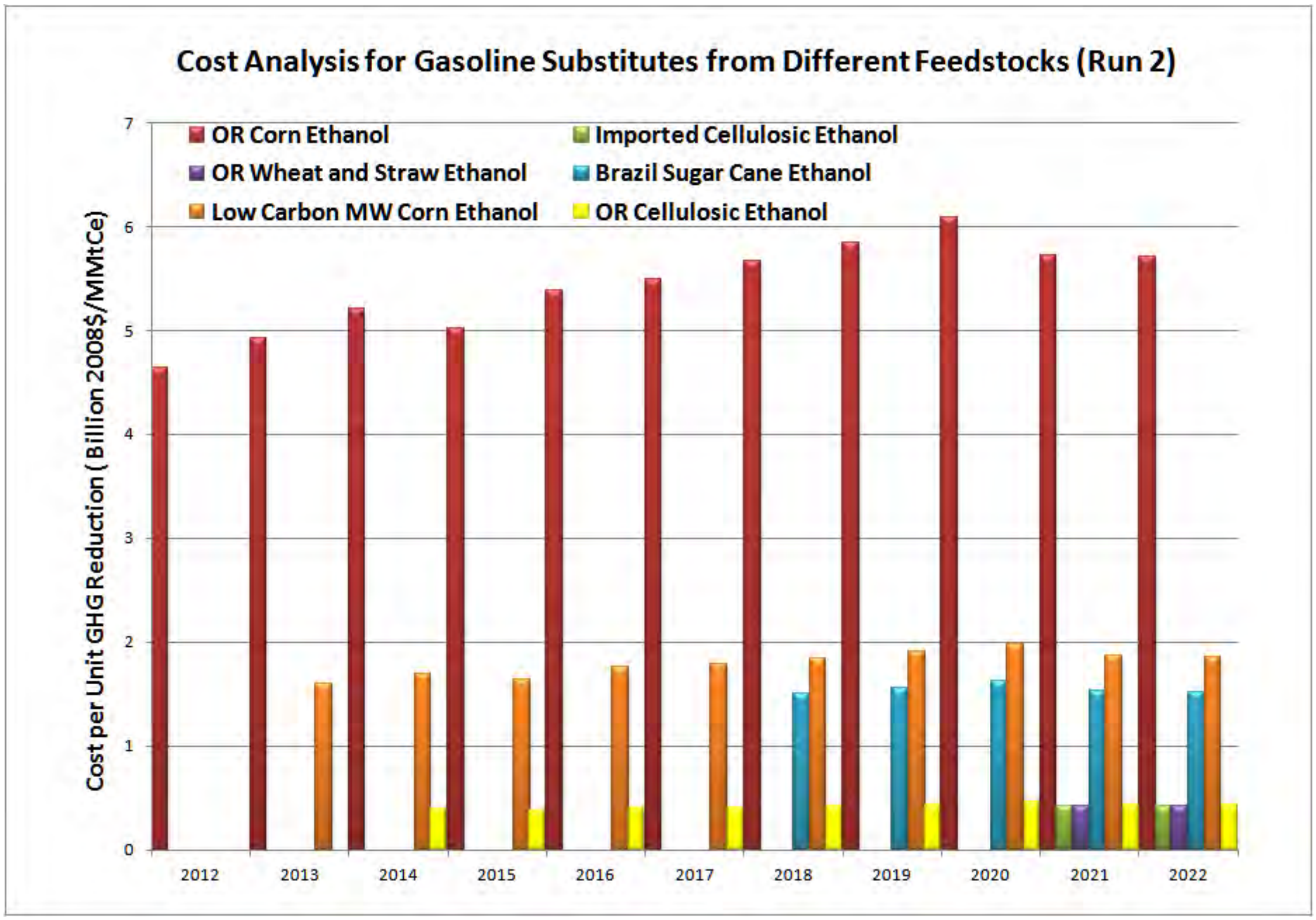
Decomposition Analysis

- Gasoline substitutes

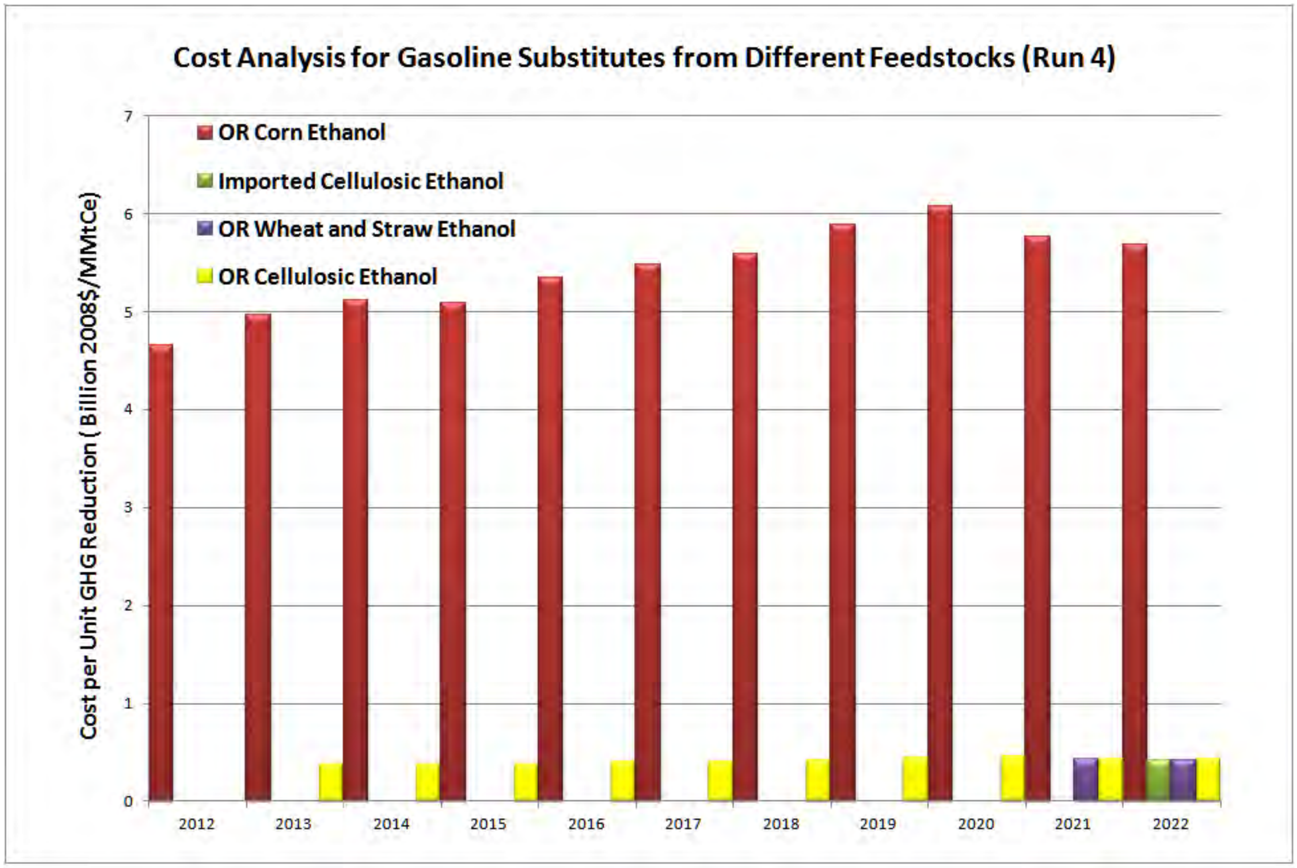
Shown below is the decomposition analysis for gasoline substitutes in run 2 (left columns) and run 4 (right columns) in terms of GHG emission reduction. For both runs, adoption of MW corn ethanol contributes negatively to GHG reduction, due to higher carbon intensity of such fuel compared to regular gasoline. Ethanol from Oregon wheat and straws, which has significantly lower carbon intensity, helps to reduce majority of GHG emission over this ten years period in both runs, while ethanol from some other feedstocks (e.g. imported cellulosic ethanol) contributes significantly less to GHG emission reduction. Due to larger amount of gasoline substitutes from more diversified feedstocks, run 2 has a larger amount of total GHG reduction by replacing gasoline with ethanol biofuels.



Cost analysis for gasoline substitutes in run 2 is made in terms of billion (2008 dollars) per million metric tons of GHG emission reduction. Between 2012 and 2022, Oregon corn ethanol has the highest cost per unit GHG reduction, which is about three times that of low carbon MW corn ethanol, four times that of Brazil sugar cane ethanol, and slightly ten times that of imported cellulosic ethanol, Oregon wheat and straw ethanol and Oregon cellulosic ethanol.



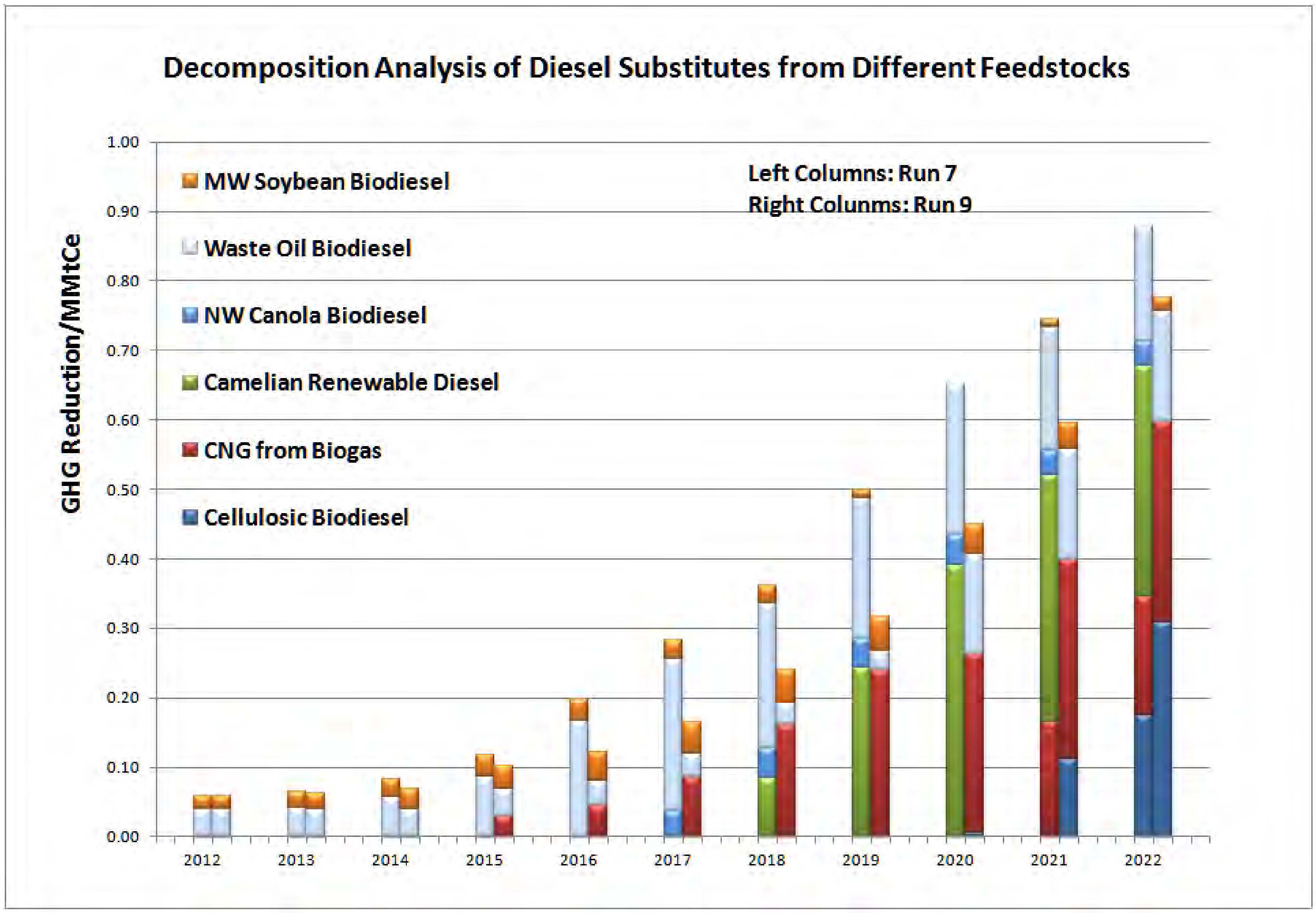
Similarly, run 4 also has Oregon corn ethanol as the least cost efficient biofuel. However, run 4 does not adopt medium cost efficient biofuels, including ethanol from Brazil sugar cane and low carbon MW corn, resulting in lower cost per unit GHG reduction from 2019 to 2022.



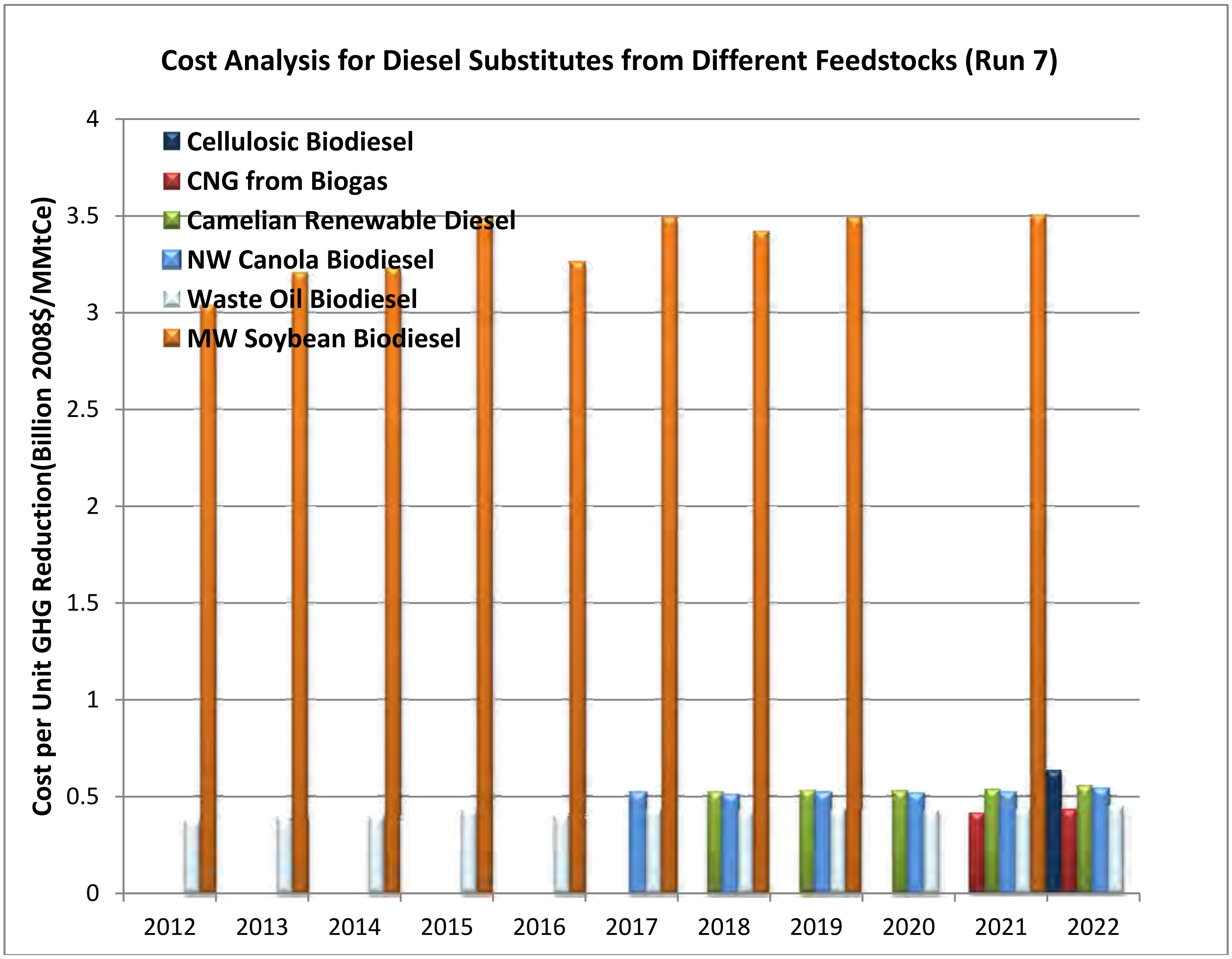
- Diesel substitutes

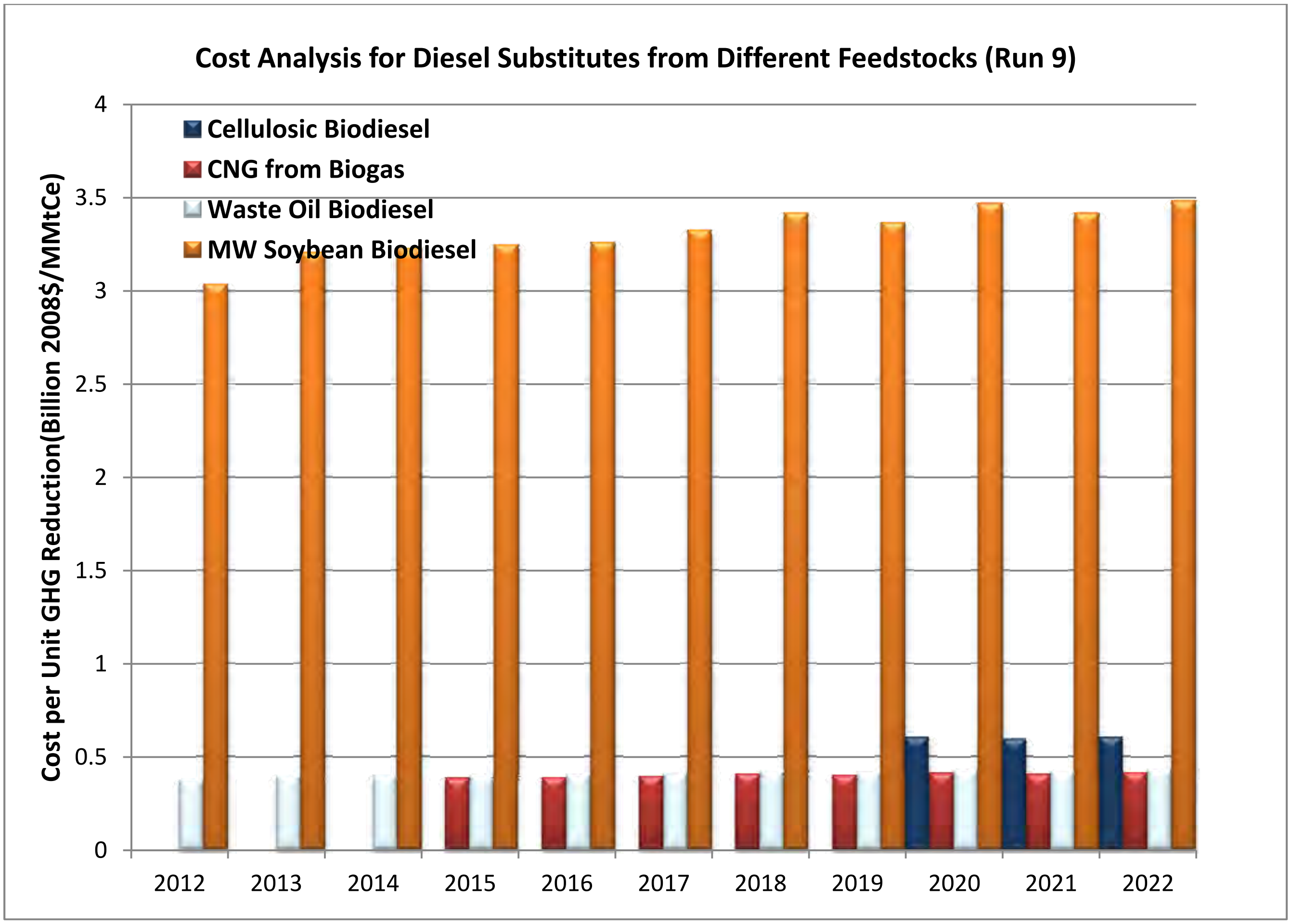
For the case of diesel substitutes, run 7 (left columns) has an overall higher level of GHG reduction than that of run 9 (right columns), due to larger amount of biodiesels adopted in run 7 from more varied feedstocks.

Unlike the common major contributor of GHG reduction mentioned previously, run 7 and run 9 does not share the same major GHG reduction contributor, except for the first three years, in which waste oil biodiesel reduces majority of GHG emission for both runs. While the contribution of waste oil biodiesel continues to grow in the first several years, such contribution stays stagnant or even slightly less in the final years for both runs. In run 7, camelian renewable diesel begins to help reduce GHG emission in year 2018 and becomes the major contributor from year 2020, followed by waste oil biodiesel, CNG from biogas and cellulosic biodiesel. Meanwhile, in run 9, CNG biogas arises in 2015 and becomes the major GHG reduction contributor from 2017 until when cellulosic biodiesel reduces similar amount of GHG emission in 2022.



MW soybean biodiesel, which has the highest cost per unit GHG reduction, is used every year during this ten years period for both run 7 and run 9, except for 2020 and 2022 in run 7. Such discontinuing use of this less cost efficient biodiesel and adoption of other more cost efficient biodiesels for run 7 results in a lower average cost per unit GHG reduction for run 7 compared to run 9.


Cost Analysis for Diesel Substitutes from Different Feedstocks (Run 7)
Cost per Unit GHG Reduction(Billion 2008$/MMtCe)
4
3.5
3
2.5
2
1.5
1
0.5
0
Cellulosic Biodiesel
CNG from Biogas
Camelian Renewable Diesel
NW Canola Biodiesel
Waste Oil Biodiesel
MW Soybean Biodiesel
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022



Quantification Methods and Results, and Key Assumptions: Please see Data Sources language above, and DEQ-commissioned reports on LCFS adoption.

LCFS-D: Mixed Biofuels Without Indirect Land Use Change Adjustment

Measure Description

Low-Carbon Fuel Standard (LCFS) policies set a standard for the carbon intensity of the overall fuel mix utilized by the on-road fleet, but do not mandate the use of any one particular fuel over another. This type of rule seeks economic efficiency by allowing consumers and producers to make their own decisions about which blend of conventional and alternative fuels they prefer in meeting the standard. The analysis of a LCFS led by Oregon's Department of Environmental Quality took into account the market-oriented nature of LCFS policies by considering eight alternative scenarios, which sought to bracket the range of potential market responses to such a rule. Those eight responses are identified as Scenarios A through H. These scenarios cover a wide range of potential fuel types (conventional and cellulosic biofuels, natural gas, and electricity) and production locations (in-state, around the US, and international). The scenarios also model the differences in responses to the LCFS standard depending on whether or not fuel carbon content of biofuels is adjusted for emissions generated by Indirect Land Use Change (ILUC).

Scenario D envisions a market response that looks beyond ethanol to electricity as a fuel for an expanded fleet of electric vehicles and plug-in hybrid electric vehicles. This scenario assumes that by 2035, the electric-vehicle and plug-in electric vehicle fleets grow by a combined 225,000 units above the business-as-usual projection. Ethanol is still used significantly in this scenario, and feedstocks include in-state cellulosic ethanol as well as northwest corn and waste stocks. Cellulosic feedstocks include forest residue, grass waste, food waste and wheat straw. This scenario takes into account ILUC, which increases the estimated carbon content of certain biofuels in order to reflect the anticipated clearing of additional land for farming.

For the heavy-duty sector, Scenario D, similar to Scenario A, envisioned a market response which maximized in-state production and refinement of cellulosic biodiesel and waste-oil-based biodiesel. However, this scenario relied much more heavily on expansion of natural-gas trucks and the fuel to supply them, reducing the need for new biodiesel sources and infrastructure. Cellulosic feedstocks include forest residue, grass waste, food waste and wheat straw. This scenario takes into account ILUC, which increases the estimated carbon content of certain biofuels in order to reflect the anticipated clearing of additional land for farming.

This section provides summary descriptive of each of the scenarios analyzed in the LCFS analysis for the OR DEQ study. For the OR DOE study, only Scenario B and Scenario D were selected for further analysis for GHG reduction estimation and cost effectiveness analysis. While Scenario B and Scenario D were selected for further analysis, as described in a later section on the 'decomposition analysis,' it is also important to consider the possibility that the future compliance of LCFS may be closer to other feasible scenarios.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Low Federal Action: Initial planning completed but little follow-through; fuel blend becomes somewhat less carbon-intensive by 2022 but achieves only a third of the effect expected of the full 10% reduction target. Production and investment tax credits for alternative fuels or advanced technologies are either not renewed or maintained at only marginally effective levels.

Moderate Federal Action: Federal government supports alternative fuels and alternative technologies through production and investment tax credits, and through continuation of subsidies such as the electric-vehicle tax credit. These are effective at inducing investment in fuels and charging infrastructure, improving uptake of cleaner fuels. Demand reaches approximately two thirds of that necessary to meet full 10% emissions-intensity reduction target. This level of demand is maintained through 2050.

Moderate Federal and State Action: Oregon supports federal action with sufficient communications, outreach, and incentive programs to enable full investment on the production side, as well as full adoption of new technologies and fuels on the consumer side. The full LCFS target is met in 2022, and maintained through 2050.

Timing (Start, Phase In, End): Adoption of out-of-state biofuels would begin immediately in 2013, though adoption of significant domestically-produced biofuels would begin only after 2020, when the first newly-constructed ethanol and biodiesel plants would achieve operation. In those scenarios where electric vehicles are anticipated to grow significantly (D and E), adoption of vehicles and charging infrastructure would begin immediately and would occur incrementally. Significant capital investment stops in 2022 when the target (or share of the target) is reached, but vehicle and fuel purchases will remain different from the business-as-usual scenario throughout the period until 2050.

Parties Involved: Federal transportation and energy agencies, Oregon Department of Energy (DOE), Department of Transportation (DOT) and Department of Environmental Quality (DEQ), fuel industry retailers and producers, ethanol crop growers, vehicle manufacturers, the driving public.

Data Sources and Additional Background: Assumptions for all LCFS analyses are described in detail by the Oregon DEQ-commissioned study on the economic impacts of an LCFS policy in the state. Scenario details and extensive data on assumptions and inputs may all be found on the DEQ website.

Estimated Net GHG Reductions and Net Financial Costs or Savings

For the OR DOE study, only Scenario B and Scenario D were selected for further analysis for GHG reduction estimation and cost effectiveness analysis.

GHG Reduction by Adopting Substitutes from Different Feedstocks for Gasoline& Diesel

For the OR DOE project, JFA undertook a decomposition analysis

7. First, we undertook a decomposition analysis of individual gasoline and diesel substitutes from various feedstocks in terms of GHG emission reduction in Scenario B (run 2 +run 7) and Scenario D (run 4 +run9).

8. Second, we undertook a decomposition analysis of overall GHG emission difference for individual gasoline & diesel substitutes between 2012 and 2022 in Scenario B and Scenario D

9. Third and finally, we conducted a decomposition cost analysis for biofuels in Scenario B and Scenario D with regards to GHG emission reduction in this ten year period.

As a result of the decomposition analysis, JFA estimated values for GHG reduction potential and cost effectiveness for the following thirteen (13) fuel types or 'feedstocks'

- TLU 9 /LCFS1 -- MW Corn Ethanol
- TLU 10/LCFS2 -- OR Corn Ethanol
- TLU 11/LCFS3 -- Imported Cellulosic Ethanol
- TLU 12/LCFS4 -- Oregon Wheat Straw Ethanol
- TLU 13/LCFS5 -- Brazil Sugar Cane Ethanol
- TLU 14/LCFS6 -- Low Carbon MW Corn
- TLU 15/LCFS7 -- OR Cellulosic Ethanol
- TLU 16/LCFS8 -- Cellulosic
- TLU 17/LCFS9 -- CNG from biogas
- TLU 18/LCFS10 -- Camelian RD
- TLU 19/LCFS 11 -- NW Canola
- TLU 20/LCFS 12 -- Waste Oil
- TLU 21/LCFS 13 -- MW Soybean

TLU - 9 LCFS1 -- MW Corn Ethanol

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0000	0.0000	-0.0962	-0.2212	($16.85)	($132.12)	$597.27	$597.27
#2: Moderate Federal Action	0.0000	0.0000	-0.0962	-0.2212	($16.85)	($132.12)	$597.27	$597.27

#3: Moderate Federal and State Action	0.0000	0.0000	-0.0962	-0.2212	($16.85)	($132.12)	$597.27	$597.27

TLU -10 LCFS2 -- OR Corn Ethanol

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
#1: Low Federal Action	0.0075	0.0172	0.0841	0.1934	$50.23	$115.52	$597.27	$597.27
#2: Moderate Federal Action	0.0075	0.0172	0.0841	0.1934	$50.23	$115.52	$597.27	$597.27
#3: Moderate Federal and State Action	0.0075	0.0172	0.0841	0.1934	$50.23	$115.52	$597.27	$597.27

TLU -11 LCFS3 -- Imported Cellulosic Ethanol

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
#1: Low Federal Action	0.0078	0.0178	0.0078	0.0178	$0.33	$0.76	$42.46	$42.46
#2: Moderate Federal Action	0.0078	0.0178	0.0078	0.0178	$0.33	$0.76	$42.46	$42.46

#3: Moderate Federal and State Action	0.0078	0.0178	0.0078	0.0178	$50.23	$0.76	$42.46	$42.46

TLU -12 LCFS4 -- Oregon Wheat Straw Ethanol
Point-of-combustion
Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.2167	0.4984	0.2581	0.5937	$10.96	$25.21	$42.46	$42.46
#2: Moderate Federal Action	0.2167	0.4984	0.2581	0.5937	$10.96	$25.21	$42.46	$42.46
#3: Moderate Federal and State Action	0.2167	0.4984	0.2581	0.5937	$0.33	$25.21	$42.46	$42.46

TLU -13 LCFS5 -- Brazil Sugar Cane Ethanol
Point-of-combustion
Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0697	0.1602	0.3929	0.9037	$60.77	$139.78	$154.68	$154.68

#2: Moderate Federal Action	0.0697	0.1602	0.3929	0.9037	$60.77	$139.78	$154.68	$154.68
#3: Moderate Federal and State Action	0.0697	0.1602	0.3929	0.9037	$10.96	$139.78	$154.68	$154.68

TLU -14 LCFS6 -- Low Carbon MW Corn

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0571	0.1312	0.4407	1.0137	$87.70	$201.72	$198.99	$198.99
#2: Moderate Federal Action	0.0571	0.1312	0.4407	1.0137	$87.70	$201.72	$198.99	$198.99
#3: Moderate Federal and State Action	0.0571	0.1312	0.4407	1.0137	$60.77	$201.72	$198.99	$198.99

TLU -15 LCFS7 -- OR Cellulosic Ethanol

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.7358	1.6924	3.0368	6.9846	$140.53	$323.21	$46.27	$46.27

#2: Moderate Federal Action	0.7358	1.6924	3.0368	6.9846	$140.53	$323.21	$46.27	$46.27
#3: Moderate Federal and State Action	0.7358	1.6924	3.0368	6.9846	$87.70	$323.21	$46.27	$46.27

TLU -16 LCFS8 -- Cellulosic

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.1168	0.2686	0.1168	0.2686	$7.36	$16.93	$63.03	$63.03
#2: Moderate Federal Action	0.1168	0.2686	0.1168	0.2686	$7.36	$16.93	$63.03	$63.03
#3: Moderate Federal and State Action	0.1168	0.2686	0.1168	0.2686	$140.53	$16.93	$63.03	$63.03

TLU -17 LCFS9 -- CNG from biogas

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.1141	0.2625	0.2240	0.5151	$9.45	$21.73	$42.18	$42.18

#2: Moderate Federal Action	0.1141	0.2625	0.2240	0.5151	$9.45	$21.73	$42.18	$42.18
#3: Moderate Federal and State Action	0.1141	0.2625	0.2240	0.5151	$7.36	$21.73	$42.18	$42.18

TLU -18 LCFS10 -- Camelian RD

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.2216	0.5096	0.9366	2.1543	$249.60	$574.08	$266.48	$266.48
#2: Moderate Federal Action	0.2216	0.5096	0.9366	2.1543	$249.60	$574.08	$266.48	$266.48
#3: Moderate Federal and State Action	0.2216	0.5096	0.9366	2.1543	$9.45	$574.08	$266.48	$266.48

TLU -19 LCFS 11 -- NW Canola

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0229	0.0526	0.1581	0.3636	$48.96	$112.60	$309.65	$309.65

#2: Moderate Federal Action	0.0229	0.0526	0.1581	0.3636	$48.96	$112.60	$309.65	$309.65
#3: Moderate Federal and State Action	0.0229	0.0526	0.1581	0.3636	$249.60	$112.60	$309.65	$309.65

TLU -20 LCFS 12 -- Waste Oil

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.1105	0.2540	1.0533	2.4225	$47.83	$110.01	$45.41	$45.41
#2: Moderate Federal Action	0.1105	0.2540	1.0533	2.4225	$47.83	$110.01	$45.41	$45.41
#3: Moderate Federal and State Action	0.1105	0.2540	1.0533	2.4225	$48.96	$110.01	$45.41	$45.41

TLU -21 LCFS 13 -- MW Soybean

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0000	0.0000	0.1397	0.3212	$52.59	$120.97	$376.56	$376.56

#2: Moderate Federal Action	0.0000	0.0000	0.1397	0.3212	$52.59	$120.97	$376.56	$376.56
#3: Moderate Federal and State Action	0.0000	0.0000	0.1397	0.3212	$47.83	$120.97	$376.56	$376.56

TLU - 9 LCFS1 -- MW Corn Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0000	0.0000	-0.1443	-0.3318	($86.16)	($198.17)	$597.27	$597.27
#2: Moderate Federal Action	0.0000	0.0000	-0.1443	-0.3318	($86.16)	($198.17)	$597.27	$597.27
#3: Moderate Federal and State Action	0.0000	0.0000	-0.1443	-0.3318	($86.16)	($198.17)	$597.27	$597.27

TLU -10 LCFS2 -- OR Corn Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0112	0.0258	0.1261	0.2901	$75.34	$173.28	$597.27	$597.27

#2: Moderate Federal Action	0.0112	0.0258	0.1261	0.2901	$75.34	$173.28	$597.27	$597.27
#3: Moderate Federal and State Action	0.0112	0.0258	0.1261	0.2901	$75.34	$173.28	$597.27	$597.27

TLU -11 LCFS3 -- Imported Cellulosic Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0116	0.0267	0.0116	0.0267	$0.49	$1.14	$42.46	$42.46
#2: Moderate Federal Action	0.0116	0.0267	0.0116	0.0267	$0.49	$1.14	$42.46	$42.46
#3: Moderate Federal and State Action	0.0116	0.0267	0.0116	0.0267	$0.49	$1.14	$42.46	$42.46

TLU -12 LCFS4 -- Oregon Wheat Straw Ethanol

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.3250	0.7476	0.3872	0.8906	$16.44	$37.81	$42.46	$42.46

#2: Moderate Federal Action	0.3250	0.7476	0.3872	0.8906	$16.44	$37.81	$42.46	$42.46
#3: Moderate Federal and State Action	0.3250	0.7476	0.3872	0.8906	$16.44	$37.81	$42.46	$42.46

TLU -13 LCFS5 -- Brazil Sugar Cane Ethanol
Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.1045	0.2403	0.5893	1.3555	$91.16	$209.67	$154.68	$154.68
#2: Moderate Federal Action	0.1045	0.2403	0.5893	1.3555	$91.16	$209.67	$154.68	$154.68
#3: Moderate Federal and State Action	0.1045	0.2403	0.5893	1.3555	$91.16	$209.67	$154.68	$154.68

TLU -14 LCFS6 -- Low Carbon MW Corn
Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0856	0.1968	0.6611	1.5205	$131.56	$302.58	$198.99	$198.99

#2: Moderate Federal Action	0.0856	0.1968	0.6611	1.5205	$131.56	$302.58	$198.99	$198.99
#3: Moderate Federal and State Action	0.0856	0.1968	0.6611	1.5205	$131.56	$302.58	$198.99	$198.99

TLU -15 LCFS7 -- OR Cellulosic Ethanol

Full Energy-Cycle Results:

	GHG Reductions ($MMtCO_2e$)							
Scenario	2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	1.1037	2.5386	4.5552	10.477	$210.79	$484.82	$46.27	$46.27
#2: Moderate Federal Action	1.1037	2.5386	4.5552	10.477	$210.79	$484.82	$46.27	$46.27
#3: Moderate Federal and State Action	1.1037	2.5386	4.5552	10.477	$210.79	$484.82	$46.27	$46.27

TLU -16 LCFS8 -- Cellulosic

Full Energy-Cycle Results:

	GHG Reductions ($MMtCO_2e$)							
Scenario	2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.1751	0.4028	0.1751	0.4028	$11.04	$25.39	$63.03	$63.03

#2: Moderate Federal Action	0.1751	0.4028	0.1751	0.4028	$11.04	$25.39	$63.03	$63.03
#3: Moderate Federal and State Action	0.1751	0.4028	0.1751	0.4028	$11.04	$25.39	$63.03	$63.03

TLU -17 LCFS9 -- CNG from biogas
Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.1712	0.3938	0.3360	0.7727	$14.17	$32.59	$42.18	$42.18
#2: Moderate Federal Action	0.1712	0.3938	0.3360	0.7727	$14.17	$32.59	$42.18	$42.18
#3: Moderate Federal and State Action	0.1712	0.3938	0.3360	0.7727	$14.17	$32.59	$42.18	$42.18

TLU -18 LCFS10 -- Camelian RD
Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.3323	0.7643	1.4050	3.2314	$374.40	$861.12	$266.48	$266.48

#2: Moderate Federal Action	0.3323	0.7643	1.4050	3.2314	$374.40	$861.12	$266.48	$266.48
#3: Moderate Federal and State Action	0.3323	0.7643	1.4050	3.2314	$374.40	$861.12	$266.48	$266.48

TLU -19 LCFS 11 -- NW Canola

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0343	0.0789	0.2371	0.5454	$73.43	$168.90	$309.65	$309.65
#2: Moderate Federal Action	0.0343	0.0789	0.2371	0.5454	$73.43	$168.90	$309.65	$309.65
#3: Moderate Federal and State Action	0.0343	0.0789	0.2371	0.5454	$73.43	$168.90	$309.65	$309.65

TLU -20 LCFS 12 -- Waste Oil

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.1657	0.3811	1.5799	3.6338	$71.75	$165.02	$45.41	$45.41

#2: Moderate Federal Action	0.1657	0.3811	1.5799	3.6338	$71.75	$165.02	$45.41	$45.41
#3: Moderate Federal and State Action	0.1657	0.3811	1.5799	3.6338	$71.75	$165.02	$45.41	$45.41

TLU -21 LCFS 13 -- MW Soybean

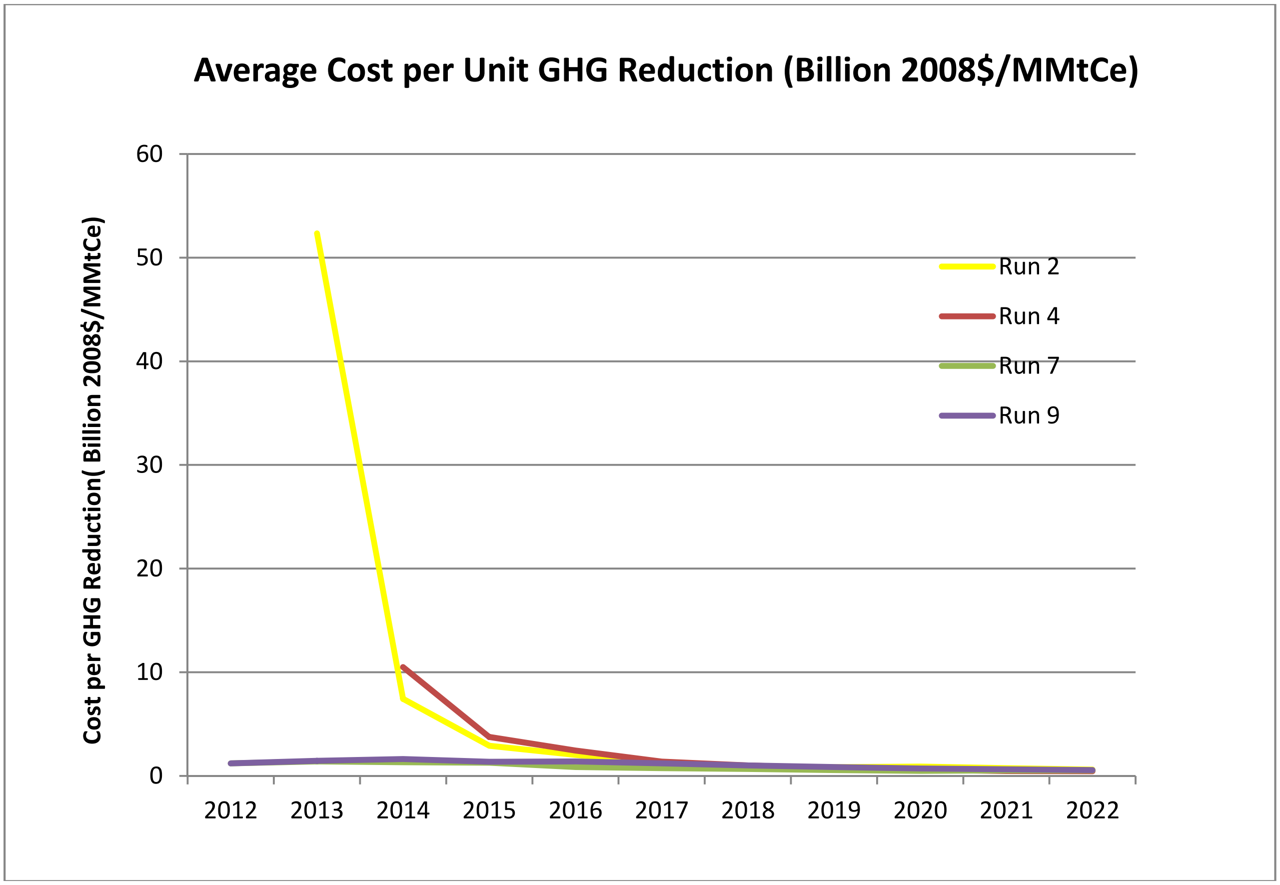
Full Energy-Cycle Results:

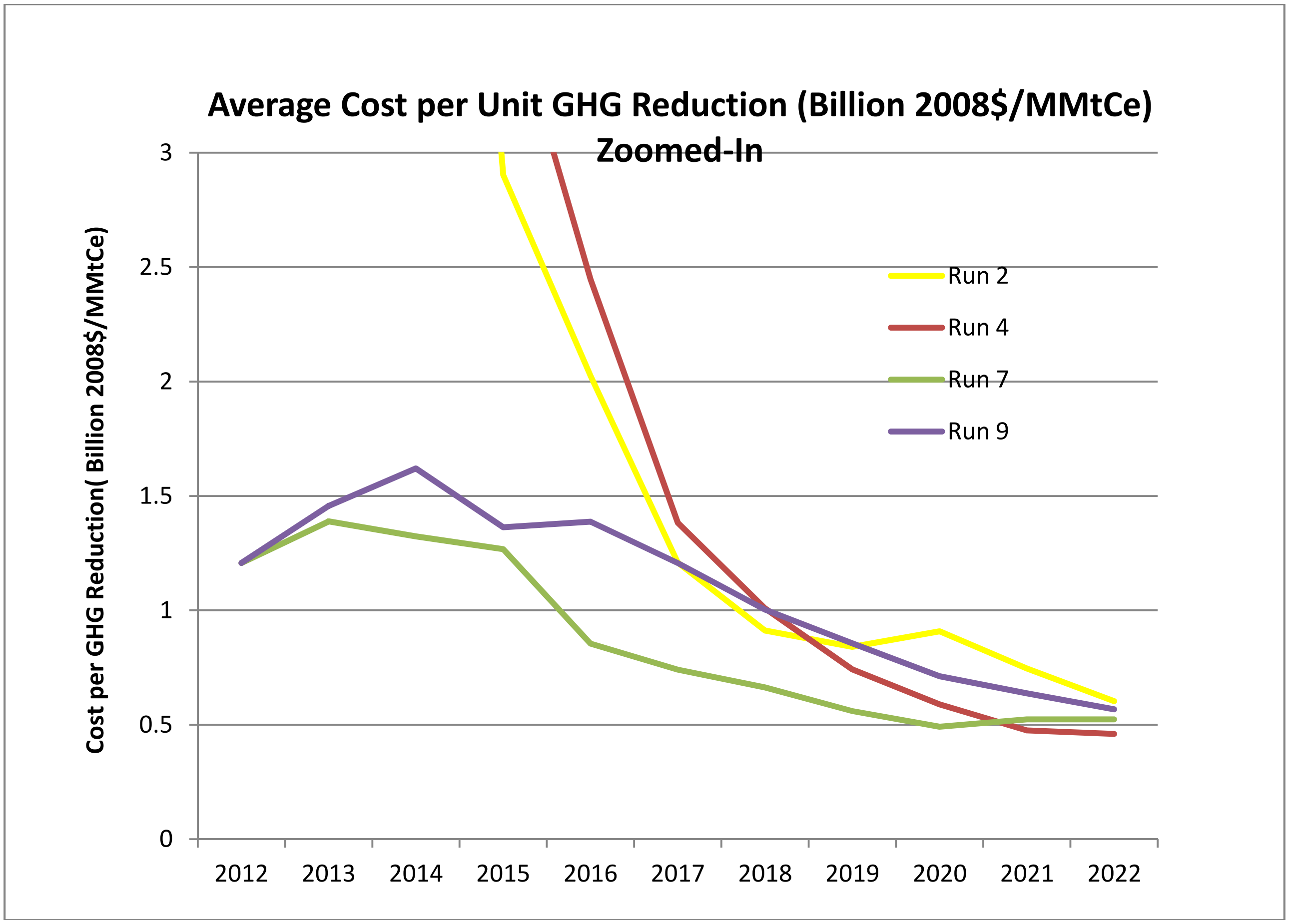
Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0000	0.0000	0.2095	0.4819	$78.89	$181.45	$376.56	$376.56
#2: Moderate Federal Action	0.0000	0.0000	0.2095	0.4819	$78.89	$181.45	$376.56	$376.56
#3: Moderate Federal and State Action	0.0000	0.0000	0.2095	0.4819	$78.89	$181.45	$376.56	$376.56

Overview

In order to reduce greenhouse gas (GHG) emission during the next ten years, biofuels will be adopted. While GHG emission can be reduced in all scenarios by using biofuels as substitutes for gasoline and diesel respectively, we are interested in decomposing biofuels from individual feedstocks in terms of GHG emission reduction and cost per unit GHG emission reduction in the period between year 2012 and 2022. Specifically, Scenario B (run 2 + run 4) and Scenario D (run 7 + run 9) are examined.

The average cost per unit GHG reduction for run 2 and run 4 is the highest in the first few years of this period, starting as high as over 50 billion (2008$) dollars per million metric tons of carbon dioxide equivalent (MMtCe) for run 2 in 2013 and 10 billion (2008$) dollars per MMtCe for run 4 in 2014, due to the relatively small amount of GHG reduction in these years with adoption of less efficient biofuels. However, with the usage of increasing amount of biofuels of low carbon intensity, the average cost per unit GHG reduction is reduced to approximately 0.5 billion (2008$) dollars per MMtCe in 2022 for all runs in Scenario B and Scenario D.

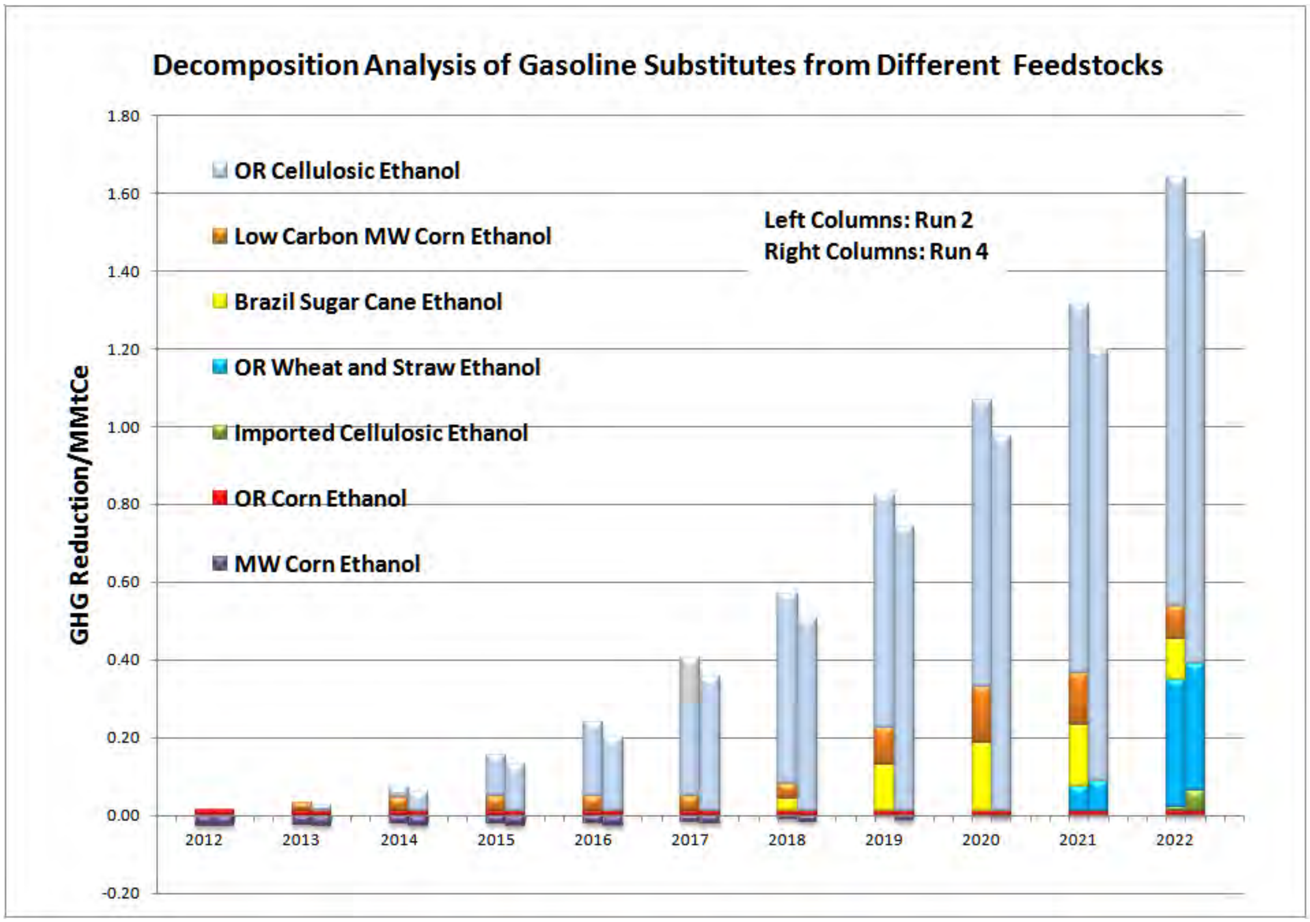

Average Cost per Unit GHG Reduction (Billion 2008$/MMtCe)
Cost per GHG Reduction(Billion 2008$/MMtCe)
60
50
40
30
20
10
0
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Run 2
Run 4
Run 7
Run 9



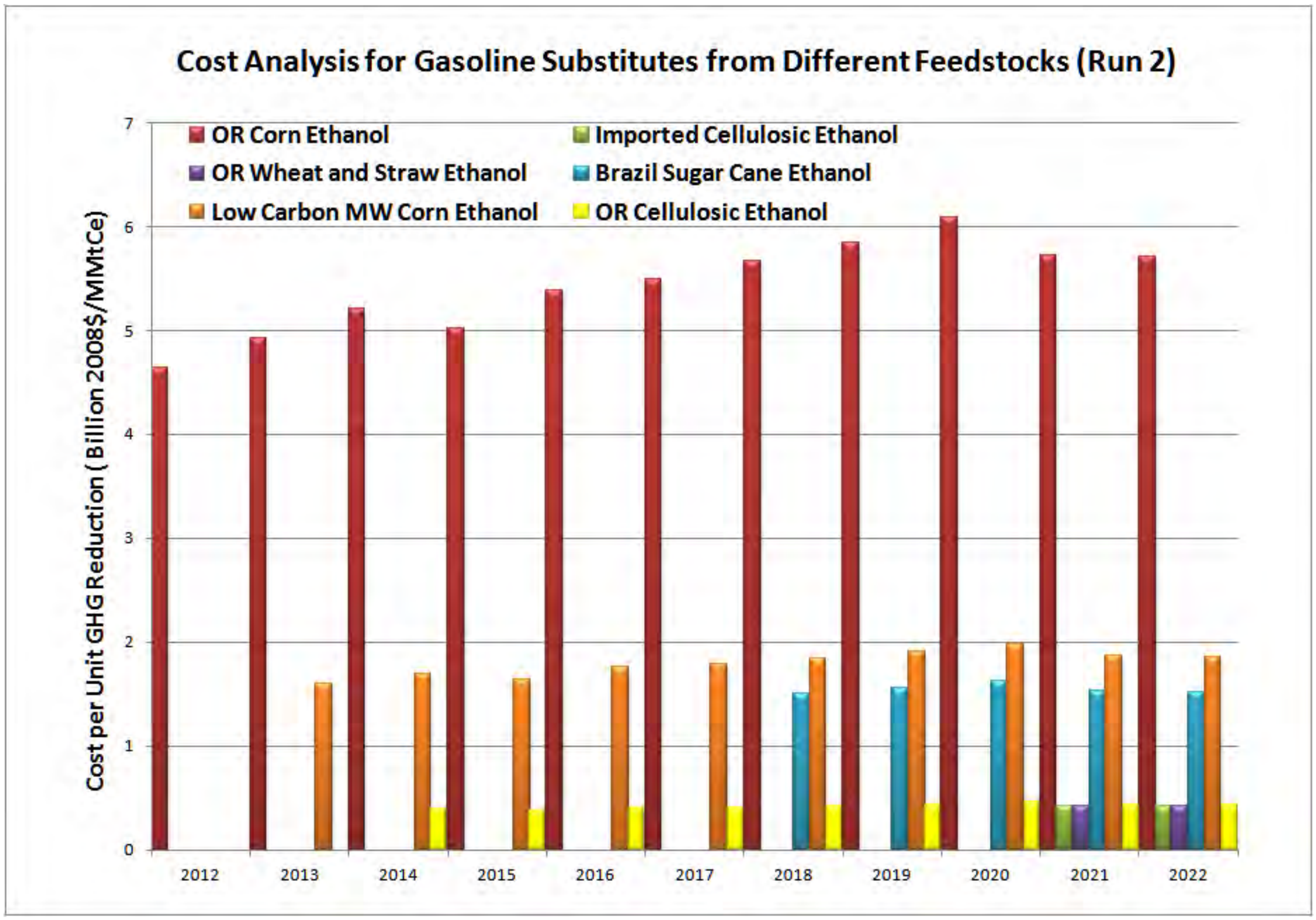
Decomposition Analysis

- Gasoline substitutes

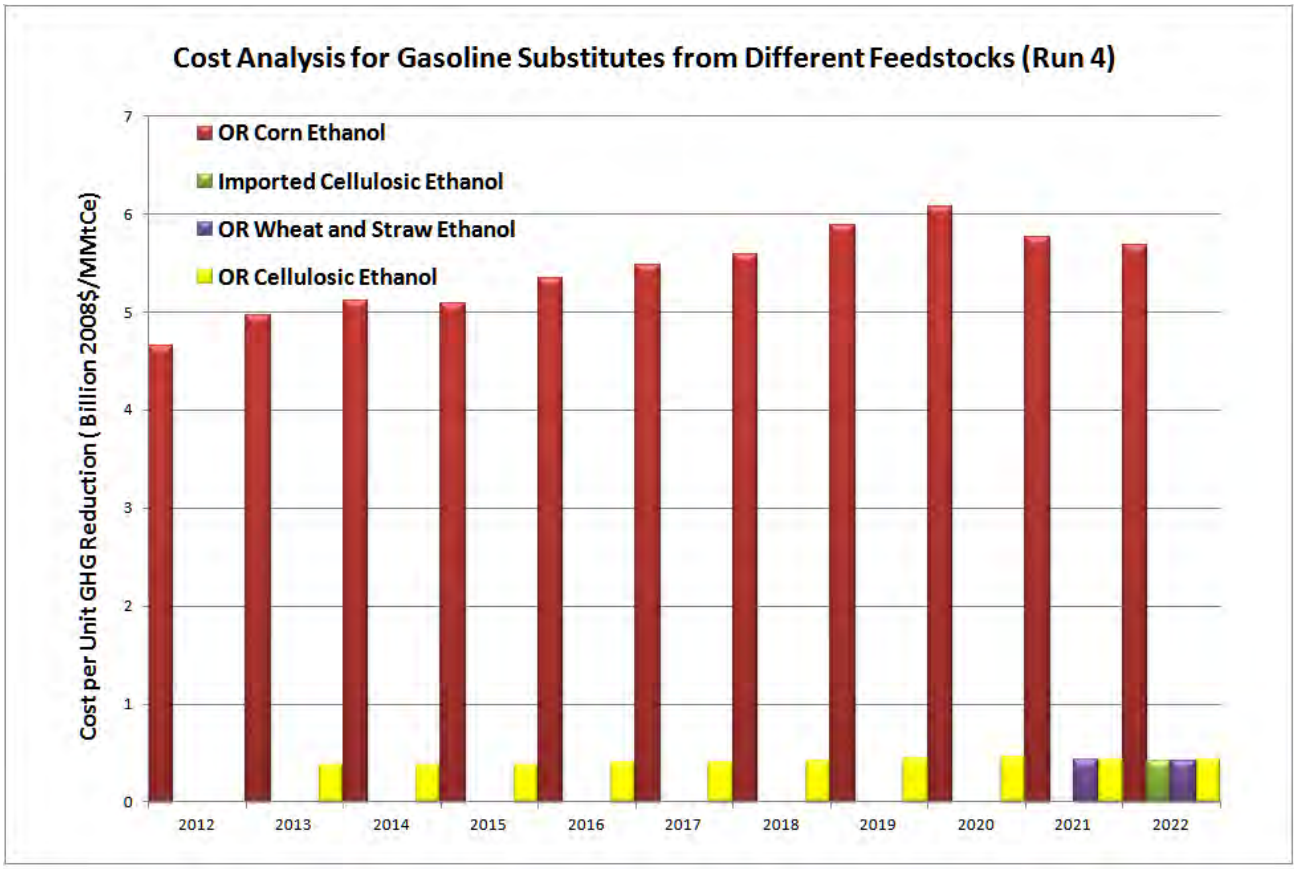
Shown below is the decomposition analysis for gasoline substitutes in run 2 (left columns) and run 4 (right columns) in terms of GHG emission reduction. For both runs, adoption of MW corn ethanol contributes negatively to GHG reduction, due to higher carbon intensity of such fuel compared to regular gasoline. Ethanol from Oregon wheat and straws, which has significantly lower carbon intensity, helps to reduce majority of GHG emission over this ten years period in both runs, while ethanol from some other feedstocks (e.g. imported cellulosic ethanol) contributes significantly less to GHG emission reduction. Due to larger amount of gasoline substitutes from more diversified feedstocks, run 2 has a larger amount of total GHG reduction by replacing gasoline with ethanol biofuels.



Cost analysis for gasoline substitutes in run 2 is made in terms of billion (2008 dollars) per million metric tons of GHG emission reduction. Between 2012 and 2022, Oregon corn ethanol has the highest cost per unit GHG reduction, which is about three times that of low carbon MW corn ethanol, four times that of Brazil sugar cane ethanol, and slightly ten times that of imported cellulosic ethanol, Oregon wheat and straw ethanol and Oregon cellulosic ethanol.



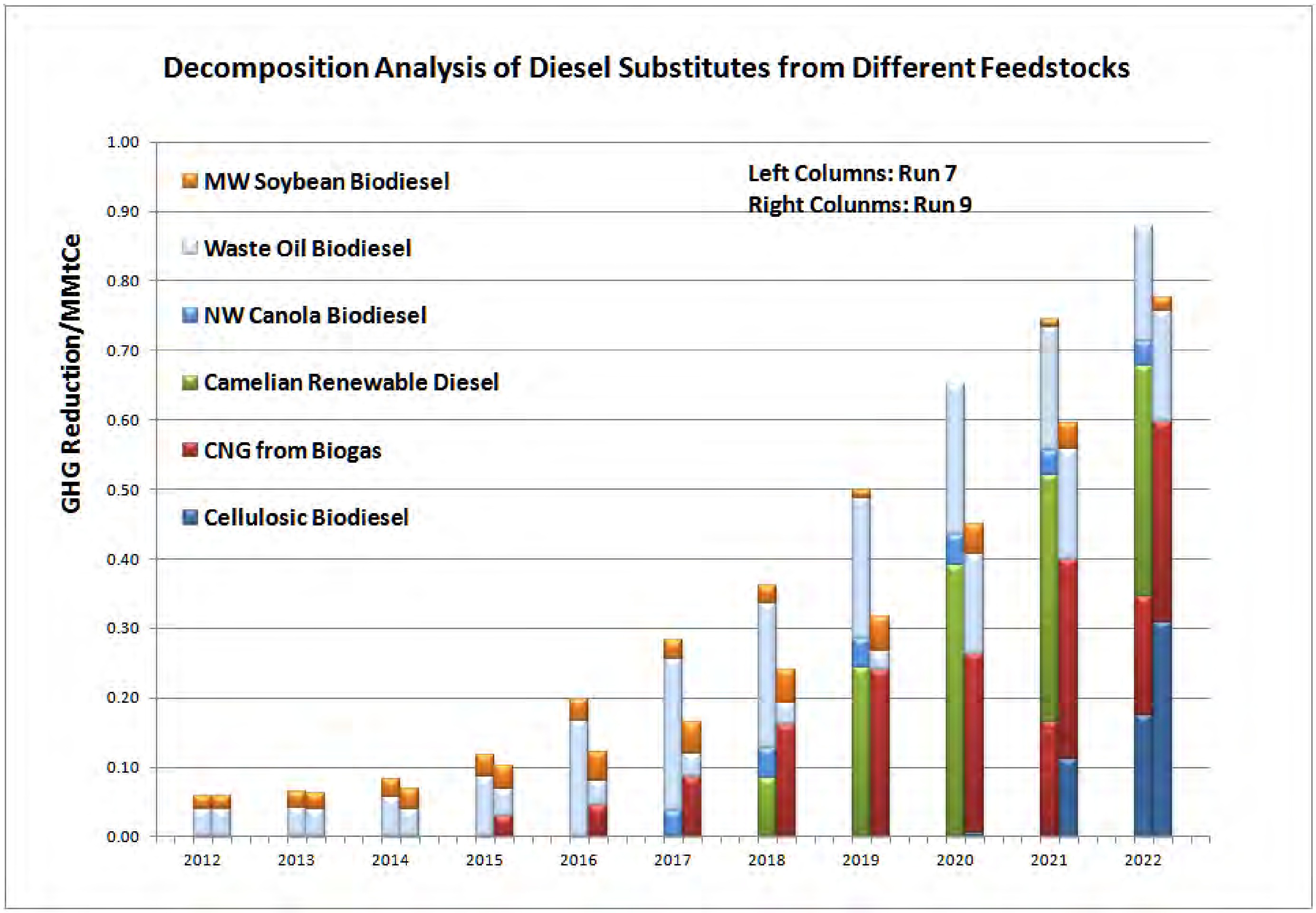
Similarly, run 4 also has Oregon corn ethanol as the least cost efficient biofuel. However, run 4 does not adopt medium cost efficient biofuels, including ethanol from Brazil sugar cane and low carbon MW corn, resulting in lower cost per unit GHG reduction from 2019 to 2022.



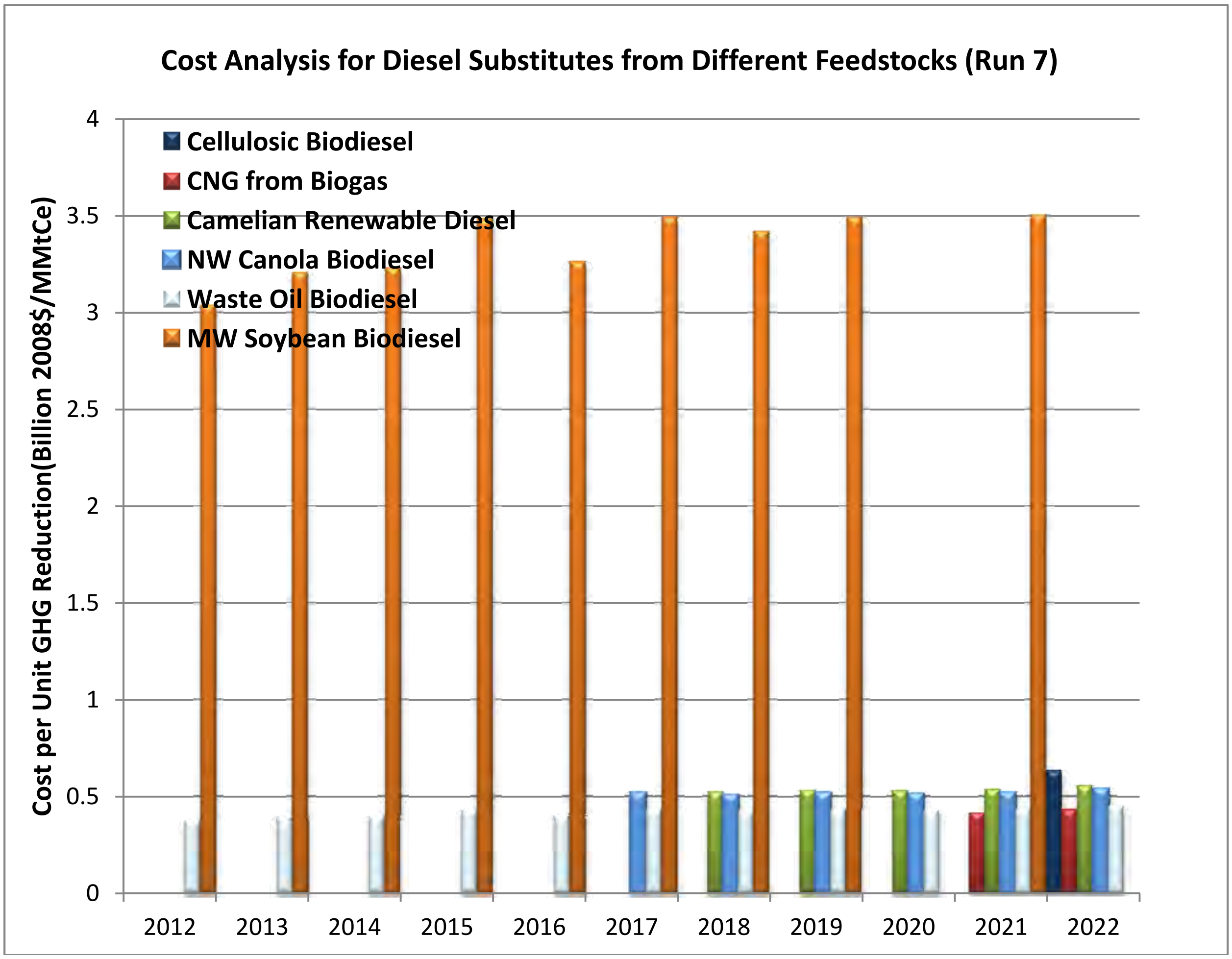
- Diesel substitutes

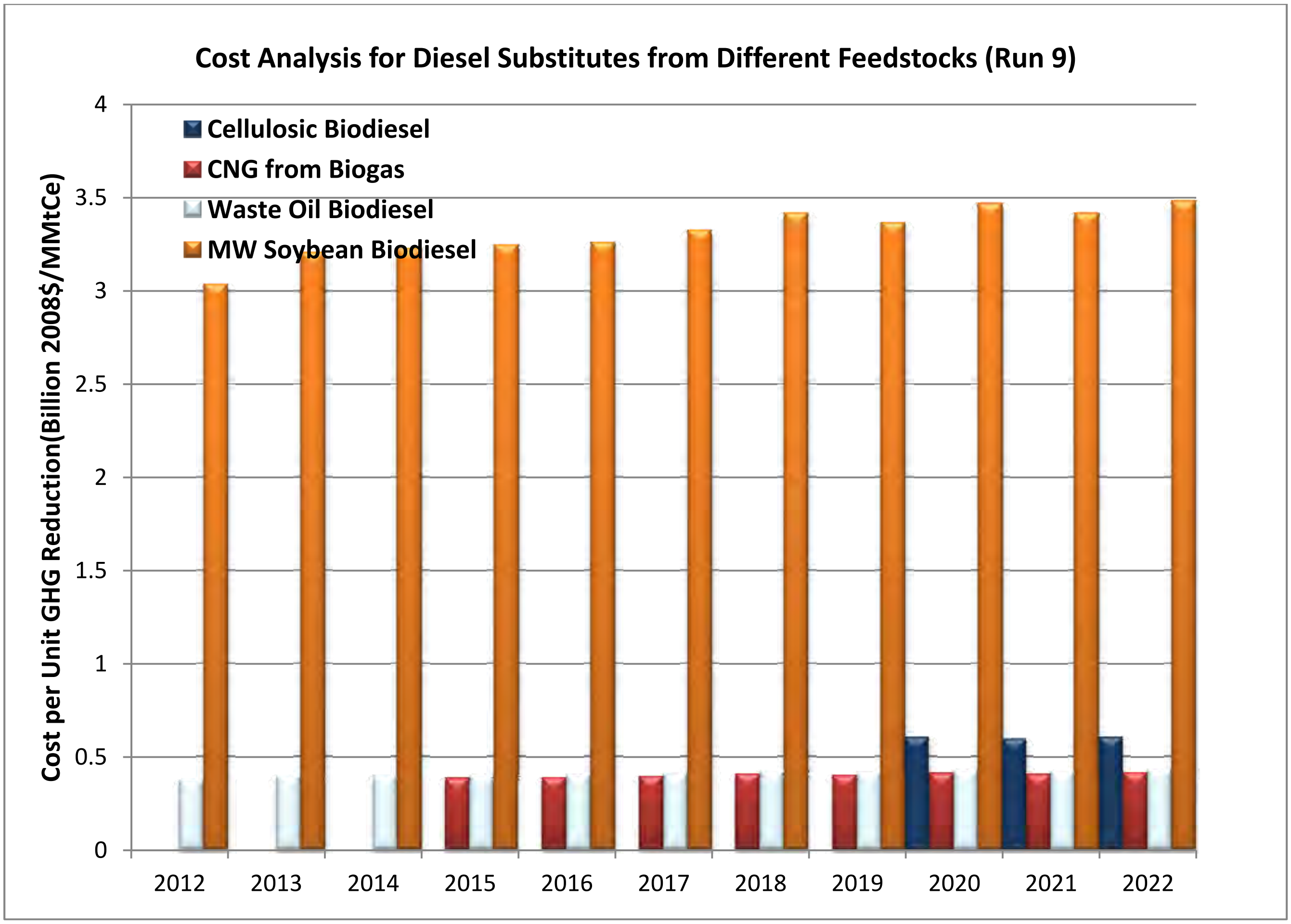
For the case of diesel substitutes, run 7 (left columns) has an overall higher level of GHG reduction than that of run 9 (right columns), due to larger amount of biodiesels adopted in run 7 from more varied feedstocks.

Unlike the common major contributor of GHG reduction mentioned previously, run 7 and run 9 does not share the same major GHG reduction contributor, except for the first three years, in which waste oil biodiesel reduces majority of GHG emission for both runs. While the contribution of waste oil biodiesel continues to grow in the first several years, such contribution stays stagnant or even slightly less in the final years for both runs. In run 7, camelian renewable diesel begins to help reduce GHG emission in year 2018 and becomes the major contributor from year 2020, followed by waste oil biodiesel, CNG from biogas and cellulosic biodiesel. Meanwhile, in run 9, CNG biogas arises in 2015 and becomes the major GHG reduction contributor from 2017 until when cellulosic biodiesel reduces similar amount of GHG emission in 2022.



MW soybean biodiesel, which has the highest cost per unit GHG reduction, is used every year during this ten years period for both run 7 and run 9, except for 2020 and 2022 in run 7. Such discontinuing use of this less cost efficient biodiesel and adoption of other more cost efficient biodiesels for run 7 results in a lower average cost per unit GHG reduction for run 7 compared to run 9.


Cost Analysis for Diesel Substitutes from Different Feedstocks (Run 7)
Cellulosic Biodiesel
CNG from Biogas
Camelian Renewable Diesel
NW Canola Biodiesel
Waste Oil Biodiesel
MW Soybean Biodiesel
Cost per Unit GHG Reduction(Billion 2008$/MMtCe)
0
0.5
1
1.5
2
2.5
3
3.5
4
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022



Quantification Methods and Results, and Key Assumptions: Please see Data Sources language above, and DEQ-commissioned reports on LCFS adoption.

Key Uncertainties (including sensitivities)

The Oregon DEQ analysis of the economic impacts of a low-carbon fuel standard identified several key uncertainties around which it built its own selection of LCFS scenarios. An LCFS is appealing as an alternative to fuel-supply mandates because it allows the participants in the fuel market (both producers and consumers) to identify the cleaner fuels they most prefer, and does not require the production or consumption of any fuel at any fixed level. Oregon DEQ identified the following uncertainties:

- The development of an in-state biofuels production sector vs. reliance on imported biofuels
- Reliance on advanced or cellulosic biofuels to achieve greater emissions reduction with less petroleum displacement vs. reliance on conventional biofuels with smaller emissions-reduction benefits per gallon
- Market response that focuses on biofuels entirely vs. market response that focuses on other fuel sources, such as natural gas and electricity
- A future economy in which petroleum prices are significantly higher than biofuels prices vs. one in which they are significantly lower than biofuels prices vs. one in which all fuel prices remain roughly at parity with each other
- A market response that achieves reductions primarily from the heavy-duty sector vs. a market response that seeks reductions from both the heavy and light-duty sectors
- A market response in which regulated parties are required to take into account ILUC vs. one in which ILUC is not taken into account

Other costs, such as the capital and operating costs of refineries, may also change significantly, altering the picture of costs and savings achieved as well as the timing of availability of fuels. The timing of the investment is subject to market forces and regulatory compliance requirements for siting and permitting as well.

In addition, biofuels face supply limitations. For the DEQ analysis, because Oregon represents only around 1% of the national demand for on-road transportation fuels, biofuels supply was not considered a limiting factor, but it could become a factor if the rest of the country were to increase its demand for biofuels at the same time as Oregon.

TLU 22-27 / FR 1-6 – Freight Options

The strategies analyzed are consistent with the scenarios for freight movements and heavy duty vehicles developed as part of the larger statewide planning process. For further information about these options and data, please refer to the reports and data produced by the Oregon Department of Transportation (ODOT) as part of the Oregon Sustainable Transportation Initiative (OSTI) project, and the associated Statewide Transportation Strategy (STS).

Measure Number	Measure Category for Microeconomic Analysis
TLU-22	FR1 -- Land Use Policy Changes
TLU-23	FR2 -- Urban Traffic Congestion Relief
TLU-24	FR3 -- Idle Reduction Strategies
TLU-25	FR4 -- More Energy Efficient Transporter Operations
TLU-26	FR5 -- Mode Shift of Freight in Response to Higher Fees
TLU-27	FR6 --Low Carbon Fuels

TLU – 22/ FR-1 Industrial Land Use Policy and Practice Changes

Measure Description

Improve industrial land use planning and practices to encourage development patterns that support low-emissions goods movement. Examples include:

- Revising land use codes to streamline permitting of alternative fueling stations (e.g., LNG)
- Preserving industrial lands near energy efficient freight corridors (rail lines, ports)
- Encouraging more flexible land use codes to allow for the co-location of shippers and receivers
- Explore policy changes or potential subsides to incent the development of urban consolidation centers

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: All cities and counties examine land use policies and practices to identify potential code changes. Monitor progress to ensure that industrial uses are locating in efficient locations.

Federal Action: None, unless related to fuel station/pipeline permits.

Oregon Action: Appropriate state agencies assist local governments in streamlining code. State agencies evaluate state laws that encumber more efficient industrial land uses.

Timing (Start, Phase In, End): Evaluation of land use policies and relevant state laws/rules could start immediately and should be reviewed on an on-going basis. Local agencies should evaluate the potential to recruit operators of urban consolidation centers. Changes in land uses will take time and be incremental in nature.

Parties Involved: Relevant state and local agencies, industrial land developers, distribution center operators.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0023	0.0052	0.0272	0.0626	($5.44)	($12.52)	($200.00)	($200.00)
#2: Moderate Federal Action	0.0113	0.0261	0.0624	0.3129	-12.4745	($62.58)	($200.00)	($200.00)
#3: Moderate Federal and State Action	0.0227	0.0521	0.1247	0.6258	($24.95)	($125.17)	($200.00)	($200.00)

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0034	0.0078	0.0408	0.0939	($5.44)	($12.52)	($133.33)	($133.33)

#2: Moderate Federal Action	0.0170	0.0391	0.0936	0.4694	($12.47)	($62.58)	($133.33)	($133.33)
#3: Moderate Federal and State Action	0.0340	0.0782	0.1871	0.9387	($37.42)	($125.17)	($200.00)	($133.33)

TLU – 23/FR-2 Urban Traffic Congestion Relief

Measure Description

Improve traffic flow on the congested freight corridors in Oregon's cities. Traffic flow improvements could be related to bottleneck removal projects, system expansion, or variable tolling to reduce non-freight vehicle demand.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Congested freight routes in Oregon cities are identified and a plan is developed to reduce congestion for freight vehicles. Improvements could include strategic capacity increases (bottleneck removal), better system management, and congestion pricing to reduce congestion.

Federal Action: Federal funding likely needed, permits may be required to change how federal-aid highways operate if concepts like tolls are pursued.

Oregon Action: ODOT and local agencies should coordinate to develop, fund, and implement freight traffic congestion relief projects.

Timing (Start, Phase In, End): Additional funding sources may need to be identified to accelerate the rate of implementation. Over time, the implementation of a light vehicle VMT fee or carbon fee may provide additional resources.

Parties Involved: ODOT and local agencies.

Data Sources and Additional Background: ODOT's Freight Master Plan and other research from groups like the Port of Portland identify key bottlenecks and congested areas for trucks in the State. Note that ODOT has not specifically identified the costs of urban congestion reduction as part of the OSTI process.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
#1: Low Federal Action	0.0045	0.0104	0.0544	0.1252	($5.14)	($11.83)	($94.51)	($94.51)
#2: Moderate Federal Action	0.0227	0.0521	0.1247	0.6258	-11.7886	($59.14)	($94.51)	($94.51)
#3: Moderate Federal and State Action	0.0454	0.1043	0.2495	1.2516	($23.58)	($118.29)	($94.51)	($94.51)

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
#1: Low Federal Action	0.0068	0.0156	0.0816	0.1877	($5.14)	($11.83)	($63.00)	($63.00)
#2: Moderate Federal Action	0.0340	0.0782	0.1871	0.9387	($11.79)	($59.14)	($63.00)	($63.00)

#3: Moderate Federal and State Action	0.0680	0.1564	0.3742	1.8775	($35.37)	($118.29)	($94.51)	($63.00)

TLU 24/ FR-3 Idle Reduction Strategies

Measure Description

Reduce the emissions of idling freight vehicles in the State. Specifically target areas that have a large number of vehicles idling for an extended period of time including truck stops, shipping terminals, and ports.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Install ground-based power (sometimes called shorepower) at the State's major truck stops and port facilities.

Federal Action: Encourage the adoption of an international shorepower standard for ships.

Oregon Action: Local agencies should review land use codes to ensure that they do not inhibit the ability to install ground-based power supplies at truck stops or ports.

Timing (Start, Phase In, End): Additional funding sources may need to be identified to accelerate the rate of implementation. Over time, the implementation of a light vehicle VMT fee or carbon fee may provide additional resources.

Parties Involved: ODOT and local agencies.

Data Sources and Additional Background: Based on research from Nelson\Nygaard and Stanford University, it costs about $7,000 per parking spot/loading zone to install ground-based power for trucks (www.climateactionreserve.org%2Fwp-content%2Fuploads%2F2009%2F03%2FTruck_Stop_Electrification_Issue_Paper.pdf)

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)	2013-2022			

	2022	2035	Total (2013-2022)	Total (2013-2035)	NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO2e)	2013-2035 CE ($/tCO2e)
#1: Low Federal Action	0.0023	0.0052	0.0272	0.0626	($5.82)	($13.39)	($213.89)	($213.89)
#2: Moderate Federal Action	0.0113	0.0261	0.0624	0.3129	-13.3408	($66.93)	($213.89)	($213.89)
#3: Moderate Federal and State Action	0.0227	0.0521	0.1247	0.6258	($26.68)	($133.86)	($213.89)	($213.89)

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO2e)	2013-2035 CE ($/tCO2e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0034	0.0078	0.0408	0.0939	($5.82)	($13.39)	($142.59)	($142.59)
#2: Moderate Federal Action	0.0170	0.0391	0.0936	0.4694	($13.34)	($66.93)	($142.59)	($142.59)
#3: Moderate Federal and State Action	0.0340	0.0782	0.1871	0.9387	($40.02)	($133.86)	($213.89)	($142.59)

TLU 25 / FR-4 Energy Efficient Transporter Operations

Measure Description

Change how freight vehicle fleets operate to focus more on greenhouse gas emissions reduction. Examples include eco-driving and slow steaming.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Establish a national fuel efficient truck speed limit that improves the efficiency of truck freight travel. Currently, a maximum speed of 50 MPH would provide the most efficient movement of heavy trucks from a GHG emissions perspective.

Federal Action: Implement rulemaking to require states to adopt a national fuel efficient speed limit. Update periodically to respond to changing vehicle technologies.

Oregon Action: Encourage the establishment of a new national truck speed limit.

Timing (Start, Phase In, End): Lobbying to push for an updated national speed limit could begin in the near term. This speed limit and more GHG efficient speeds for other modes could be enhanced through a national carbon fee.

Parties Involved: ODOT and Federal Highway Administration.

Data Sources and Additional Background: GHG emissions estimates based on output from California Air Resources Board's EMFAC emissions model.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0227	0.0521	0.2720	0.6257	($194.79)	($448.02)	($716.02)	($716.02)
#2: Moderate Federal Action	0.0567	0.1304	0.3117	1.5643	-223.181	($1,120.05)	($716.02)	($716.02)

#3: Moderate Federal and State Action	0.2267	0.5214	1.2468	6.2571	($892.73)	($4,480.21)	($716.02)	($716.02)

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0340	0.0782	0.4081	0.9386	($194.79)	($448.02)	($477.35)	($477.35)
#2: Moderate Federal Action	0.0850	0.1955	0.4675	2.3464	($223.18)	($1,120.05)	($477.35)	($477.35)
#3: Moderate Federal and State Action	0.3401	0.7822	1.8702	9.3856	($1,339.09)	($4,480.21)	($716.02)	($477.35)

TLU 26/FR-5 Mode Shift of Freight in Response to Full-Cost Pricing

Measure Description

Implement full-cost pricing (including externality fees for climate change, air pollution, environmental degradation, and other impacts) to encourage the shift in shipping mode for those commodities and goods that are eligible to shift modes (e.g., aircraft to truck, truck to train or water).

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Establish a regional or national externality fee program to send more accurate price signals to shippers and consumers about the costs of shipping by a given mode. Use fees to help relieve modal bottlenecks that could constrain the ability to shift modes.

Federal Action: This strategy would be substantially enhanced with a national carbon fee or other externality fees. May need to dedicate additional funding (potentially from the full-cost fees) to additional transportation infrastructure investment.

Oregon Action: Encourage the adoption of regional or national carbon and externality fees. Assist in the identification and removal of modal bottlenecks for freight.

Timing (Start, Phase In, End): The timing for the full-cost fees necessary for this strategy are likely fairly far into the future. Fees would also likely be phased in over time so ramp-up will take time. To the extent that funding is feasible, modal bottlenecks could be addressed in advance of any price induced mode shifts.

Parties Involved: ODOT, state ports, railroads, Federal government.

Data Sources and Additional Background: See OSTI report on freight mode shift analysis and elasticity research.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO_2e$)	2013-2035 CE ($/tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0635	0.1460	0.7618	1.7521	($69.82)	($160.58)	($91.65)	($91.65)
#2: Moderate Federal Action	0.1587	0.3650	0.8729	4.3802	-79.9988	($401.44)	($91.65)	($91.65)
#3: Moderate Federal and State Action	0.6348	1.4600	3.4915	17.5207	($320.00)	($1,605.77)	($91.65)	($91.65)

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO_2e$)	2013-2035 CE ($/tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				

#1: Low Federal Action	0.0952	0.2190	1.1427	2.6281	($69.82)	($160.58)	($61.10)	($61.10)
#2: Moderate Federal Action	0.2381	0.5475	1.3093	6.5703	($80.00)	($401.44)	($61.10)	($61.10)
#3: Moderate Federal and State Action	0.9522	2.1901	5.2372	26.2810	($479.99)	($1,605.77)	($91.65)	($61.10)

TLU 27 / FR-6 Low Carbon Fuels

Measure Description

Encourage the more rapid adoption of low carbon fuels.

Measure Design Specifications and Data Sources

Goals or Level of Effort:

Base: Promote, regulate, and/or incent the development and adoption of low carbon fuels nationally. Goal will be to reduce average fuel carbon content (relative to conventional fuels like diesel and jet fuel) by 20% by 2050.

Federal Action: To be successful, this strategy will likely require action at the federal level to mandate low carbon fuels.

Oregon Action: Continue to pursue reductions in fuel carbon content beyond the 10% reduction goal defined for 2020. Support federal and regional efforts to reduce fuel carbon content.

Timing (Start, Phase In, End): In 2009, the state legislature adopted a low carbon fuel standard which outlined a 10% reduction in fuel carbon content by 2020. Additional legislation would be required to meet the target set above. Moreover, the GHG emissions reductions assumed in the OSTI work rely on national average fuel carbon content decreasing by 20%; this would likely require federal action.

Parties Involved: Oregon state agencies, Federal government.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$)	2013-2022			

	2022	2035	Total (2013-2022)	Total (2013-2035)	NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
#1: Low Federal Action	0.1270	0.2920	1.5235	3.5041	$190.44	$438.02	$125.00	$125.00
#2: Moderate Federal Action	0.3174	0.7300	1.7457	8.7603	218.2178	$1,095.04	$125.00	$125.00
#3: Moderate Federal and State Action	1.2696	2.9201	6.9830	35.0414	$872.87	$4,380.17	$125.00	$125.00

Full Energy-Cycle Results:

Scenario	GHG Reductions (MMtCO$_2$e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.1904	0.4380	2.2853	5.2562	$190.44	$438.02	$83.33	$83.33
#2: Moderate Federal Action	0.4761	1.0950	2.6186	13.1405	$218.22	$1,095.04	$83.33	$83.33
#3: Moderate Federal and State Action	1.9044	4.3801	10.4745	52.5620	$1,309.31	$4,380.17	$125.00	$83.33

TLU 28-37 / LD 1-10 – Light Duty Travel Options

The strategies analyzed are consistent with the scenarios for light duty vehicle travel options developed as part of the larger statewide planning process. For further information about these options and data, please refer to the reports and data produced by the Oregon Department of Transportation (ODOT) as part of the Oregon Sustainable Transportation Initiative (OSTI) project, and the associated Statewide Transportation Strategy (STS).

Measure Number	Measure Category for Microeconomic Analysis
TLU-28	LD1 -- Transit Growth
TLU-29	LD2 -- Walk/Bike Short SOV mode shift
TLU-30	LD3 -- ITS &Operations
TLU-31	LD4 – PAYD
TLU-32	LD5 – TDM
TLU-33	LD6 – EcoDrive
TLU-34	LD7 -- Parking Management
TLU-35	LD8 -- Externality Taxes
TLU-36	LD9 -- Congestion Charges
TLU-37	LD10 – Carsharing

TLU -28 LD1 -- Transit Growth

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0164	0.0492	0.0569	0.3835	$47.22	$318.29	$829.86	$829.86
#2: Moderate Federal Action	0.0818	0.2460	0.2845	1.9177	$236.09	$1,591.46	$829.86	$829.86
#3: Moderate Federal and State Action	0.1636	0.4921	0.5690	3.8355	$472.17	$3,182.93	$829.86	$829.86

TLU -29 LD2 -- Walk/Bike Short SOV mode shift

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0052	0.0093	0.0210	0.1016	($14.54)	($70.41)	($693.23)	($693.23)
#2: Moderate Federal Action	0.0258	0.0467	0.1049	0.5078	($72.70)	($352.05)	($693.23)	($693.23)
#3: Moderate Federal and State Action	0.0515	0.0934	0.2097	1.0157	($145.39)	($704.10)	($693.23)	($693.23)

TLU -30 LD3 -- ITS &Operations

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0017	0.0011	0.0052	0.0211	($0.26)	($1.04)	($49.47)	($49.47)
#2: Moderate Federal Action	0.0084	0.0054	0.0261	0.1055	($1.29)	($5.22)	($49.47)	($49.47)

#3: Moderate Federal and State Action	0.0168	0.0108	0.0522	0.2110	($2.58)	($10.44)	($49.47)	($49.47)

TLU -31 LD4 -- PAYD

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0391	0.0622	0.0979	0.8292	($82.57)	($699.08)	($843.09)	($843.09)
#2: Moderate Federal Action	0.1954	0.3108	0.4897	4.1460	($412.86)	($3,495.42)	($843.09)	($843.09)
#3: Moderate Federal and State Action	0.3907	0.6217	0.9794	8.2919	($825.71)	($6,990.84)	($843.09)	($843.09)

TLU -32 LD5 -- TDM

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0061	0.0082	0.0205	0.1011	($9.05)	($44.71)	($442.06)	($442.06)
#2: Moderate Federal Action	0.0305	0.0411	0.1023	0.5057	($45.24)	($223.56)	($442.06)	($442.06)
#3: Moderate Federal and State Action	0.0609	0.0821	0.2047	1.0115	($90.48)	($447.13)	($442.06)	($442.06)

TLU -33 LD6 -- EcoDrive

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0246	0.0657	0.0659	0.6441	($12.22)	($119.47)	($185.49)	($185.49)
#2: Moderate Federal Action	0.1232	0.3283	0.3295	3.2205	($61.12)	($597.37)	($185.49)	($185.49)
#3: Moderate Federal and State Action	0.2464	0.6566	0.6590	6.4410	($122.24)	($1,194.73)	($185.49)	($185.49)

TLU -34 LD7 -- Parking Management

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0237	0.0482	0.0895	0.4694	($62.06)	($325.37)	($693.13)	($693.13)
#2: Moderate Federal Action	0.1183	0.2408	0.4477	2.3471	($310.28)	($1,626.85)	($693.13)	($693.13)
#3: Moderate Federal and State Action	0.2366	0.4817	0.8953	4.6943	($620.56)	($3,253.71)	($693.13)	($693.13)

TLU -35 LD8 -- Externality Taxes

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0079	0.0461	0.0207	0.2726	($6.38)	($84.21)	($308.93)	($308.93)
#2: Moderate Federal Action	0.0396	0.2303	0.1033	1.3629	($31.91)	($421.03)	($308.93)	($308.93)
#3: Moderate Federal and State Action	0.0793	0.4606	0.2066	2.7258	($63.82)	($842.06)	($308.93)	($308.93)

TLU -36 LD9 -- Congestion Charges

Point-of-combustion

Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	-0.0012	0.0006	-0.0012	-0.0345	$0.68	$19.54	($566.47)	($566.47)
#2: Moderate Federal Action	-0.0062	0.0028	-0.0060	-0.1725	$3.42	$97.69	($566.47)	($566.47)
#3: Moderate Federal and State Action	-0.0123	0.0057	-0.0121	-0.3449	$6.85	$195.38	($566.47)	($566.47)

TLU -37 LD10 -- Carsharing

Point-of-combustion Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0016	0.0020	0.0062	0.0233	($5.29)	($19.99)	($856.76)	($856.76)
#2: Moderate Federal Action	0.0082	0.0099	0.0309	0.1167	($26.45)	($99.97)	($856.76)	($856.76)
#3: Moderate Federal and State Action	0.0163	0.0199	0.0617	0.2334	($52.89)	($199.94)	($856.76)	($856.76)

TLU -28 LD1 -- Transit Growth

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
#1: Low Federal Action	0.0245	0.0738	0.0853	0.5753	$70.83	$477.44	$829.86	$829.86
#2: Moderate Federal Action	0.1227	0.3691	0.4267	2.8766	$354.13	$2,387.19	$829.86	$829.86
#3: Moderate Federal and State Action	0.2454	0.7381	0.8535	5.7532	$708.26	$4,774.39	$829.86	$829.86

TLU -29 LD2 -- Walk/Bike Short SOV mode shift

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0077	0.0140	0.0315	0.1524	($21.81)	($105.61)	($693.23)	($693.23)
#2: Moderate Federal Action	0.0386	0.0701	0.1573	0.7618	($109.04)	($528.07)	($693.23)	($693.23)
#3: Moderate Federal and State Action	0.0773	0.1402	0.3146	1.5235	($218.09)	($1,056.15)	($693.23)	($693.23)

TLU -30 LD3 -- ITS &Operations

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0025	0.0016	0.0078	0.0317	($0.39)	($1.57)	($49.47)	($49.47)
#2: Moderate Federal Action	0.0126	0.0081	0.0391	0.1583	($1.94)	($7.83)	($49.47)	($49.47)
#3: Moderate Federal and State Action	0.0252	0.0162	0.0782	0.3165	($3.87)	($15.66)	($49.47)	($49.47)

TLU -31 LD4 -- PAYD

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0586	0.0932	0.1469	1.2438	($123.86)	($1,048.63)	($843.09)	($843.09)
#2: Moderate Federal Action	0.2931	0.4662	0.7345	6.2189	($619.28)	($5,243.13)	($843.09)	($843.09)
#3: Moderate Federal and State Action	0.5861	0.9325	1.4691	12.4379	($1,238.57)	#########	($843.09)	($843.09)

TLU -32 LD5 -- TDM

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$) 2022	2035	Total (2013-2022)	Total (2013-2035)	2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
#1: Low Federal Action	0.0091	0.0123	0.0307	0.1517	($13.57)	($67.07)	($442.06)	($442.06)
#2: Moderate Federal Action	0.0457	0.0616	0.1535	0.7586	($67.86)	($335.35)	($442.06)	($442.06)
#3: Moderate Federal and State Action	0.0914	0.1232	0.3070	1.5172	($135.72)	($670.69)	($442.06)	($442.06)

TLU -33 LD6 -- EcoDrive

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)	2013-2022		

	2022	2035	Total (2013-2022)	Total (2013-2035)	NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
#1: Low Federal Action	0.0370	0.0985	0.0989	0.9662	($18.34)	($179.21)	($185.49)	($185.49)
#2: Moderate Federal Action	0.1848	0.4925	0.4943	4.8308	($91.68)	($896.05)	($185.49)	($185.49)
#3: Moderate Federal and State Action	0.3696	0.9849	0.9885	9.6615	($183.36)	($1,792.10)	($185.49)	($185.49)

TLU -34 LD7 -- Parking Management

Full Energy-Cycle Results:

Scenario	GHG Reductions (MMtCO$_2$e)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	0.0355	0.0722	0.1343	0.7041	($93.08)	($488.06)	($693.13)	($693.13)
#2: Moderate Federal Action	0.1774	0.3612	0.6715	3.5207	($465.42)	($2,440.28)	($693.13)	($693.13)
#3: Moderate Federal and State Action	0.3548	0.7225	1.3430	7.0414	($930.84)	($4,880.56)	($693.13)	($693.13)

TLU -35 LD8 -- Externality Taxes

Full Energy-Cycle Results:

Scenario	GHG Reductions (MMtCO$_2$e)				2013-2022 NPV ($MM2010)	2013-2035 NPV	2013-2022 CE	2013-2035 CE
	2022	2035	Total	Total				

			(2013-2022)	(2013-2035)		($MM2010)	($/tCO₂e)	($/tCO₂e)
#1: Low Federal Action	0.0119	0.0691	0.0310	0.4089	($9.57)	($126.31)	($308.93)	($308.93)
#2: Moderate Federal Action	0.0595	0.3454	0.1549	2.0443	($47.86)	($631.55)	($308.93)	($308.93)
#3: Moderate Federal and State Action	0.1189	0.6909	0.3099	4.0886	($95.73)	($1,263.09)	($308.93)	($308.93)

TLU -36 LD9 -- Congestion Charges

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
#1: Low Federal Action	-0.0018	0.0008	-0.0018	-0.0517	$1.03	$29.31	($566.47)	($566.47)
#2: Moderate Federal Action	-0.0092	0.0042	-0.0091	-0.2587	$5.14	$146.53	($566.47)	($566.47)
#3: Moderate Federal and State Action	-0.0185	0.0085	-0.0181	-0.5174	$10.27	$293.07	($566.47)	($566.47)

TLU -37 LD10 -- Carsharing

Full Energy-Cycle Results:

Scenario	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				

#1: Low Federal Action	0.0024	0.0030	0.0093	0.0350	($7.93)	($29.99)	($856.76)	($856.76)
#2: Moderate Federal Action	0.0122	0.0149	0.0463	0.1750	($39.67)	($149.96)	($856.76)	($856.76)
#3: Moderate Federal and State Action	0.0245	0.0298	0.0926	0.3501	($79.34)	($299.91)	($856.76)	($856.76)

Appendix D: Agricultural, Forestry, and Waste Management (AFW) Measure Descriptions and Related Materials

AFW-1 Dairy Methane Energy Production

Measure Description

Develop dairy anaerobic digestion and methane utilization projects at dairies not already expected to adopt this technology during the planning period. Anaerobic digestion of manure reduces methane emissions during manure management and also provides a carbon neutral energy source for producing electricity or thermal energy. This additional energy offsets GHG emissions from fossil-based sources. For the purposes of cost curve development, this measure assumes that all projects will include construction of an anaerobic digester and that the methane produced will be used to generate electricity with an engine-generator set.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: All medium to large dairies that are not expected to have a digester project in place within the planning period will have a project installed.[1] For this measure, it is assumed that the achievable abatement potential is limited by the cost effectiveness achieved by the group of projects considered. Limitations are assumed to be constrained by upper limit acceptance within carbon market pricing (e.g. CA AB32 Cap & Trade). This value is assumed to be <$20/t$CO_2$e.

- ***Federal Action Scenario (Low):*** Addresses application of digesters and engine/generator sets at large dairies.
- ***Federal Action Scenario (Moderate):*** Addresses application of digesters and engine/generator sets at medium dairies.
- ***Oregon Action Scenario:*** Same as the Federal Action Scenario (Moderate).

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2020 at large dairies and 2025 for medium dairies.

Parties Involved: OR Department of Agriculture, dairy producers, local county extension offices.

Data Sources and Additional Background: Data on herd populations at OR dairies, as well as planned and existing projects from ODOA;[2] NW Dairy Association feasibility study;[3] Climate Trust/Energy Trust White Paper;[4] and previous dairy methane project studies reviewed by CCS.

[1] Note that definitions for dairy sizes are different in this analysis from those used by ODOA: >700 head for large; 200-700 head for medium; and <200 head for small.
[2] M. Kays, ODOA, personal communications and spreadsheets provided to S. Roe, CCS, May 30, 2012.
[3] ECOregon, *Oregon Dairy Digester Feasibility Study, Summary Report,* prepared for the NW Dairy Association, January 25, 2010.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.18	0.16	1.1	3.3	$50	$63	$45	$19
Mod. Fed. Action	0.23	0.23	1.4	4.4	$65	$85	$47	$19
OR Action	0.23	0.23	1.4	4.4	$65	$85	$47	$19

Full Energy-Cycle Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/$tCO_2e$)	2013-2035 CE ($/$tCO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.19	0.07	1.2	3.5	$50	$63	$45	$18
Mod. Fed. Action	0.25	0.24	1.5	4.5	$65	$85	$47	$18
OR Action	0.25	0.24	1.5	4.5	$65	$85	$47	$18

Quantification Methods:

This assessment covers a simplified set of assumptions regarding how dairy energy will be recovered and utilized. It is assumed that anaerobic digesters will be installed and engine/generator sets will be used to convert the methane into electricity, which will all be used on site to offset dairy owner grid-based purchases. There are potentially other uses of energy (e.g. heat recovery for hot water) and products (e.g. fiber, digestate) which are not being addressed in this measure analysis.

ODOA data for all dairies in the state by size range were assembled and those sites for which there were already projects in place or planned were removed from the assessment of abatement potential. Due to a relative lack of digester project data for ODOA defined small dairies (<200 head), dairy sizes were assessed using different size ranges as follows: small (<500), medium (500-1,200 head), and large (>1,200 head). Capital costs per head for each size range were developed from a number of studies which are cited in the agriculture analysis workbook. Average capital costs/head are about: $1,700 (small); $1,300 (medium); and $1,100 (large).

[4] *Growing Oregon's Biogas Industry: A Review of Oregon's Biogas Potential and Benefits,* The Climate Trust and Energy Trust of Oregon, February 2011.

These costs were held constant through the planning period which assumes continued "learning by doing" will offset inflation.

Similarly, these studies provided information on operations and maintenance (O&M) costs and electricity generation; however, these data were not available for all sites. Therefore, it was not possible to generate separate estimates by dairy size for O&M costs. Therefore, single estimates covering all projects for annual O&M ($0.029/kWh generated) and electricity generation (0.83 MWh/head-yr) were derived.

GHG reductions were derived using the average dairy cattle methane emissions rate from EPA's SIT Agriculture Module (1.36 tCO_2e/head-yr). Reductions were estimated using a value of average methane emissions for US dairy cattle at sites with active projects (0.502 tCO_2e/head-yr).

Capital costs were annualized assuming a 15-year project life and 100% financing at 5% interest. Total measure costs each year from 2013-2035 were the sum of annualized capital, O&M, and electricity savings.

Key Assumptions & Uncertainties (including sensitivities)

- As mentioned above, this is a simplified analysis that doesn't cover other configurations of dairy methane projects, including those that utilize both power and heat, those that would sell power to the grid rather than on-site use, and the value of co-products (fiber, fertilizer).
- The analysis doesn't capture potentially significant costs that could begin later in the period of analysis for engine/gen set replacement or overhaul, as the early projects approach/reach the end of their useful lives.
- A key sensitivity is the selection of electricity production per head. The value used in this analysis (0.83 MWh/head-yr) is fairly conservative based on the data reviewed. A recent Oregon feasibility analysis for a manure and food waste co-digestion project indicated a range of 0.73-1.20 MWh/head-yr.[5] At the higher end of the range, the overall cost effectiveness of the scenarios drops to the $12-13/$tCO_2e$ range.

[5] http://www.oregon.gov/energy/RENEW/docs/CREFF/VolbedaFeasiblityStudy.pdf?ga=t.

AFW-2 Co-Digestion of Livestock Waste and Food Processing Waste and Methane Energy Production

Measure Description

Building off of the dairy anaerobic digestion measure (AFW-1), this measure covers opportunities to co-digest dairy manure and food processing waste. Anaerobic digestion of manure and food processing waste reduces methane emissions during manure/waste management and also provides a carbon neutral energy source for producing electricity or thermal energy. This additional energy offsets GHG emissions from fossil-based sources. For the purposes of cost curve development, this measure assumes that all dairy projects addressed under AFW-1 will co-digest an additional 10% (by weight) of organic waste from nearby food processors. Hence, this option completely overlaps AFW-1 and partly overlaps AFW-3 (which addresses digestion of food processing waste specifically).

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure: All medium to large dairies addressed under AFW-1 will co-digest food processing waste (an incremental 20% by volume). As with AFW-1, it is assumed that the achievable abatement potential is limited by the cost effectiveness achieved. Limitations are assumed to be constrained by upper limit acceptance within carbon market pricing (e.g. CA AB32 Cap & Trade). This value is assumed to be <\$20/tCO_2e.

- ***Federal Action Scenario (Low):*** Addresses projects at all large dairies (>1,200 head).
- ***Federal Action Scenario (Moderate):*** Addresses projects at all medium to large dairies ((>500 head).
- ***Oregon Action Scenario:*** Also brings in projects at small dairies. On their own, the cost effectiveness at small dairies would exceed the \$20/tCO_2e threshold; however, when packaged with the larger sites, the overall cost effectiveness is less than \$20/tCO_2e.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2020 at large dairies and 2025 for medium dairies.

Parties Involved: OR Department of Agriculture, dairy producers, local county extension offices; OR Department of Environmental Quality, food processors.

Data Sources and Additional Background: Definitions of large, medium and small dairies are different than those used by ODOA (ODOA definitions are: >700 head for large; 200-700 head for medium; and <200 head for small. This is because there are very few digester projects that have been developed at dairies of even <500 head. Medium size dairies with digester projects tend to be in the 500-1,200 head range. OR dairy herd sizes, locations, and planned/existing projects from ODOA;[6] NW Dairy Association feasibility study;[7] Climate Trust/Energy Trust

[6] M. Kays, ODOA, personal communications and spreadsheets provided to S. Roe, CCS, May 30, 2012.
[7] ECOregon, *Oregon Dairy Digester Feasibility Study, Summary Report,* prepared for the NW Dairy Association, January 25, 2010.

White Paper;[8] previous dairy methane project studies reviewed by CCS. Available data on food processing waste generation and management is limited. One recent estimate from the White Paper cited previously on survey work in the Portland area is 100,000 tons/yr. But statewide estimates were not identified. Data on solid waste management of all food waste (includes both food processor waste and food waste in the municipal solid waste stream) are available from the project's assessment of waste management measures. Based on current dairy herd populations in all size ranged and manure generation rates, over half a million tons of food waste could be co-digested at levels considered in this measure.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

Note: for cost curve and macro-modeling: this measure has complete overlap with AFW-1.

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.24	0.21	1.4	4.2	$29	$17	$20	$4
Mod. Fed. Action	0.31	0.29	1.8	5.7	$45	$46	$25	$8
OR Action	0.37	0.35	2.1	6.8	$63	$85	$30	$12

Full Energy-Cycle Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.26	0.23	1.6	4.6	$29	$17	$18	$4
Mod. Fed. Action	0.31	0.31	2.0	6.2	$45	$46	$23	$7
OR Action	0.40	0.38	2.3	7.4	$63	$85	$28	$11

Quantification Methods:

GHG Reductions. The analysis built off of the AFW-1 measure by estimating the additional methane that could be generated by co-digesting food processor waste at levels of 10% by weight. A recent feasibility study for a project in Oregon (Volbeda dairy) provided key inputs to this assessment of both GHG reductions and costs.[9] Information provided in this study indicates

[8] *Growing Oregon's Biogas Industry: A Review of Oregon's Biogas Potential and Benefits*, The Climate Trust and Energy Trust of Oregon, February 2011.
[9] http://www.oregon.gov/energy/RENEW/docs/CREFF/VolbedaFeasiblityStudy.pdf?ga=t.

that methane generation rates increase by about 8% for every 2% (by weight) added food waste.[10] The GHG reductions were estimated by determining the additional methane generation achieved via co-digestion from the AFW-1 measure analysis and the subsequent avoided electricity benefit.

There are potentially some additional GHG reductions that would occur from reduced transport of food processing waste depending on the method and distance to BAU management locations. Also, GHG reductions from either wastewater treatment or solid waste management (landfilling) are likely; however, additional information on current waste generation and management activities would be needed to address these.

Net Societal Costs. The Volbeda dairy feasibility study cost data were used to construct estimates of the additional costs needed to construct co-digestion projects from those addressed under AFW-1. Additional capital costs include larger digester capacity, larger engine/generator sets, food waste handling/storage facilities, and power inter-connection to the grid.[11] These additional costs suggest an increase of about 30% to the overall capital costs for each project. Since the Volbeda site is considered a large dairy (1,975 head), the increase in capital costs for small to medium-sized dairies was increased to 50% to provide a greater level of conservatism.

For O&M costs, the Volbeda dairy study data suggest an increase in 4% to cover the additional food processing waste handling. To provide more conservative estimates for small to medium dairies, this value was doubled.

In addition to the avoided costs for electricity, avoided waste management costs were estimated using the average Oregon landfill tipping fee of $35/ton and assuming that the dairy/digester operator would charge a tipping fee of half this amount.

Key Assumptions & Uncertainties (including sensitivities)

- Incremental capital and O&M cost estimates are based on one feasibility study. Although this study is specific to a co-digestion project in Oregon, the application of its cost estimates to co-digestion projects broadly carries a significant level of uncertainty, especially for smaller dairies. It is worth noting that this study's capital costs of over $3,000/head were double those that were used in AFW-1. This is likely due, at least in part, to the complete mix digester technology selected, which appears to be much more expensive than other commonly-employed technologies (e.g. plug flow and covered lagoon).

- Additional GHG reductions from reduced food processing waste transport and management; these are not currently captured in this analysis.

[10] Specifically, added fats, oils, and greases which have much higher volatile solids content and methane generation potential.
[11] Unlike AFW-1, due to the additional power produced in this measure, it is unlikely that most sites would be able to use all electricity on-site; therefore, it is assumed that all power for this option is supplied to the grid.

AFW-3 Crop Nutrient Management

Measure Description

Improve the efficiency of commercial nitrogen-based fertilizers through implementation of best management practices and/or new technology. Significant cost savings can be achieved through lower fertilizations costs, which have increased significantly over the past 10-15 years. Increased crop yields are also possible through increases in nitrogen use efficiency. Also, ammonia is a primary nitrogen fertilizer or feedstock for production of other nitrogen fertilizers. Natural gas is the primary feedstock for manufacturing ammonia. Hence, reductions in nitrogen fertilizer use will also reduce upstream use of natural gas.

Excess nitrogen applied to soils and not metabolized by plants can be emitted to the atmosphere as nitrous oxide (N_2O), leached into groundwater or surface water, or volatilized as ammonia. There are five general methods to increase nitrogen efficiency and lower N_2O emissions. The first four of these are the use of the right application rate, right product, right timing, and right placement (the "four R's"). A fifth method involves the use of nitrification or urease inhibitors (in this assessment they are collectively referred to as nitrification inhibitors and the acronym NI is used). Precision agriculture utilizes several new technologies that can address the four R's. These technologies include the use of variable rate fertilizer application, the global positioning system and remotely-sensed data (satellite data), and yield monitors, often referred to collectively as precision agriculture (PA). This measure focuses on increased use of PA for nutrient management.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure: Apply PA in all crop production where the farm is at least 500 acres (PA might not be cost effective at farms smaller than this level). Crops targeted are corn and other row crops, wheat, seed grass, and barley. Crop-specific data on PA application are lacking, so the analysis of this measure will produce one set of GHG abatement potential and costs. NI is also assessed for GHG abatement potential on the same crops targeted as for PA. Based on available information it appears that NI application may offer better cost effectiveness than PA.

- ***Federal Action Scenario (Low):*** Based on the estimated abatement potential for NI application as outlined above.
- ***Federal Action Scenario (Moderate):*** Based on the estimated abatement potential for NI and PA.
- ***Oregon Action Scenario:*** Same as the moderate federal action scenario above.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended measure goal by 2035.

Parties Involved: OR Department of Agriculture, crop growers, local county extension offices.

Data Sources and Additional Background: Oregon Agripedia (crop production statistics and farm size distributions), information on GHG reduction potentials for precision nutrient management and nitrification inhibitors,[12] previous nutrient management project studies reviewed by CCS (see individual citations).

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.10	0.24	0.58	2.9	-$18	-$75	-$31	-$26
Mod. Fed. Action	0.15	0.34	0.82	4.1	-$20	-$92	-$24	-$22
OR Action	0.15	0.34	0.82	4.1	-$20	-$92	-$24	-$22

Addresses reductions in nitrous oxide emissions from nitrogen fertilizer use only.

Full Energy-Cycle Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.11	0.25	0.61	3.1	-$18	-$75	-$29	-$24
Mod. Fed. Action	0.16	0.37	0.88	4.4	-$20	-$92	-$23	-$21
OR Action	0.16	0.37	0.88	4.4	-$20	-$92	-$23	-$21

Captures reductions in N_2O, as well as the upstream emissions from nitrogen fertilizer consumption.

Quantification Methods:

Crop production data for 2010 were taken from the OR Agripedia.[13] Crops specified in the measure design (corn, other row crops, wheat, barley and seed grass totaled 1,581,450 acres. As specified in the measure design, precision nutrient management techniques might not be as cost effective for small operations of less than 500 acres, so an adjustment was made using Agripedia data to estimate the fraction of these acres for smaller operations. Using the mid-point of the range for all farm sizes, an estimate of 46% of all acreage for small farms was derived. These acres were subtracted from the total for specified crops above. Also, no data were identified to

[12] *Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States, A Synthesis of the Literature*, Technical Working Group on Agricultural Greenhouse Gases (T-AGG) Report, Nicolas Institute for Environmental Policy Solutions, Duke University, March 2011.
[13] http://www.oregon.gov/ODA/docs/pdf/pubs/agripedia_stats.pdf?ga=t.

estimate the current number of larger operations/acres in Oregon that have already adopted similar precision nutrient management techniques (including use of GPS-enhanced variable rate fertilization application and nitrification inhibitors). An assumption was made that only 10% of current operations employ such methods. These adjustments left a targeted area of 654,720 acres for precision nutrient application (hereafter abbreviated as PA for "precision agriculture").

Separate estimates of GHG abatement potential and costs were made for application of nitrification inhibitors (NI). NI in this analysis includes the use of both nitrification inhibitors and urease inhibitors. The same crops and acreage as identified above were targeted for use of NI, except that these were adjusted down by 10% to account for the use of nitrate-based fertilizers (where NI is not effective). Nitrate-based fertilizers represent less than 10% of the synthetic fertilizer applied in the US.[14]

GHG reduction estimates were derived for all crop acres adopting either PA or NI each year through 2035. Emission reductions for nitrous oxide from the T-AGG study referenced above are 0.38 tCO_2e/ha-yr for PA and 1.01 38 tCO_2e/ha-yr for NI. The study also provides an estimate of energy-cycle reductions of 0.07 38 tCO_2e/ha-yr for PA; however, since a similar estimate for NI was not available, CCS developed a set of energy-cycle reductions based on a study of natural gas use for fertilizer nitrogen production[15] and upstream energy and process emissions data from the US EPA national inventory.[16]

Costs for adoption of PA and NI were based on information from the literature (references are cited within the Agriculture Measures Quantification workbook). Average adoption costs for PA from three studies were $9.85/acre ($2005). This value includes costs for enhanced soil monitoring, capital costs for a yield monitor, truck mounted computer/GIS software and variable rate application equipment. Application of PA could result in enhanced crop yields; however, sufficient data to corroborate this were not identified, so maintenance of yields for PA was assumed. The T-AGG study indicates average fertilizer N application rate reductions at 15%.

For NI, average application costs are $7.16/acre ($2005). These materials are applied with fertilizer, so no additional incremental costs are assumed. A 3% increase in yield is expected based on the average seen between the use of nitrification inhibitors and urease inhibitors.

Escalation rates for the value of crop production and NI were assumed to follow the US inflation rate (2.0%), while nitrogen fertilizers were treated differently. From 2000-2011, the annual growth rate has been over 10%. This trend was assumed to continue through 2020; but then to follow the inflation rate through 2035 (new supplies of US natural gas should result in lower growth rates in the future).

Key Assumptions & Uncertainties (including sensitivities)

- The minimal and moderate Federal scenarios covering abatement potential for NI and NI+PA are additive. While it is conceptually sound (PA covers nitrogen timing and placement while

[14] http://www.ers.usda.gov/Data/fertilizeruse/.
[15] http://www.extension.iastate.edu/Publications/PM2089i.pdf.
[16] 2011 EPA National GHG inventory: section 4, Industrial Processes; http://epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Chapter-4-Industrial-Processes.pdf.

NI reduces nitrogen loss), we have not seen examples of where both technologies have been studied together.

- Reductions in N_2O and nitrogen fertilizer use are representative of what can be achieved on the targeted crops for this measure.
- Future fertilizer costs are reasonably accurate.

AFW-4a MSW Anaerobic Digestion and Biogas Use

Measure Description

Anaerobic digestion, the conversion of biodegradable material by bacteria in the absence of oxygen, produces a biogas, which is mostly comprised of methane (CH_4). The biogas may be combusted to produce energy that is considered to be "zero carbon" because the combustion of biogas has a net zero emissions of greenhouse gases. One potential source of digestible biodegradable material in the waste sector is municipal solid waste (MSW) biomass, including: fats, oils and greases (FOG), food waste, yard waste, and certain paper wastes that are biodegradable at a rapid rate. It is likely that MSW biomass will be transported to centralized anaerobic digestion facilities that may accept MSW biomass from surrounding communities, farms, and food manufacturing facilities.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: Achieve 75% of the potential capacity (based on rated potential) for biogas energy production from MSW, according to "Growing Oregon's Biogas Industry" by The Climate Trust and Energy Trust of Oregon.[17] In practice, the target should be adjusted should revenue from a given technology not exceed the development and annual operation cost. Potential revenue streams include federal and state incentives, sales of renewable electricity, offsetting purchased power costs, and sale of GHG offsets (however, revenue from the sale of GHG offsets is not included in the analysis of this measure).

- ***Federal Action Scenario (Low):*** Assumes that the Renewable Electricity Production Tax Credit of $0.011/kWh will not be continued past the current timeframe, which requires open-loop biomass electricity generation facilities to be online by December 31, 2013 to receive the tax credit.[18] Qualifying anaerobic digestion electricity generation facilities that are online by the required data are eligible to receive the tax credit for the first ten years of operation. Therefore, under this scenario, any projects addressed by this measure would be eligible for the tax credit, as long as those projects are operational by 2013.
- ***Federal Action Scenario (Moderate):*** Assumes continuation of federal Renewable Electricity Production Tax Credit of $0.011/kWh. Tax credit will be adjusted for expected inflation.
- ***Oregon Action Scenario:*** Assumes funding is available from an incentive program that provides an additional 50% above the federal incentive. Since this is being added on top of the Federal Action, and eligible costs cannot overlap, it is assumed that the incremental state funding provided is half of the federal incentive.

[17] *Growing Oregon's Biogas Industry: A Review of Oregon's Biogas Potential and Benefits,* The Climate Trust and Energy Trust of Oregon, February 2011.
http://www.climatetrust.org/documents/GrowingORBiogasIndustryWhitePaper.pdf

[18] Open-loop biomass resources are those not specifically produced for the purpose of renewable energy (such as switchgrass grown solely for liquid biofuel production).

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2022.

Parties Involved: OR DEQ, The Climate Trust, Energy Trust of Oregon, ODOE, Bonneville Environmental Foundation.

Data Sources and Additional Background: Climate Trust/Energy Trust White Paper;[19] waste management and composition data provided by ODEQ; EPA Waste Reduction Model (WARM);[20] CalRecycle MSW Anaerobic Digestion Report.[21]

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.81	0.81	3.4	14	-$37	-$131	-$11	-$9
Mod. Fed. Action	0.81	0.81	3.4	14	-$37	-$131	-$11	-$9
OR Action	0.81	0.81	3.4	14	-$37	-$131	-$11	-$9

Full Energy-Cycle Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	1.9	1.9	8.0	33	-$37	-$131	-$5	-$4
Mod. Fed. Action	1.9	1.9	8.0	33	-$37	-$131	-$5	-$4
OR Action	1.9	1.9	8.0	33	-$37	-$131	-$5	-$4

[19] *Growing Oregon's Biogas Industry: A Review of Oregon's Biogas Potential and Benefits,* The Climate Trust and Energy Trust of Oregon, February 2011.
[20] US EPA. Waste Reduction Model. Available at: http://www.epa.gov/climatechange/waste/calculators/Warm_home.html
[21] *Current Anaerobic Digestion Technologies Used for Treatment of Municipal Organic Solid Waste*, California Integrated Waste Management Board (now CalRecycle), March 2008, http://www.calrecycle.ca.gov/publications/organics/2008011.pdf

Quantification Methods:

Projected results of the implementation of AFW-4a are based on an analysis of baseline MSW anaerobic digestion activity in Oregon, resource potential, and a simplified cost analysis including up-front capital cost, operations and maintenance (O&M) cost, and expected societal cost-savings from the perspective of the project developers and waste management system ratepayers (i.e. residential and commercial waste management customers). The projects initiated as a result of the implementation of this measure will divert MSW biomass (paper, wood waste, yard waste, and food waste)[22] from landfill disposal, generating energy[23] from biogas created as a result of the anaerobic digestion process.

The potential energy production capacity from MSW anaerobic digestion in Oregon is 30 MW, according to "Growing Oregon's Biogas Industry."[24] However, this source states that 5 MW of capacity are already in development, so the baseline energy production capacity is assumed to be 25 MW. The 2022 implementation target is 75% of achievable capacity, which is multiplied by the baseline production capacity to set the capacity target at 18.75 MW. The MSW anaerobic digestion project already planned will produce 5 MW of energy using 150,000 tons per year of MSW biomass, informing the assumption that 30,000 tons of MSW biomass is necessary to produce 1 MW of power. Therefore, the quantity of MSW needed to achieve the 2022 target of this measure is 562,500 tons, generating 147,825 MWh of electricity (assuming 90% capacity utilization).[25]

GHG emission reductions resulting from the implementation of this measure include: indirect reductions resulting from avoided in-state grid-based electricity generation, direct in-state reductions resulting from avoided landfill disposal of MSW biomass, and upstream GHG emission reductions due to reduced embedded energy of MSW biomass deposited in landfills. GHG emission reductions from offset grid-based electricity generation were calculated using the annual Oregon electricity supply emission intensity forecast, consistent with the Common Assumptions Workbook. Avoided landfill disposal GHG emission reductions were estimated using results from a WARM run based on the composition of MSW biomass from Oregon and the quantity of MSW biomass digested in each year.[26] The upstream GHG emission reductions were estimated based on the reduced embedded emissions that were produced by the same WARM run. Upstream GHG emission reductions were separated between in-state and out-of-state using the Oregon 2005 Consumption-based Inventory.[27]

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[22] Food waste includes food scraps in addition to fats, oils, and grease (FOG)
[23] Electricity generation is assumed in this analysis, although direct heat and high BTU gas production are also potential energy conversion methods.
[24] *Growing Oregon's Biogas Industry: A Review of Oregon's Biogas Potential and Benefits,* The Climate Trust and Energy Trust of Oregon, February 2011.
[25] 90% capacity utilization assumption consistent with: http://www.mrec.org/pubs/Anaerobic_Report.pdf.
[26] Upstream GHG reductions were found from WARM by utilizing the "source reduction" management stream in WARM to account for the MSW that is diverted to anaerobic digesters. This is a reasonable substitution, as there should be minimal GHG emissions at anaerobic digesters that are destroying and utilizing biogas.
[27] "Consumption-based Greenhouse Gas Emissions Inventory for Oregon." Oregon Department of Environmental Quality. 2005. Available at: http://www.deq.state.or.us/lq/consumptionbasedghg.htm

Implementation costs of AFW-4a include cost of up-front capital and O&M, which includes preprocessing of MSW.[28] These costs were estimated by applying cost-to-throughput regression curves from a report from the California Integrated Waste Management Board,[29] assuming that there are five MSW biomass anaerobic digestion facilities developed as a result of this measure, and each facility processes the same amount of MSW biomass. The resulting cost factors (in 2010 dollars) are $25.2 million in capital cost per facility, and $18 per ton MSW processed in O&M costs. The O&M cost is escalated at 2% annually to account for possible increased cost of materials, energy, and labor.

The cost-savings realized by this measure includes the avoided cost of avoided electricity system generation and avoided MSW disposal. The avoided cost of electricity generation in each year is consistent with the project Common Assumptions workbook. The avoided cost of disposal, in theory, represents the avoided cost of collecting and transporting MSW, managing MSW at landfills (as well as composting and recycling facilities), and the eventual construction of building new transfer stations and management facilities to handle MSW generated by a growing population. However, a comprehensive analysis to put a complete cost figure on the true avoided cost of MSW disposal was not available at the time of this analysis. Therefore, the 2006 average landfill tipping fee of $35 per ton[30] (adjusted to 2010$ and inflated at 2% annually) is used as a proxy for the avoided cost of MSW disposal.

Capital costs were annualized assuming a 30-year project life and 100% financing at 5% interest. Total measure costs each year from 2013-2035 were the sum of annualized capital cost, O&M cost, avoided MSW disposal cost savings and avoided electricity cost savings. The net measure cost was discounted at 5% to evaluate the net present value of the net measure cost in 2010, which was used as the basis for the per-ton of GHG emission reduction cost-effectiveness calculation.

Key Assumptions & Uncertainties (including sensitivities)

- Availability of financing opportunities and incentives for public entities such as MSW anaerobic digestion plants are uncertain.
- This is a simplified analysis that doesn't cover other configurations of biogas utilization facilities, including those that utilize both power and heat, those that would produce direct heat or high-BTU gas as opposed to electricity, and the value of co-products (fiber, fertilizer).
- Availability of MSW biomass may be restricted due to the implementation of other measures aimed at waste prevention, recycling, composting, and increasing the utilization of biomass throughout Oregon's economy. While an initial check of the total biomass supply in Oregon against the biomass demand generated by all Cost Curve measures does not produce a concern regarding the availability of MSW biomass for the implementation

[28] Note that it is assumed that there is no net change to MSW collection costs. There may be a marginal cost associated with increased collection should customers be asked to separate digestible biomass from regular garbage and recyclables.
[29] *Current Anaerobic Digestion Technologies Used for Treatment of Municipal Organic Solid Waste*, California Integrated Waste Management Board (now CalRecycle), March 2008, http://www.calrecycle.ca.gov/publications/organics/2008011.pdf
[30] "The State of Garbage in America", *Biocycle*, October 2010.

of AFW-4a, the analyses of all measures are based on projections, and therefore laden with uncertainty.

- Capital and O&M costs are based on a case study which uses a very small sample size of facilities. While flourishing in Europe, MSW anaerobic digestion is a very new technology in the United States and the costs of its implementation are uncertain.

AFW-4b Wastewater Treatment Plant Biogas Production and Use

Measure Description

Anaerobic digestion, the conversion of biodegradable material by bacteria in the absence of oxygen, produces a biogas, which is mostly comprised of methane (CH_4). The biogas may be combusted to produce energy that is considered to be "zero carbon" because the combustion of biogas has a net zero emissions of greenhouse gases. Two potential sources of digestible biodegradable material in the waste sector are wastewater treatment plant (WWTP) or sludge and municipal solid waste (MSW) biomass including fats, oils and greases (FOG), food waste, yard waste, and certain paper wastes that are biodegradable at a rapid rate.

This measure identifies two processes for generating electricity and/or heat through biogas generation at anaerobic digesters:

1. Switch from aerobic treatment of WWTP solids to anaerobic treatment with biogas recovery and utilization. Generally this can only be accomplished at treatment plants with treating greater than 1 million gallons of wastewater per day. There are about 50 treatment plants in Oregon of this size.
2. Co-digest food waste and/or FOG at WWTP anaerobic digestion facilities to increase the production potential of biogas.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: Achieve 75% of the potential capacity (based on rated potential) for biogas production at WWTPs, according to "Growing Oregon's Biogas Industry" by The Climate Trust and Energy Trust of Oregon, including increased production potential from FOG co-digestion.[31] In practice, the target should be adjusted should revenue from a given technology not exceed the development cost. Potential revenue streams include federal and state incentives, sales of renewable electricity, offsetting purchased power costs, and sale of GHG offsets (however, revenue from the sale of GHG offsets is not included in the analysis of this measure).

- ***Federal Action Scenario (Low):*** Assumes that the Renewable Electricity Production Tax Credit of $0.011/kWh will not be continued past the current timeframe, which requires open-loop biomass electricity generation facilities to be online by December 31, 2013 to receive the tax credit.[32] Qualifying anaerobic digestion electricity generation facilities that are online by the required date are eligible to receive the tax credit for the first ten years of operation. Therefore, under this scenario, any projects addressed by this measure would be eligible for the tax credit, as long as those projects are operational by 2013. This scenario only assesses GHG reduction and cost-effectiveness from a low-level of effort, specifically only the switch from aerobic to anaerobic digestion of WWTP solids at larger (>1 million gallons per day) WWTPs in Oregon.

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[31] *Growing Oregon's Biogas Industry: A Review of Oregon's Biogas Potential and Benefits,* The Climate Trust and Energy Trust of Oregon, February 2011. FOG – fats, oils, and greases. http://www.climatetrust.org/documents/GrowingORBiogasIndustryWhitePaper.pdf

[32] Open-loop biomass resources are those not specifically produced for the purpose of renewable energy (such as switchgrass grown solely for liquid biofuel production).

- ***Federal Action Scenario (Moderate):*** Assumes continuation of federal Renewable Electricity Production Tax Credit of $0.011/kWh. Tax credit will be adjusted for expected inflation. This scenario assumes the level of effort expended in Scenario 1, plus the addition of FOG and food waste co-digestion.
- ***Oregon Action Scenario:*** Assumes funding is available from an incentive program that provides an additional 50% above the federal incentive. Since this is being added on top of the Federal Action, and eligible costs cannot overlap, it is assumed that the incremental state funding provided is half of the federal incentive. This scenario assumes the level of effort expended in Scenario 1, plus the addition of FOG and food waste co-digestion.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2022.

Parties Involved: OR DEQ, The Climate Trust, Energy Trust of Oregon, Oregon Association of Clean Water Agencies, ODOE, Bonneville Environmental Foundation.

Data Sources and Additional Background: ODOE Bioenergy Optimization Assessment at Wastewater Treatment Plants;[33] Final Energy Independence Project;[34] Climate Trust/Energy Trust White Paper;[35] previous WWTP anaerobic digestion project studies reviewed by the Center for Climate Strategies.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.01	0.01	0.03	0.13	$30	$91	$927	$712
Mod. Fed. Action	0.49	0.49	2.0	8.3	-$0.5	-$17	-$0.3	-$2.0
OR Action	0.49	0.49	2.0	8.3	-$0.5	-$17	-$0.3	-$2.0

[33] *Bioenergy Optimization Assessment at Wastewater Treatment Plants*, Oregon Department of Energy (Tetra Tech), March 2012.
[34] *Final Energy Independence Project*, Oregon Association of Clean Water Agencies and Energy Trust of Oregon (Kennedy/Jenks Consultants), June 2008.
[35] *Growing Oregon's Biogas Industry: A Review of Oregon's Biogas Potential and Benefits,* The Climate Trust and Energy Trust of Oregon, February 2011.

Full Energy-Cycle Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.01	0.01	0.03	0.13	$30.4	$91.2	$927	$712
Mod. Fed. Action	1.8	1.8	7.3	30.4	-$0.5	-$16.8	-$0.1	-$0.6
OR Action	1.8	1.8	7.3	30.4	-$0.5	-$16.8	-$0.1	-$0.6

Quantification Methods:

Projected results of the implementation of AFW-4b are based on an analysis of baseline anaerobic digestion activity at WWTPs in Oregon, resource potential, and a simplified cost analysis including up-front capital cost, operations and maintenance (O&M) cost, and expected societal cost-savings from the perspective of the project developers and electricity ratepayers. The projects initiated as a result of the implementation of this measure will switch from aerobic to anaerobic digestion of WWTP solids, and divert food waste and FOG from landfill disposal, generating energy from biogas created as a result of the anaerobic digestion process.[36]

The potential increase in energy production capacity from converting the processing of WWTP biosolids from aerobic to anaerobic digestion in Oregon is 3.7 MW, according to "Growing Oregon's Biogas Industry."[37] The 2022 implementation target is 75% of achievable capacity, which is multiplied by the baseline production capacity to set the capacity target at 2.8 MW. Co-digesting food waste and FOG at WWTP facilities, with both existing and new anaerobic digesters, may produce another 5.3 MW of capacity. There are currently 19 facilities with anaerobic digestion in Oregon that do not utilize biogas for energy.[38] Additionally, there are 22 facilities that treat at least one million gallons of wastewater per day that utilize aerobic digestion for processing WWTP solids. The analysis of AFW-4b includes installation of energy production technology at 19 WWTPs currently utilizing anaerobic digestion and conversion from aerobic to anaerobic digestion (plus energy production) at 12 WWTPs.[39] For the Federal Moderate and Oregon Action scenarios, food waste and FOG is co-digested with WWTP solids to increase methane generation. Based information from the "Final Energy Independence Project,"[40] it was determined that 7.45 tons of food waste and FOG are needed to produce 1 MWh of electricity. Therefore, the quantity of food waste and FOG needed to achieve the 2022 target of this measure

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[36] Electricity generation is assumed in this analysis, although direct heat and high BTU gas production are also potential energy conversion methods.
[37] *Growing Oregon's Biogas Industry: A Review of Oregon's Biogas Potential and Benefits,* The Climate Trust and Energy Trust of Oregon, February 2011.
[38] It is assumed that the methane at these facilities is currently flared. Therefore, the analysis of this measure conservatively does not account for potential GHG emission reductions due to methane destruction.
[39] This number of plants was chosen to represent an approximation of the 75% energy production potential.
[40] *Final Energy Independence Project*, Oregon Association of Clean Water Agencies and Energy Trust of Oregon (Kennedy/Jenks Consultants), June 2008.

is 310,414 tons, generating 41,687 MWh of electricity per year (assuming 90% capacity utilization).[41]

GHG emission reductions resulting from the implementation of this measure include: indirect in-state reductions resulting from avoided grid-based electricity generation, direct in-state reductions resulting from avoided landfill disposal of food waste and FOG, and upstream GHG reductions due to reduced embedded energy of MSW biomass deposited in landfills. GHG emission reductions from offset grid-based electricity generation were calculated using the annual Oregon electricity supply emission intensity forecast, consistent with the Common Assumptions Workbook. Avoided landfill disposal GHG emission reductions were estimated using results from a study from the Oregon Department of Environmental Quality that estimated the upstream and downstream emissions from food waste production and disposal, and the quantity of food waste and FOG digested in each year.[42] Upstream GHG emission reductions were separated between in-state and out-of-state using information from the Oregon 2005 consumption-based inventory.[43]

Implementation costs of AFW-4b include cost of up-front capital cost of conversion to anaerobic digestion, electricity generation equipment, and food waste/FOG receiving infrastructure, as well as incremental O&M anaerobic digestion and co-digestion of food waste and FOG.[44] The capital cost of conversion to anaerobic digestion ($1.75/gallon/day) and electricity generation ($2,000/kW-hr) were taken from a survey of anaerobic digester conversion projects,[45] and the capital cost of waste receiving stations is $1 for every 1,100 MWh/year.[46] The incremental O&M cost for anaerobic digester conversion and electricity generation are $320,000/facility and $15/kW-hr, respectively.[47] The O&M costs are escalated at 2% annually to account for possible increased cost of materials, energy, and labor.

The cost-savings realized by this measure includes the avoided cost of grid-based electricity generation and the avoided cost of food waste and FOG disposal. The avoided cost of grid-based electricity generation in each year is consistent with the project's Common Assumptions workbook. The avoided cost of disposal, in theory, represents the avoided cost of collecting and transporting waste and FOG, managing waste and FOG at landfills (as well as composting and recycling facilities), and the eventual construction of building new transfer stations and

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[41] 90% capacity utilization assumption consistent with: http://www.mrec.org/pubs/Anaerobic_Report.pdf.

[42] "Food-related alternatives6.xlsx" provided by D. Allaway of ODEQ.

[43] "Consumption-based Greenhouse Gas Emissions Inventory for Oregon." Oregon Department of Environmental Quality. 2005. Available at: http://www.deq.state.or.us/lq/consumptionbasedghg.htm

[44] Note that it is assumed that there is no net change to MSW collection costs. There may be a marginal cost associated with increased collection should customers be asked to separate digestible biomass from regular garbage and recyclables.

[45] "Evaluation of Energy Recovery Options for Conversion of Aerobic Digesters to Anaerobic Digestion," Barksdale, Oquento, and Petrik. Available at: http://www.ncsafewater.org/Pics/Training/AnnualConference/AC10TechnicalPapers/AC10_Wastewater/WW_T.PM_04.45_Barksdale.pdf

[46] *Final Energy Independence Project*, Oregon Association of Clean Water Agencies and Energy Trust of Oregon (Kennedy/Jenks Consultants), June 2008.

[47] "Evaluation of Energy Recovery Options for Convesion of Aerobic Digesters to Anaerobic Digestion," Barksdale, Oquento, and Petrik. Available at: http://www.ncsafewater.org/Pics/Training/AnnualConference/AC10TechnicalPapers/AC10_Wastewater/WW_T.PM_04.45_Barksdale.pdf

management facilities to handle waste and FOG generated by a growing population. However, a comprehensive analysis to put a complete cost figure on the avoided cost of food waste and FOG disposal was not available at the time of this analysis. Therefore, the 2006 average landfill tipping fee of $35 per ton[48] (adjusted to 2010$ and inflated at 2% annually) is used as a proxy for the avoided cost of waste and FOG disposal.

Capital costs were annualized assuming a 30-year project life and 100% financing at 5% interest. Total measure costs each year from 2013-2035 were the sum of annualized capital cost, O&M cost, avoided food waste and FOG disposal cost savings and avoided electricity cost savings. The net measure cost was discounted at 5% to evaluate the net present value of the net measure cost in 2010, which was used as the basis for the per-ton of GHG emission reduction cost-effectiveness calculation.

Key Assumptions & Uncertainties (including sensitivities)

- Availability of financing opportunities and incentives for public entities such as wastewater treatment plants are uncertain.
- This is a simplified analysis that doesn't cover other configurations of biogas utilization facilities, including those that utilize both power and heat, those that would produce direct heat or high-BTU gas as opposed to electricity, and the value of co-products (fiber, fertilizer). Additional work is needed to capture the net difference in energy (electricity) use between aerobic and anaerobic digestion facilities. This analysis assumed that all power would be used to offset on-site use of grid-based electricity; however, additional assessment should be performed to determine whether a portion of this power would likely be sold back to the utilities (and additional costs for tying into the grid applied).
- Availability of food waste and FOG may be restricted due to the implementation of other measures aimed at waste prevention and composting, and increasing the utilization of biomass throughout Oregon's economy. While an initial check of the total biomass supply in Oregon against the biomass demand generated by all Cost Curve measures does not produce a concern regarding the availability of food waste and FOG for the implementation of AFW-4b, the analyses of all measures are based on projections, and therefore laden with uncertainty.
- Capital and O&M costs are based on a case study which uses a very small sample size of facilities. Additionally, neither the data nor the resources were available to analyze this measure on a bottom-up basis, which would allow for differentiation between facilities of different sizes and a more accurate analysis of which facilities truly have potential for biogas generation, and which facilities may not be able to cost-effectively produce and utilize biogas.

[48] "The State of Garbage in America", *Biocycle*, October 2010.

AFW-5 Landfill Gas Collection & Use

Measure Description

Install landfill gas (LFG) collection and destruction systems at landfills where such systems do not already exist. The anaerobic decomposition of biodegradable waste at landfills produces landfill gas, which is approximately 50% methane (CH_4). CH_4, a potent greenhouse gas, can be destroyed through combustion, thereby reducing the environmental impact of LFG. Additionally, the combustion of CH_4 is an energy source that may be used for electricity generation or direct heat.

According to EPA NSPS guidelines, landfills with more than 2.5 million tons of waste in place (or greater than 50 mg/yr NMOC[49] emissions) are required by the EPA to install LFG collection and destruction systems.[50] This requirement does not stipulate that the LFG destroyed must be used for beneficial purposes (flaring the LFG meets the destruction requirement). Utilizing LFG for energy production adds the benefit of offset grid-based electricity production, on top of the GHG reductions realized through LFG destruction.

This measure recommends that all landfills where LFG capture and destruction are economically and technically feasible install LFG collection and destruction systems, preferably destruction systems that utilize the LFG combustion for energy production. Additionally, this measure suggests that existing LFG collection and use projects take steps to increase the LFG collection efficiency and install LFG utilization equipment wherever feasible.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: Most medium-sized, and some small, landfills that are not expected to have a LFG collection and use project in place within the planning period will have a project installed. Additionally, landfills that do have projects in place will maximize GHG reductions by increasing collection efficiency, and installing LFG utilization technology. In practice, the target should be adjusted if revenue from a given technology does not exceed the development and annual operation costs.

- ***Federal Action Scenario (Low):*** Assumes that the Renewable Electricity Production Tax Credit of $0.011/kWh will not be continued past the current timeframe, which requires LFG electricity generation facilities to be online by December 31, 2013 to receive the tax credit. Qualifying LFG electricity generation facilities that are online by the required date are eligible to receive the tax credit for the first ten years of operation. Therefore, under this scenario, any projects required by this measure would be eligible for the tax credit, as long as those projects are operational by 2013.

[49] NMOC: Non-methane organic compounds.
[50] New Source Performance Standards for Solid Waste Landfills (40 CFR Part 60). Landfills may exceed the waste in place standard, provided that the NMOC emissions are below 50 mg/year.

- ***Federal Action Scenario (Moderate):*** Assumes continuation of federal Renewable Electricity Production Tax Credit of $0.011/kWh. Tax credit will be adjusted for expected inflation.
- ***Oregon Action Scenario:*** Assumes funding is available from an incentive program that provides an additional 50% above the federal incentive. Since this is being added on top of the Federal Action, and eligible costs cannot overlap, it is assumed that the incremental state funding provided is half of the federal incentive.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the intended policy goal by 2022.

Parties Involved: EPA Landfill Methane Outreach Program, ODOE, Oregon DEQ, Oregon Global Warming Commission.

Data Sources and Additional Background: OGWC Interim Roadmap to 2020 Materials Management Measures #35-38;[51] EPA Landfill Gas Generation Model (LandGEM).[52] CCS utilized data gathered for DEQ's development of the Direct GHG Inventory and Forecast. Common assumptions from this multi-sector Cost Curve project regarding the GHG reductions from offset grid-based electricity.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.27	0.32	2.0	5.9	$18	$52	$9	$9
Mod. Fed. Action	0.27	0.32	2.0	5.9	$18	$52	$9	$9
OR Action	0.27	0.32	2.0	5.9	$18	$52	$9	$9

Full Energy-Cycle Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO$_2$e)	2013-2035 CE ($/tCO$_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.27	0.32	2.0	5.9	$18	$52	$9	$9
Mod. Fed. Action	0.27	0.32	2.0	5.9	$18	$52	$9	$9
OR Action	0.27	0.32	2.0	5.9	$18	$52	$9	$9

[51] http://www.keeporegoncool.org/sites/default/files/Integrated_OGWC_Interim_Roadmap_to_2020_Oct29_11-19Additions.pdf
[52] US EPA. Landfill Gas Generation Model. Available at: http://www.epa.gov/ttncatc1/products.html

Quantification Methods:

Projected results of the implementation of AFW-5 are based on an analysis of baseline landfill gas (LFG) collection and destruction activity in Oregon, LFG resource potential, and a simplified cost analysis including up-front capital cost, operations and maintenance (O&M) cost, and expected societal cost-savings from the perspective of the project developers and electricity ratepayers. The projects initiated as a result of the implementation of this measure will install LFG collection and utilization equipment at landfills, generating energy from the combustion of the methane component of LFG. [53]

CCS utilized the waste disposal data consistent with the Oregon GHG Inventory and Forecast (I&F) and the EPA LandGEM model to develop an estimate of the methane generation in landfills from 2013 through 2035.[54] CCS also utilized the results of the I&F to scale the results of the LandGEM run to match the baseline data from the Oregon. According to the source data, about 40% of the methane generated at landfills in Oregon is emitted, while the remainder is either combusted at sites with existing LFG collection and destruction, or oxidized before entering the atmosphere. First, the amount of methane currently collected and flared was identified, and the GHG emission reductions and cost-effectiveness of utilizing the methane that is flared under the baseline scenario was analyzed. Second, CCS estimated that 24 smaller landfills are responsible for about 80% of the uncontrolled landfill methane emissions, and the potential GHG emission reductions and cost-effectiveness of installing LFG collection and utilization systems at those sites was analyzed.

GHG emission reductions resulting from the implementation of this measure include: indirect reductions resulting from avoided in-state grid-based electricity generation and direct in-state reductions resulting from the destruction of previously uncontrolled methane emissions at landfills in Oregon. GHG emission reductions from offset grid-based electricity generation were calculated using the annual Oregon electricity supply emission intensity forecast, consistent with the Common Assumptions Workbook and the assumed incremental methane combustion at landfills (assuming 2.54 kWh/m^3 CH_4).[55] GHG emission reductions due to the combustion of landfill methane are calculated by multiplying the estimated incremental methane destroyed in each year during the policy period by the global warming potential of methane (21 tCO_2e/tCH_4).

Implementation costs of AFW-5 include cost of up-front capital cost of the installation of LFG collection (at landfills where collection is not only taking place) and energy utilization systems, as well as incremental O&M cost of project operation. The capital and O&M costs are estimated using the EPA LFGCost model. The Model inputs are established by averaging the annual MSW acceptance of the landfills in from 1992 to 2002. The assumed operating period for the sample landfills modeled is 1992 through 2035. Two model runs were conducted; one for landfills where LFG collection already exists and one for landfills that are currently uncontrolled. Up-front capital cost and annual (O&M) cost from these model runs are used to determine implementation

[53] Electricity generation is assumed in this analysis, although direct heat and high BTU gas production are also potential energy conversion methods.
[54] Oregon GHG Inventory and Forecast, "GHG model for ODOE 7.xlsx", provided to CCS by ODEQ.
[55] Conversion factor from EPA LFGCost Model. Available at: http://www.epa.gov/lmop/publications-tools/index.html (registration required).

for AFW-5. The O&M cost is escalated at 2% annually to account for possible increased cost of materials, energy, and labor.

The cost-savings realized by this measure includes the avoided cost of grid-based electricity generation. The avoided cost of grid-based electricity generation in each year, which is consistent with the project's Common Assumptions workbook, is multiplied by the annual incremental electricity generation to estimate annual cost savings from avoided grid-based electricity generation.

Capital costs were annualized assuming a 30-year project life and 100% financing at 5% interest. Total measure costs each year from 2013-2035 were the sum of annualized capital cost, O&M cost, and avoided grid-based electricity generation cost savings. The net measure cost was discounted at 5% to evaluate the net present value of the net measure cost in 2010, which was used as the basis for the per-ton of GHG emission reduction cost-effectiveness calculation.

Key Assumptions & Uncertainties (including sensitivities)

- This is a simplified analysis that doesn't cover other configurations of LFG utilization facilities, including those that utilize both power and heat, and those that would produce direct heat or high-BTU gas as opposed to electricity.
- Capital and O&M costs are based on a modeled analysis of two hypothetical landfills that are intended to represent the characteristics of the average landfill being studied. An accurate analysis of this measure would require a detailed bottom-up analysis, which, in turn, would require data on some of the smaller landfills in Oregon, for which data are not readily available. However, neither the data nor the resources were available to analyze this measure on a bottom-up basis, which would allow for differentiation between landfills of different sizes and a more accurate analysis of which facilities truly have potential for LFG gas collection and utilization, and which facilities may not be able to cost-effectively collect and utilize LFG.

AFW-6 Urban Forestry

Measure Description

This measure addresses the expansion and maintenance of urban tree canopies. By maintaining the health and longevity of existing shade trees and planting additional trees in residential, commercial and municipal areas, indirect GHG emissions will be reduced as a result of a decrease in heating and cooling needs. This measure will increase carbon sequestration levels in urban trees above business as usual levels; however, the measure is designed with a focus on achieving energy efficiency benefits.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: In order to effectively implement this urban forestry measure to achieve energy efficiency savings, it is necessary to design a program to increase the number of trees planted, such that the majority of them approach maturity by the end of the planning period (2035). GHG abatement will be maximized where the new trees are strategically-sited to achieve energy benefits through shading of residences or commercial/public structures. The overall goal is to increase the urban canopy cover to 46% over the next 40 years from a current 30%.[56]

- ***Federal Action Scenario (Low):*** Abatement potential is consistent with the measure goal as described above.
- ***Federal Action Scenario (Moderate):*** There is no additional abatement potential above that for the scenario above.
- ***Oregon Action Scenario:*** There is no additional abatement potential above that for the scenario above.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the total number of additional urban trees required by 2025. The total number of trees needed will be determined during analysis of the measure.

Parties Involved: OR Department of Forestry, county and municipal governments, commercial and residential landowners.

Data Sources and Additional Background: EPA SIT GHG I&F data, USFS background reports on the benefits and costs of urban forestry programs, OR land use data (see citations in footnotes, previous urban forestry analyses by CCS.

[56] Default urban tree canopy cover used in the EPA SIT Tool covering urban forest carbon is 30%. 46% is the 90th percentile of urban tree cover for state-level data reported in the SIT tool. In 2008, OR had an estimated 483,000 acres of urban land area in 2009: http://www.oregon.gov/ODF/STATE_FORESTS/FRP/docs/ForestFarmsPeople2009.pdf. This includes suburban areas and the urban core; residential use, commercial use, and industrial use. Low-density residential land use makes up another 1,144,000 acres in 2009; however, these appear to be mainly rural areas.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.04	0.20	0.14	1.7	$221	$602	$1,637	$359
Mod. Fed. Action	0.04	0.20	0.14	1.7	$221	$602	$1,637	$359
OR Action	0.04	0.20	0.14	1.7	$221	$602	$1,637	$359

Full Energy-Cycle Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.04	0.22	0.15	1.8	$221	$602	$1,475	$331
Mod. Fed. Action	0.81	0.22	0.15	1.8	$221	$602	$1,475	$331
OR Action	0.81	0.22	0.15	1.8	$221	$602	$1,475	$331

Quantification Methods and Results:

GHG Reductions. The assessment covers estimates of GHG reductions that achievable through suburban strategic plantings (where both carbon sequestration and energy benefits are accrued through shading and wind protection, other suburban plantings (no energy benefit; plantings that occur along streets, in parks, and other open areas), and in the urban core (no energy benefits are estimated, although some are likely to be achieved; studies are lacking in these areas dominated by multi-story buildings). GHG reductions and tree planting and maintenance costs were estimated for each of these areas.

The 2009 urban land use are in Oregon was 1,956 square kilometers (km^2).[57] Per the measure design, an increase in 16% of urban canopy is the overall goal with an emphasis on plantings where energy savings benefits will accrue. An average annual growth rate of 0.31% is assumed for OR urban land use.[58] Therefore, the urban land use in 2053 (40 years in the future, per the measure design) would be 2,376 km^2. Land use data to allow for a break-out of urban core from suburban land use was not identified in time for use in this analysis. Therefore, an assumption of

[57] http://www.oregon.gov/ODF/STATE_FORESTS/FRP/docs/ForestFarmsPeople2009.pdf Table 1.
[58] Calculated using an annual growth rate of 0.31% for OR urban area based on a forecast increase of 17.7% from 1997 to 2050 in this 2001 USFS study. http://www.fs.fed.us/pnw/pubs/rp528.pdf.

20% of OR urban land area as the urban core was made (i.e. remaining 80% is suburbs). From these data, an incremental 380 km^2 of canopy cover would be needed by 2053.

Using the estimate amount of additional canopy cover and an assumed average mature tree diameter of 12 meters, a total of 3.36 million new trees would need to be planted to meet the measure goals. Further, based on measure design, these plantings need to occur before 2025. Further assumptions needed to estimate energy savings include the mix of trees to be planted. For this analysis, 50% large deciduous and 50% medium deciduous trees were assumed (evergreens were left out to maximize savings for summer cooling).

The US EPA SIT default for carbon sequestration in urban trees (2.23 tC/ha-yr) was used to estimate the carbon sequestration for the expanded canopy in each year. US Forest Service estimates for western Washington and Oregon were used to derive energy savings.[59] According to the USFS study, two 25 ft trees strategically placed in a typical household can save $18 per year or (365 kWh) on cooling costs. The two trees also saved $7 per year in heating costs from natural gas (0.565 MMBtu/year). These energy savings estimates were then converted to GHG reductions using the emission factors documented in the project's "Common Data Workbook".

Net Societal Costs. Cost estimates from the USFS study footnoted below were used to estimate capital planting costs and annual maintenance costs per tree. For energy savings, it was assumed that savings for heating energy would come from natural gas use (the USFS studies don't specify fuel types in the estimates). Using the energy savings calculated from above and the avoided cost estimates for electricity and natural gas, the cost savings for suburban strategic plantings were estimated. Capital costs were annualized by assuming that these tree planting programs would be financed using 20 year municipal bonds. The net societal cost was determined using the stream of annualized capital costs, maintenance costs, and energy savings.

Key Assumptions & Uncertainties (including sensitivities)

Important assumptions include:

- The assumption of the split between urban core and suburban areas (20:80);
- Assumed future urban growth rate (0.31%);
- That there is a need for all of the trees targeted for strategic suburban planting locations; it could be that a large fraction of these homes are already adequately shaded;
- USFS study data on energy savings and planting and maintenance costs are fairly accurate;
- Mechanism for financing this measure (20-year municipal bonds with a 4% yield).

[59] Western Washington and Oregon Community Tree Guide: Benefits, Costs and Strategic Planting: http://www.fs.fed.us/psw/programs/uesd/uep/products/cufr_164.pdf.

AFW-7 Afforestation/Reforestation

Measure Description

Afforestation refers to establishing forests on land that has not historically been forested (e.g., rangeland or grassland areas). Reforestation refers to the re-establishment of forest cover on areas that were once forested but now have little or no cover (e.g., croplands or other cleared areas). Each of these approaches, involve practices such as soil preparation, erosion control, tree planting, and maintenance activities during early years to ensure conditions that support forest establishment and growth. Expansion of forested areas provides future biomass production that can be used in the manufacture of durable wood products (e.g., furniture, structures) and renewable energy. GHG reductions occur as a result of higher levels of carbon sequestration from the BAU land cover, as well as future use of forest biomass for producing durable wood products (which can store carbon for decades) and biomass energy that offsets fossil fuel use.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: Convert rangelands or croplands to forest cover by 2035 in areas of the state where it makes sense economically (i.e. opportunity costs are sufficiently low that the project could be attractive as a carbon offset). A set of GHG reduction (carbon sequestration) and cost estimates will be developed for rangelands and another for croplands based on a 2007 study for the California Energy Commission.[60] This study provides estimates of carbon sequestration on either rangeland or cropland (wheat and hay) in OR. Note that the bulk of GHG benefits for this measure will occur in the post-2035time-frame.

- ***Federal Action Scenario (Low):*** Based on abatement potential for rangelands and wheat acreage at a WestCarb Study cost of \$2.40/tCO_2e.
- ***Federal Action Scenario (Moderate):*** Based on abatement potential for rangelands and wheat acreage at a WestCarb Study cost of \$10/tCO_2e.
- ***Oregon Action Scenario:*** Based on abatement potential for rangelands and wheat acreage at a WestCarb Study cost of \$20/tCO_2e.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013 and would ramp up linearly each year to reach the total number of hectares converted by 2035.

Parties Involved: OR Department of Forestry, Oregon Department of Agriculture, agricultural land owners, local county extension offices.

Data Sources and Additional Background: 2007 CEC Study footnoted below; EPA SIT GHG I&F data, previous afforestation/reforestation analyses by CCS.

[60] *Carbon Sequestration through Changes in Land Use in Oregon: Costs and Opportunities,* October 2007, http://www.energy.ca.gov/2007publications/CEC-500-2007-074/CEC-500-2007-074.PDF. Commonly referred to as the OR WestCarb Study.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/tCO₂e)	2013-2035 CE ($/tCO₂e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Cropland: Low Fed. Action	0.00	0.00	0.00	0.00	N/A	N/A	N/A	N/A
Cropland: Mod. Fed. Action	5.2	11	29	143	$556	$1,651	$19	$12
Cropland: OR Action	5.4	12	30	149	$625	$1,858	$21	$12
Rangeland: Low Fed. Action	0.006	0.01	0.03	0.15	$0.18	$0.48	$5.8	$3.1
Rangeland: Mod. Fed. Action	3.8	8.4	21	105	$250	$679	$12	$6.4
Rangeland: OR Action	15	33	84	418	$2,744	$7,463	$33	$18

Full Energy-Cycle Results

Same as in-state results above, since only carbon sequestration is being analyzed.

Quantification Methods and Results:

GHG Reductions. These estimates are based on the results of the OR WestCarb Study referenced in the footnote above. The total areas identified in this study for cropland (hay and wheat) and rangeland suitable for re-/afforestation projects that could produce reductions with a cost effectiveness of less than $20/tCO$_2$ were used as starting points. The totals were 870,000 hectares (ha) of cropland and 6.3 million ha of rangeland.

As per the measure design, implementation begins in 2013 with equal amounts of area being planted in each year. The study's estimates for net carbon sequestration over 40 years were used to estimate annual carbon sequestration for converted croplands (13.7 tCO$_2$/ha-yr) and rangelands (5.3 tCO$_2$/ha-yr). This analysis only addressed sequestration, so any additional reductions associated with lower fuel use or process emissions due to changes in land management (i.e. crop production to forest) were not included.

Net Societal Costs. OR WestCarb Study data were used as the primary source of information. Cost components include capital costs for site prep and planting, annual establishment costs, and opportunity costs (lost revenue from use of the land for crop or beef production purposes). It was assumed that no timber harvest (including thinning) revenue would occur within the planning period (through 2035).

For rangelands, capital costs were $550/acre; and for croplands, the capital costs were $425/acre. Annual establishment costs over the first five years are $70/acre for both rangelands and croplands. The nominal opportunity cost for rangelands was assumed to be $10/acre-yr based on a range of $1-$20/acre provided in the WestCarb Study. For croplands, a nominal opportunity cost could not be inferred from information provided in the study. Therefore, a weighted average value of $89/acre-yr was derived using enterprise budget data for spring wheat, winter wheat, and hay from Oregon crop enterprise budgets[61] and the 2010 harvested acreage for each of these crops. Financing assumptions for capital costs are 100% financing of capital costs over 35 years at 4% interest.

Key Assumptions & Uncertainties (including sensitivities)

- These estimates should be seen as the upper end potential for this measure in OR; even with attractive financing available, large-scale conversion of rangeland and cropland is not likely to occur in the absence of a carbon market;

- This assessment does not include an analysis of the effects of using these converted areas for timber production; in that case, some thinning would occur within the planning period (typically after stands have reached an age of 15-20 years). Net costs for these activities would need to factor in the potential value of the thinned material (e.g. for fiber or energy).

[61] http://arec.oregonstate.edu/oaeb/

AFW-8 Forest Management for Carbon Sequestration

Measure Description

This measure covers management activities that promote forest productivity and increase the amount of carbon sequestered in forest biomass. Forest management practices that can lead to higher levels of carbon sequestration include increasing rotation schedules for timber production, thinning and density management, prescribed burning and fire risk reduction, and management of insects and disease. This measure draws from a 2007 study for the California Energy Commission covering carbon sequestration opportunities in Oregon.[62] The two forest management changes addressed in this study were increased rotation schedules and increasing the area of riparian zones along streams (note that some would consider the latter of these to be a form of afforestation/reforestation).

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: Rotation Schedules (RS): for timberland, extend the rotation schedules by 15 years on about 320,000 hectares (~284,000 hectares are private timber lands). Riparian Zones (RZ): for riparian zones, set aside an additional 8,400 hectares that are near their optimal rotation age.

- ***Federal Action Scenario (Low):*** Abatement potential identified by the CEC Study footnoted below at an aggregate \$38/tCO_2e.
- ***Federal Action Scenario (Moderate):*** No additional federal action is assumed above the Low Federal Action Scenario above.
- ***Oregon Action Scenario:*** No additional federal action is assumed above the Low Federal Action Scenario above.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013. It is assumed that all agreements with private land owners are in place by 2023.

Parties Involved: OR Department of Forestry, private land owners.

Data Sources and Additional Background: 2007 CEC Study footnoted below; EPA SIT GHG I&F data, previous forest management analyses by CCS.

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[62] *Carbon Sequestration through Changes in Land Use in Oregon: Costs and Opportunities,* October 2007, http://www.energy.ca.gov/2007publications/CEC-500-2007-074/CEC-500-2007-074.PDF.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2e$)	2013-2035 CE ($/t$CO_2e$)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
RS: Low Fed. Action	0.6	0.6	3.1	10	$431	$945	$140	$91
RS: Mod. Fed. Action	0.6	0.6	3.1	10	$431	$945	$140	$91
RS: OR Action	0.6	0.6	3.1	10	$431	$945	$140	$91
RZ: Low Fed. Action	0.005	0.005	0.03	0.09	$28	$69	$1,001	$746
RZ: Mod. Fed. Action	0.005	0.005	0.03	0.09	$28	$69	$1,001	$746
RZ: OR Action	0.005	0.005	0.03	0.09	$28	$69	$1,001	$746

Full Energy-Cycle Results

Same as the in-state results; only carbon sequestration benefits are addressed. Any net changes in benefits or costs for other outcomes of this measure (e.g. reduced energy use during harvests due to forest conservation) are assumed to be negligible.

Quantification Methods:

GHG Reductions. Information from the WestCarb Study footnoted above was used to develop reduction and cost estimates. For RS, this study identified about 284,000 hectares where age extension could be applied where the costs would be less than $38/tCO2. Per the measure design, it was assumed that all agreements with private timberland owners would be in place in 10 years. An average incremental sequestration rate was derived from the WestCarb Study of 1.97 tCO_2/ha-yr. This was applied in each year to the cumulative area of rotation schedule agreements to derive annual sequestration estimates.

For RZ, the WestCarb Study identified about 8,400 ha where riparian zone conservation programs should be targeted. Per the design, it was also assumed that all agreements (e.g. conservation agreements) were in place within 10 years. Based on the study, an average incremental sequestration rate of 0.60 tCO_2/ha-yr was derived. This was applied to the cumulative area protected in each year to derive incremental sequestration estimates.

Net Societal Costs. For RS, the total costs estimated in the WestCarb Study were divided by the total area and then adjusted to $2010. This yielded a cost of $4,236/ha. It was assumed that these costs, to be paid to the timber land owner, would be financed over 15 years (the length of age extension) at a rate of 4%.

For RZ, a similar approach was taken using the WestCarb Study results. The estimated costs were $6,164/ha. It was assumed that these conservation easements would be financed over 35 years at 4%.

Key Assumptions & Uncertainties (including sensitivities)

- Not uncommon with forest conservation measures, the cost effectiveness estimates are fairly high. These differ from the targeted WestCarb value of <$38/t$CO_2$ because the CE values are derived over a much shorter period of time. For example, if the CE was analyzed through 2065, then the value for RS would drop to $35/t$CO_2$. The value for RZ would drop substantially as well; however, it would still remain near $400/t$CO_2$. A much longer time horizon (>200 years), such as that used in the WestCarb Study, would be needed to capture a full understanding of the benefits and costs for setting aside riparian areas.

AFW-9 Enhanced Materials Management in New Building Construction – Maximize Use of Low Carbon (including Reclaimed) Building Materials

Measure Description

"Net zero" energy buildings are defined by the OGWC Interim Roadmap to 2020[63] as "those that produce all of the operational energy used by the building in any given year." The "net zero" building concept also requires zero carbon resulting from building materials, including embedded carbon due to upstream emissions resulting from use of building materials. While it is not feasible for all building materials at new buildings to be "zero carbon," "net zero" building would require developers to purchase offsets to account for the embedded emissions within building products. This means that developers would need to estimate the carbon impacts of materials selection, which would spur the development of carbon footprinting and associated data. This alone has been shown to sometimes lead to reductions in life cycle GHGs. In addition, builders could reduce their offset expenses by selecting materials that contribute to lower whole-building GHG impacts. Lower carbon, including reclaimed, building materials reduce emissions holistically across the life cycle, including upstream industrial manufacturing emissions and downstream waste disposal emissions.

This measure targets the building materials aspect of "net zero" buildings. Specifically, materials used for the construction of new buildings will be low-carbon (including reclaimed) building materials to the extent that the use of such materials is economically and technically feasible. While this measure allows builders to purchase GHG offsets to offset embedded emissions within the building materials used, the cost and GHG reductions from the purchase of GHG offsets will not be considered in the quantitative analysis of this measure.

In place of – or in addition to – a "net zero" standard, Federal, State, and local governments may incentivize the use of reclaimed or low-carbon building materials through tax credits, loans, or grant programs.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: Reduce embedded emissions within newly-installed building materials by 17% by 2022 through the use of building materials with increased recycled content versus minimal recycled content in traditional building materials.[64]

- ***Federal Action Scenario (Low):*** Assumes implementation of federal incentive programs (similar to the Residential Energy Efficiency Tax Credit or Renewable Energy Tax Credit) designed to supply up to 30% of installation costs. The assumed "net zero" tax

[63] http://www.keeporegoncool.org/sites/default/files/Integrated_OGWC_Interim_Roadmap_to_2020_Oct29_11-19Additions.pdf

[64] In addition to using materials with increased recycled content, the embedded carbon intensity of building materials may be decreased by utilizing low-impact materials (i.e. green concrete) and reclaimed materials. These materials may also be used to meet the targets suggested by this measure, especially when they are more cost-effective than materials with high recycled content. However, due to data and resource limitations, only high recycled content materials are analyzed for this measure.

credit would supply builders with a tax credit for maximizing the use of reclaimed and low carbon building materials.

- ***Federal Action Scenario (Moderate):*** same as Scenario 1 above.
- ***Oregon Action Scenario:*** same as Scenario 1 above.

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013, ramping up linearly to full implementation in 2022.

Parties Involved: OR Legislature, Building Codes Division, ODOE, Oregon DEQ.

Data Sources and Additional Background: OGWC Interim Roadmap to 2020[65] Materials Management Measure #6. DEQ provided CCS with the analysis used for the OGWC quantification, which served in part as the basis for this analysis; 2007 Economic Census;[66] Consumption-based emission inventory of Oregon;[67] Presentation from *One Planet Initiative* on "Reducing the carbon footprint of buildings;"[68] It is important to note that much of the GHG reductions associated with this measure will be upstream (i.e. avoided manufacturing of cement, steel, and wood products from raw materials), and the geographic origin of the avoided upstream emissions may be uncertain. A portion of the in-state results include upstream GHG reductions. The upstream GHG reductions are broken out between in-state and out-of-state using information from the 2005 Consumption-based emission inventory of Oregon.

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.31	0.41	1.6	6.2	$188	$480	$119	$77
Mod. Fed. Action	0.31	0.41	1.6	6.2	$188	$480	$119	$77
OR Action	0.31	0.41	1.6	6.2	$188	$480	$119	$77

[65] "Interim Roadmap to 2020" The Oregon Global Warming Commission. Available at: http://www.keeporegoncool.org/sites/default/files/Integrated_OGWC_Interim_Roadmap_to_2020_Oct29_11-19Additions.pdf
[66] US Census Bureau. 2007 Economic Census. Available at: http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t
[67] "Consumption-based Greenhouse Gas Emissions Inventory for Oregon." Oregon Department of Environmental Quality. 2005. Available at: http://www.deq.state.or.us/lq/consumptionbasedghg.htm
[68] "Reducing the carbon footprint of buildings: materials and technologies." Ben Gill, *BioRegional Development Group*. Available at: http://ecoweek.netfirms.com/ecoweek/files/2010/files/speakers_ppt/benjamin_gill_ecoweek_2010a.pdf

Full Energy-Cycle Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	1.2	1.6	6.3	25	$188	$480	$30	$19
Mod. Fed. Action	1.2	1.6	6.3	25	$188	$480	$30	$19
OR Action	1.2	1.6	6.3	25	$188	$480	$30	$19

Quantification Methods:

Projected results of the implementation of AFW-9 are based on an analysis of baseline upstream GHG emissions resulting from the production and transportation of building materials, as well as the incremental cost of implementing a program to replace traditional building materials with building materials that have increased recycled content in new residential and commercial buildings.

CCS utilized the model created to assess the related measure in Oregon Global Warming Commission's Interim Roadmap to 2020 as the baseline upstream GHG emissions from building materials used to construct new residential and commercial buildings.[69] Baseline building materials costs were estimated using 2007 Economic Census data; specifically, the cost of materials, components, and supplies for residential, commercial, and institutional construction.[70] Oregon new housing starts historical data and forecast data were used in conjunction with the Economic Census data to project the baseline residential and commercial new building construction materials cost through 2035. Building costs are escalated at 5% per year, an assumption consistent with the average increase from 2012 to 2017, as predicted by the Associated General Contractors of America.[71]

GHG emission reductions resulting from the implementation of this measure include the in-state and out-of-state upstream GHG reductions resulting from the replacement of traditional building materials with building materials that have a higher recycled content. Although the measure goal addresses additional strategies for reducing the carbon impact of producing building materials (such as cleaner production and use of reclaimed materials), adequate information on the costs of such strategies was not available for inclusion in this modeling exercise. GHG emission reductions from the use of higher recycled content building materials were calculated by multiplying the baseline upstream GHG emissions by the target building materials upstream GHG reduction (17% by 2020, increasing linearly from 0% in 2012 to full implementation by

[69] Workbook provided to CCS by ODEQ.
[70] 2007 North American Industry Classification System codes include: 236115, 236116, 236117, 236220.
[71] "Construction and Materials Outlook." AGC of America. May 2012. Available at: http://www.agc.org/galleries/econ/Construction-Materials_Outlook.pdf

2022). Upstream GHG emission reductions were separated between in-state and out-of-state using the Oregon 2005 Consumption-based Inventory.[72]

Implementation costs of AFW-9 include compliance cost for builders and program administration cost for the state and/or municipal governments. The per-project compliance cost for residential buildings is assumed to be $500 per project (housing start) and the program administration cost is $200,000 per year, each escalating at 2% per year.[73] The total compliance cost of commercial buildings is assumed have the same ratio of residential-to-commercial cost as the baseline materials cost.

The cost-savings realized by this measure includes the savings realized to builders by switching to materials with a higher recycled content. The presentation from the *Bioregional Development Group* shows that materials with recycled content at levels optimized for cost-effectiveness of greenhouse gas reductions reduce materials cost by 0.55%. This factor of 0.55% is multiplied by the baseline materials cost to estimate the cost savings from the switch to building materials with maximum recycled content.

Total measure costs each year from 2013-2035 were the sum of program administration cost, compliance cost, and high recycled content building materials cost savings. The net measure cost was discounted at 5% to evaluate the net present value of the net measure cost in 2010, which was used as the basis for the per-ton of GHG emission reduction cost-effectiveness calculation.

Key Assumptions & Uncertainties (including sensitivities)

- This is a simplified analysis that doesn't cover other possibilities for reducing the GHG emission intensity of building materials, such as low-impact materials, and use of reclaimed materials. Also, this analysis does not consider the possibility of builders purchasing GHG offsets to reduce the overall footprint of new building construction where traditional materials substitution for low-intensity materials is not cost-effective. This measure analysis also does not consider using less building materials, constructing smaller buildings, or buildings that are more efficient from an engineering standpoint – using fewer materials for the same amount of floor space.
- Very little research has been done to analyze the incremental cost of reducing the carbon intensity of building materials. With the exception of the cost savings factor taken from the *Bioregional Development Group* presentation, all of the factors used to estimate the cost-effectiveness of this measure are based on the professional judgment and mutual agreement of ODEQ and CCS. Additional study on the cost of implementation is recommended before instituting building material carbon intensity requirements.

[72] "Consumption-based Greenhouse Gas Emissions Inventory for Oregon." Oregon Department of Environmental Quality. 2005. Available at: http://www.deq.state.or.us/lq/consumptionbasedghg.htm
[73] Cost assumptions provided by D. Allaway at ODEQ. Administration cost assumes 2 FTEs for program administration, including development of the reporting system.

AFW-10 Waste Prevention

Measure Description

Waste prevention, also referred to as source reduction, is achieved through a strategy – or suite of strategies – that reduce the amount of materials that require management as wastes. As defined in Oregon, waste prevention does not include diversion practices such as recycling or composting; it is the "reduce, reuse" element of "reduce, reuse, recycle." Traditionally through of as a waste management method, waste prevention is the most preferable, proceeding recycling/composting, combustion with energy recovery, and landfill disposal in Oregon's statutory hierarchy of waste management methods. However, waste prevention actually involves changes to how materials are purchased and used, not how they are managed at end-of-life. Waste prevention can address hundreds of discrete behaviors and materials. For the purpose of analysis, this measure focuses solely on food waste and packaging waste prevention measures.

The OGWC Interim Roadmap to 2020[74] assessed potential GHG reductions resulting from a reduction of food waste at the retail and consumer level by 5-50%, stating that the amount of food waste has reached 40% of the available food supply in recent years. Methods to reduce food waste at the consumer level include meal planning, food storage, and proper food preparation practices. Food waste prevention at the retail level can be achieved through better forecasting, inventory control, food storage, portion control, and reutilization.

Another opportunity for waste prevention, separate from food waste prevention, is the reduction of product packaging waste. Efforts may be increased in future years to reduce the mass of materials used for product packaging, thereby reducing both the quantity of materials used in packaging, and the mass of the waste stream as a whole. ODEQ conducted a pilot project between 2002 and 2005 to reduce the use and waste of packaging materials.[75] The results of this pilot study were used to inform the development of the packaging waste prevention portion of this measure.

Measure Design Specifications and Data Sources

Goals/Level of Effort and Action Scenarios:

Measure Goal: Reduce the mass of food and packaging waste generated annually by 10% by 2022 by implementing strategies at the consumer and retail level. Implement strategies to reduce packaging waste across the state by 10% by 2022.

- ***Federal Action Scenario (Low):*** Assumes no cost share of State research funding for the study and implementation of waste prevention strategies.
- ***Federal Action Scenario (Moderate):*** Assumes 50% cost share of State research funding for the study and implementation of waste prevention strategies.
- ***Oregon Action Scenario:*** same as Scenario 2 above.

[74] http://www.keeporegoncool.org/sites/default/files/Integrated_OGWC_Interim_Roadmap_to_2020_Oct29_11-19Additions.pdf
[75] http://www.deq.state.or.us/lq/sw/packaging/evaluationreport.htm

Timing (Start, Phase In, End): Implementation of this policy would begin in 2013. Target levels of waste prevention will be met by 2022, continuing through 2035. Assume a linear ramp-up between policy implementation and full compliance (2013-2022).

Parties Involved: Oregon Legislature, Oregon DEQ, Oregon Department of Agriculture, food retail trade associations, retail packaging and product manufacturers, packaging industry.

Data Sources and Additional Background: OGWC Interim Roadmap to 2020[76] Materials Management Measure #8. ODEQ provided CCS with the analysis used for the OGWC quantification, which served in part as the basis for this analysis. The EPA Waste Reduction Model and associated documentation were used to determine the GHG reductions yielded from the prevention of packaging waste.[77] Upstream emissions of food waste were quantified with the help of DEQ, and consultation of the UK "Love Food Hate Waste" report and other similar reports produced in the U.S. and Europe that assess the upstream emissions resulting from food consumption and waste.[78] The ODEQ packaging waste reduction pilot project was used as the primary data source for the packaging waste portion of this measure.[79] It is important to note that much of the GHG reductions associated with this measure will be upstream, and the geographic origin of the avoided upstream emissions may be uncertain. Upstream GHG emission reductions for food and packaging waste prevention were separated between in-state and out-of-state using the Oregon 2005 Consumption-based Inventory.[80]

Estimated Net GHG Reductions and Net Financial Costs or Savings

Summary of Analysis Results

In-State Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.12	0.14	0.62	2.3	-$1,218	-$3,554	-$1,952	-$836
Mod. Fed. Action	0.12	0.14	0.62	2.3	-$1,218	-$3,554	-$1,952	-$836
OR Action	0.12	0.14	0.62	2.3	-$1,218	-$3,554	-$1,952	-$836

[76] "Interim Roadmap to 2020" The Oregon Global Warming Commission. Available at: http://www.keeporegoncool.org/sites/default/files/Integrated_OGWC_Interim_Roadmap_to_2020_Oct29_11-19Additions.pdf
[77] US EPA. Waste Reduction Model. Available at: http://www.epa.gov/climatechange/waste/calculators/Warm_home.html
[78] "Preparatory Study of Food Waste Across EU 27". *European Commission*. Available at: http://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf
[79] "Business Packaging Waste Prevention Product." Oregon Department of Environmental Quality. Available at: http://www.deq.state.or.us/lq/sw/packaging/evaluationreport.htm
[80] "Consumption-based Greenhouse Gas Emissions Inventory for Oregon." Oregon Department of Environmental Quality. 2005. Available at: http://www.deq.state.or.us/lq/consumptionbasedghg.htm

Full Energy-Cycle Results

Curve	GHG Reductions ($MMtCO_2e$)				2013-2022 NPV ($MM2010)	2013-2035 NPV ($MM2010)	2013-2022 CE ($/t$CO_2$e)	2013-2035 CE ($/t$CO_2$e)
	2022	2035	Total (2013-2022)	Total (2013-2035)				
Low Fed. Action	0.67	0.79	3.5	13	-$1,218	-$3,554	-$347	-$272
Mod. Fed. Action	0.67	0.79	3.5	13	-$1,218	-$3,554	-$347	-$272
OR Action	0.67	0.79	3.5	13	-$1,218	-$3,554	-$347	-$272

Quantification Methods:

Projected results of the implementation of AFW-10 are based on an analysis of baseline food and packaging waste generation and landfill disposal activity in Oregon, and a simplified cost analysis including program administration cost, compliance cost, cost savings from reduced purchase of food or packaging, and expected societal cost-savings from the perspective of waste management system ratepayers (i.e. residential and commercial waste management customers). The projects initiated as a result of the implementation of this measure will reduce the amount of food and packaging waste that are produced, transported, and enter the waste stream.

The baseline quantity of food waste generated in Oregon and disposed in landfills is taken from a Solid Waste Management Profile developed from solid waste management and composition data provided to CCS by ODEQ.[81] The baseline quantity of packaging waste generated in Oregon is estimated by multiplying the total in-state generation of MSW from the Solid Waste Management Profile by the percentage of MSW that is estimated to be packaging waste (15%, based on Oregon waste composition data provided to CCS). The aforementioned baseline quantities of waste generated are multiplied by the waste prevention targets for food and packaging waste to yield the target quantities of waste prevented for food and packing wastes.

GHG emission reductions resulting from the implementation of this measure include: direct in-state reductions resulting from avoided landfill disposal of food and packing waste, and upstream in-state and out-of-state reductions due to reduced production of food and packaging waste deposited in landfills, including industrial manufacturing and agricultural food production. Avoided food waste landfill disposal, and upstream and downstream GHG emission reductions were estimated using results from a study from the Oregon Department of Environmental Quality that estimated the upstream and downstream emissions from food waste production and disposal, and the quantity of food waste prevented in each year.[82] Avoided packaging waste landfill disposal upstream and downstream GHG emission reductions were estimated using results from a WARM run based on the assumed composition and quantity of packaging waste

[81] While a reduction in generation (waste prevention) may reduce the amount of waste managed through other streams (i.e. composting, anaerobic digestion), it is assumed for the purposes of this analysis that waste prevention activities will reduce only the amount of waste deposited in landfills.
[82] "Food-related alternatives6.xlsx" provided by D. Allaway of ODEQ.

prevented in each year. Upstream GHG emission reductions were separated between in-state and out-of-state using the Oregon 2005 Consumption-based Inventory.[83]

Implementation costs of AFW-10 include cost of annual program administration cost for food waste prevention, and annual program administration and compliance costs for packaging waste prevention. The food waste prevention program administration cost is based on the "Love Food Hate Waste" program in the United Kingdom. The costs of this program – assumed to be equivalent to the cost of a similar program in Oregon – are about $4 million in the first year, and $3 million in each year thereafter.[84] The implementation costs of packaging waste prevention are based on DEQ's pilot project that included costs of business recruitment, technical assistance, business costs, and oversight costs of $310,000, or about $570 per ton of waste prevented. We assume that these per-ton costs of the pilot project are consistent with a larger expansion. The program administration and business costs are escalated at 2% annually to account for possible increased cost of materials, energy, and labor.

The cost-savings realized by this measure includes cost savings for the consumer and manufacturer due to the reduced amount of food and packaging consumed and the avoided cost of food and packaging waste disposal. The consumer cost savings due to reduced food purchasing is taken from the results of "Love Food Hate Waste", and is estimated at $2,800 saved per ton of food waste prevented. The cost savings from packaging waste prevention is estimated from the results of the Oregon Packaging Waste Prevention Study, and is about $2,300 saved per ton of waste prevented. Again, we assume that these per-ton savings can be realized with program expansion in Oregon. The avoided cost of food and packaging waste disposal, in theory, represents the avoided cost of collecting and transporting waste, managing waste at landfills (as well as composting and recycling facilities), and the eventual construction of building new transfer stations and management facilities to handle waste generated by a growing population and economy. However, a comprehensive analysis to put a succinct cost figure on the true avoided cost of food and packaging waste disposal was not available at the time of this analysis. Therefore, the 2006 average landfill tipping fee of $35 per ton[85] (adjusted to 2010$ and inflated at 2% annually) is used as a proxy for the avoided cost of food and packaging waste disposal.

Total measure costs each year from 2013-2035 were the sum of annualized capital cost, O&M cost, avoided MSW disposal cost savings and avoided electricity cost savings. The net measure cost was discounted at 5% to evaluate the net present value of the net measure cost in 2010, which was used as the basis for the per-ton of GHG emission reduction cost-effectiveness calculation.

Key Assumptions & Uncertainties (including sensitivities)

- This is a simplified analysis that doesn't cover other possibilities for waste prevention, and does not provide prescriptive implementation measures to achieve the waste prevention targets set forth. It is possible that other waste streams, such as paper, plastic,

[83] "Consumption-based Greenhouse Gas Emissions Inventory for Oregon." Oregon Department of Environmental Quality. 2005. Available at: http://www.deq.state.or.us/lq/consumptionbasedghg.htm
[84] "Preparatory Study of Food Waste Across EU 27". *European Commission*. Available at: http://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf
[85] "The State of Garbage in America", *Biocycle*, October 2010.

glass, and metal, may be re-used or reduced in a way that is not covered by this measure. Additionally, the packaging waste prevention portion of this measure solely looks at packaging waste prevention from the producer point-of-view, when in-fact it may be that the consumer reaps additional benefit (and may have a role to play) from packaging waste prevention.

- The cost information for the analysis in this measure is taken from a very small population of the work done thus far on the environmental and economic benefits of waste prevention. Further study is needed to pinpoint the most effective – and most cost-effective – implementation waste prevention strategies.
- The goal of 10% reduction in food waste generation is drawn from the U.K. "Love Food Hate Waste" program, which has estimated a 5% reduction in food waste generation after several years of program implementation. Research by the same organization suggests that up to 83% of household food waste is avoidable or potentially avoidable, and a recent case study funded by DEQ demonstrated a 47% reduction in food waste at several facilities on the Hillsboro Intel campus.[86] So a 10% reduction is technically feasible although it has not yet been demonstrated on a large geographic scale.
- The goal of 10% reduction in packaging waste generation has not been evaluated for feasibility at a broad geographic scale, although multiple case studies produced by Oregon DEQ suggest that much larger reductions are sometimes attainable on a package-specific basis.[87]

[86] http://www.deq.state.or.us/lq/pubs/docs/sw/compost/FoodWastePreventionCaseStudy-Aug2010.pdf
[87] See http://www.deq.state.or.us/lq/sw/packaging/casestudies.htm for case studies.

Appendix E:
Guidelines and Common Methods & Data for Micro-Economic Analysis

THE CENTER FOR
CLIMATE STRATEGIES

Memo

To: Members of the Center for Climate Strategies (CCS) Team for the Oregon Department of Energy (ODOE) Cost Curves Project

From: Stephen Roe and Randy Strait, (CCS)

CC: Bill Drumheller, ODOE

Re: Guidelines and Common Methods & Data for Micro-Economic Analysis

Date: May 25, 2012

The purpose of this "Quantification Memo" is to provide and explain the guidelines, general methods, and common data sources needed for developing the greenhouse gas (GHG) mitigation cost curves for this project. The text below covers the guidelines and methods, while a companion Excel workbook ("ODOE Micro-analysis Common Data.xls") will house the common data. Some examples of common data are provided at the end of this memo.

Introduction: Direct vs. Indirect Effects and Linkages

Socio-economic impacts of measures and scenarios (groups of measures) include direct, indirect, and distributional effects. Direct effects are those borne or created by the specific entities, households or populations subject to the measure or implementing the new measures. Indirect effects are other than those specifically involved in implementing the measure recommendation. For instance, new vehicle standards may directly affect manufacturers and consumers of cars. Indirectly, their sales may increase or decrease local taxes and spending on goods and services that benefit from or are hurt by increased disposable income of the manufacturing workforce and consumers. These direct and indirect economic analyses are sequentially linked, with overlap. Direct effects must be calculated first in order for indirect effects and distributional impacts to be calculated.

Direct physical effects of GHG impacts will be the focus of micro-economic analysis to develop the cost curves for this project. Indirect GHG effects will be evaluated under the macro-economic modeling phase of the project. Examples of direct and indirect net costs and benefits metrics are included at the end of this memo for purposes of illustration.[1]

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[1] For additional reference see the economic analysis guidelines developed by the Science Advisory Board of the US EPA available at: http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html.

I. General Guidelines

Specification of GHG Measure Design Parameters

For each measure analyzed, a brief description of the measure needs to be accompanied by a series of design parameters that drive the micro-economic quantification of GHG reductions and net societal costs. These include:

- *Level of effort* (or goals for the proposed action).
- *Timing* (start and stop dates for the actions addressed within the measure, including a ramp-up schedule toward full implementation).
- *Affected parties* include public or private entities that would be involved in implementing the measure.
- *Other definitional issues* or eligibility provisions (e.g. renewable fuel definitions, details on business as usual emissions addressed by the measure, etc.).

For many measures, the analysis should address multiple levels of implementation, which will mean that multiple goals and potentially timing need to be assessed.

Specification of Implementation Mechanisms (Policy Levers) for Each Measure

In addition, the instruments or mechanisms used to implement each measure need to be identified to at least address features affecting implementation cost (and potential variations in effectiveness as warranted). A variety of instruments or mechanisms exist, including:

- *Voluntary and/or negotiated agreements*
- *Technical assistance*
- *Targeted financial assistance*
- *Taxes or fees*
- *Other pricing mechanisms*
- *Codes and standards*
- *Disclosure and reporting*
- *Information and education*

The impacts of each are measure specific. For instance, some measures may require technical assistance or additional government staffing to implement, and the cost for these additional services should be included. Similarly, expected government grants or low cost loan programs should be specified and the annual flow of grant money should be tracked separately from the rest of the net societal cost components.

The focus in this section should be on likely implementation mechanisms that drive or otherwise impact the net costs of the measure. Secondly, there is a need to identify expected federal or state "actions" (standards or other regulations) that would affect the technical potential for any measure analyzed. These additional federal and state actions are analyzed in an iterative fashion, whereby the federal action reduces the technical potential to some degree, and then any additional state action also removes some incremental amount of the measure technical potential.

Administrative costs associated with any measure will not be included in the net costs.

Coverage and Metrics of Measure Impacts

Quantitative estimates will be developed for the following types of impacts where applicable and within the analytical capacity of the contract:

- *Net GHG reduction potential:* expressed as Million Metric Tons Carbon Dioxide Equivalent ($MMtCO_2e$) removed, including net effects of carbon sequestration or sinks, measured as an incremental change against a forecasted baseline; where very small denominations of GHGs are involved, Metric Tons (tCO_2e) may be used with notation. With the exception of net reductions resulting from lower electricity use, GHG reductions occurring in-state need to be specified separately from those potentially occurring out of state (e.g. upstream GHG reductions from lower fuel use or materials consumption)
- *Non-GHG physical impacts:* specify annual reductions in energy use [e.g. megawatt-hours (MWh) of electricity and terajoules (TJ) of fuels]; also, specify annual reductions in water consumption, and materials consumption as appropriate (e.g. fertilizer, solid waste). As with net GHG reductions, break-out known in-state reductions from those potentially occurring out of state. Not only will these be needed to quantify net GHG reductions, they will also be used as input to macro-economic modeling.
- *Individual or "stand-alone" impacts* of measures, as well as *aggregate or interactive effects* of measure sets and scenarios ("system-wide" impacts); these will be measured as an incremental change against a forecasted baseline. Each measure will first be analyzed on a "stand-alone" basis which ignores any overlap or interaction with other measures. Aggregate impacts will be assessed when the scenarios for macro-economic assessment have been established. At that stage, the measures to be included in each scenario (as well as the specific set of design parameters for each measure) will be specified. Appropriate adjustments to the net GHG reductions for each measure will then be developed to account for overlap or other interactive effects.
- *Direct economic impacts*, quantified as an annual future stream of *net costs/savings* [also used to quantify *cost effectiveness* when paired with GHG reductions (expressed as $/$tCO_2e$ removed]; this will include avoided costs of measure options, such as avoided cost of investment in infrastructure or services from efficiency measures, as data are available. NOTE: per agreement with ODOE, administrative costs associated with implementing a measure will not be included in these direct costs.
- *Indirect or secondary economic impacts* on jobs, income, economic growth, and prices, also known as *macro-economic impacts,* which arise from or in association with direct costs and savings will be developed during the macro-economic modeling phase of the project.
- *Full energy-cycle impacts,* including in-state net energy and GHG emission effects related to all energy inputs and outputs of projects or best practices, as possible based on the availability of data and relevance. Note: as mentioned under GHG reductions above, the upstream energy/GHG impacts will typically be specified separately from those associated with in-state energy consumption, unless it is known that the upstream emissions occur within the State. Upstream impacts will be in the form of net CO_2e

reductions only, since the upstream energy reductions would be too cumbersome to track and not available across all sectors.

- *Discounting* or time value of assets: this project will use standard rates of 5 percent/yr real and 7 percent/yr nominal, applied to net flows of costs or savings over the time period from year of implementation to the end of the planning horizon (2035 for this project.
- *Annualized impacts*, using levelization of net present value (NPV) impacts that provide both cumulative and year-specific snapshots.
- *Impacts beyond the end of the project period*; where additional significant GHG reductions or costs occur beyond the planning horizon, these will be shown for illustration (e.g. difference in cost effectiveness between the standard planning horizon approach and the full life of a technology or best practice).

Transparency of Analysis

All key elements of measure development and analysis will be explicitly provided as documentation for the project. This includes measure design and implementation mechanism choices (above) as well as the technical specification of analysis for each measure. These technical specifications for analysis include:

- *Data sources*, based on best available data and emphasizing Oregon-specific data;
- *Methods and models;*
- *Key assumptions;*
- *Key uncertainties*.

Documentation of Results

Documentation of the work completed for each measure will be provided in a standard Measure Template format that addresses the following topics to ensure consistency for comparison of information and results, and also assist with identifying data gaps.

- Sector
- Name of Measure or Measure Group, including relevant technologies or practices
- Plain English Policy Description of Measure or Measure Group (including relevant policy levers and how each measure was customized for Oregon)
- Measure Design Specifications and Data Sources
- Policy Levers and Other Implementation Mechanisms
- Related Policies and Programs in Place or Anticipated (for baseline definition)
- Quantification Results, including:
    - Estimated Net GHG Savings in target years (2020 and 2030 or 2035),
    - Cumulative GHG reduction potential and net costs/savings,
    - Net Cost/savings per cumulative $MMtCO_2e$ saved
    - Specified data sources, quantification methods, and key assumptions
- Key Uncertainties and Sensitivity Analyses, as feasible, including appropriate qualifiers to keep in mind when using the data associated with the measure and associated policy levers, such as an assessment of the associated margin of error.

The completed Measure Templates will be assembled into a separate appendix of the final report. Additional printouts of worksheets and reference materials may be provided where needed.

II. Common Methods & Data

Use of Pollutant Coverage and Global Warming Potentials

The analysis will cover the following six GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these gases will be presented using a common metric, CO_2e, which indicates the relative contribution of each gas to global average radiative forcing on a Global Warming Potential- (GWP-) weighted basis. Table 1 shows the 100-year GWPs published by the Intergovernmental Panel on Climate Change (IPCC) in its Second, Third, and Fourth Assessment Report. To be consistent with the draft GHG emissions inventory and forecast for the state of California, the 100-year GWP's published in the IPCC's Second Assessment Report will be used to convert mass emissions to a 100-year GWP basis. Use of the 100-year GWPs published in the IPCC's Second Assessment Report is also consistent with U.S. Environmental Protection Agency (EPA) and IPCC guidance for consistency with how U.S. national, state, and country-specific GHG emissions inventories have been developed in the past.

Table 1. 100-Year Global Warming Potentials from the 2nd, 3rd, and 4th IPCC Assessment Reports

Gas	100-year GWP (2nd Assessment)[2]	100-year GWP (3rd Assessment)[3]	100-year GWP (4th Assessment)[4]
CO_2	1	1	1
CH_4	21	23	25
N_2O	310	296	298
HFC-23	11,700	12,000	14,800
HFC-125	2,800	3,400	3,500
HFC-134a	1,300	1,300	1,430
HFC-143a	3,800	4,300	4,470
HFC-152a	140	120	124
HFC-227ea	2,900	3,500	3,220
HFC-236fa	6,300	9,400	794
HFC-4310mee	1,300	1,500	1,640
CF_4	6,500	5,700	7,390
C_2F_6	9,200	11,900	12,200
C_4F_{10}	7,000	8,600	8,860
C_6F_{14}	7,400	9,000	9,300
SF_6	23,900	22,200	22,800

* The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor.

[2] Second Assessment: http://www.epa.gov/climatechange/emissions/downloads/ghg_gwp.pdf 1995.
[3] Third Assessment: http://www.ipcc.ch/ipccreports/tar/wg1/248.htm, 2001.
[4] Fourth Assessment: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf, 2007.

Emission Reductions

Emission reductions for individual measures will be estimated incremental to baseline emissions based on the change (reduction) in emissions activity (e.g., physical energy or activity units), or as a percentage reduction in emissions activity (e.g., physical energy or activity units or emissions) depending on the availability of data. This information will be needed to support the cost-effectiveness calculation for each measure option. Baseline emissions are documented in ODOE's GHG I&F, a copy of which is provided in the project Central Desktop workspace.

Net Costs and Savings

Net capital outlays and receipts, operation and maintenance (O&M) costs or savings, energy/fuel costs or savings, or other direct financial costs and savings will be estimated for each of the measures. Net capital outlays should be specified for each year in which they occur for use in subsequent macro-economic modeling. For the micro-economic analyses, costs and savings will be discounted as a multi-year stream of annualized net costs/savings to arrive at the NPV cost associated with implementing the new technologies and/or best practices specified by the measure. Costs will be discounted in constant 2010 dollars using a 5 percent annual real discount rate (7 percent nominal) based on standard rates used for regulatory impact analysis at the federal and state levels.

Capital investments will be represented in terms of annualized or amortized costs over the planning period. Capital costs or savings represent the material, equipment, labor, and other costs or savings associated with the implementation of a measure option relative to the baseline or reference technology or practice. For measures that require a capital investment, these costs will be annualized using a fixed charge rate (FCR), a factor that reflects the sum of the cost of capital (equals the cost of debt plus the cost of equity), taxes, and depreciation, as well as the lifetime of the investment.

O&M costs or savings refer to labor, equipment, and fuel costs related to annual operation and maintenance of measure actions, and are differentiated into annual expenditures (i.e., variable O&M) and fixed expenditures (i.e., fixed O&M). Variable O&M estimates are provided in activity units over the full period of operation of the technology. O&M costs are described and included as the net difference between the baseline technology and the GHG-reducing alternative.

Savings calculations include avoided costs of fixed and variable measure implementation investments, as applicable, and as available data allow. For instance, location efficiency measures may reduce the required infrastructure or services associated with new communities, depending on design and other circumstances. Similarly, electricity end use efficiency may reduce the need for new power generation facilities, and fuel efficiency measures may reduce the need for new fuel production and distribution facilities.

Cost Effectiveness

Because the monetized dollar value of the impacts of GHG emissions reduction is not available, physical avoided emissions benefits are used instead as an input to cost effectiveness calculations, measured as dollars per tCO_2e (cost or savings per tonne), and referred to as "cost effectiveness". Both positive costs and cost savings (negative costs) are estimated as a part of the calculation of emissions mitigation costs. When combined with GHG impact assessments, the results of these cost estimates will be aggregated into a stepwise marginal cost curve that can be broken down by sector or subsector, as needed.

The net cost of saved carbon, or cost effectiveness, of a proposed measure is calculated by dividing the cumulative future streams of incremental costs or savings over the appropriate measure option time period, discounted back to the present time, by the cumulative undiscounted net CO_2e reductions achieved by the technology or best practice. Mathematically, the equation to be used is as follows:

$$CSC = \frac{\sum_{t=0}^{n} \left\{ \frac{((LC_m - LC_r) * A_t)}{(1 + D_r)^t} \right\}}{\sum_{t=0}^{n} (CO_2e_r - CO_2e_m)}$$

Where:

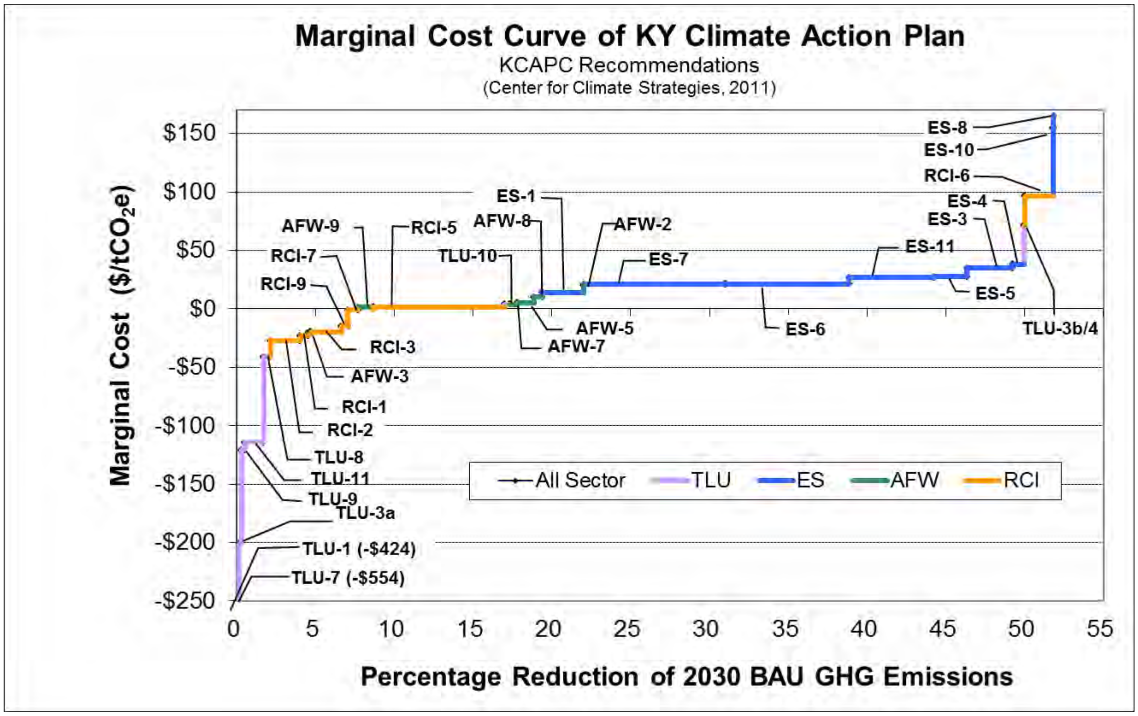
CSC	=	Cost of saved carbon (or cost-effectiveness) of a technology or best practice, $/t$CO_2e$ avoided
LCm	=	Levelized cost of a technology or best practice, $/activity unit
LCr	=	Levelized cost of the baseline or reference technology or best practice, $/activity unit
A	=	Amount of activity affected by the technology or best practice in year t, activity unit
Dr	=	Real discount rate, dimensionless
CO_2er	=	CO_2e emissions associated with the baseline or reference technology in year t, tons CO_2e
CO_2em	=	CO_2e emissions associated with a technology or best practice in year t, tons CO_2e
t	=	year in the evaluation period ($0 \leq t \leq 25$)

Activity units refer to a unit indicator of GHG emissions activity for a measure option. The activity units will vary depending on the Area (sector) and within each sector by the individual option. The activity units are used to normalize data for comparison of the measure option to the baseline. For example, for the Power Supply sector, MWh of gross electricity generation could be used as the activity unit such that dollars per megawatt-hour ($/MWh) would be used as the activity unit for the "LCm" and "LCr" terms and MWh would be used as the unit for the activity term in the equation.

The results of the analyses will be used to develop a GHG abatement cost curve, which will rank each technology or best practice in the order of its cost effectiveness for reducing a tCO_2e of emissions. This ranking will be represented in the form of a curve. Figure 1 below provides an example. Each segment of the curve represents the cost-effectiveness of a given measure option and its potential contribution to reductions from the GHG baseline, expressed as a percentage of baseline emissions. The segments on the curve appear sequentially, from most cost-effective in the lower left area of the curve, to the least cost-effective options located higher in the cost curve in the upper right area. As another example of a marginal cost curve, see the analysis conducted for measures to meet California AB32 requirements by Stanford University.[5]

[5] http://www.stanford.edu/group/peec/cgi-bin/docs/policy/research/September%2027%202008%20Discussion%20Draft%20-

Figure 1. Sample Cost Curve



Levelized Costs

In developing the cost effectiveness estimates described above, the net stream of annualized costs for each measure will be levelized over the period of time during which net costs are calculated. The levelization calculation is similar to amortization and its purpose is to develop a level stream of equal dollar payments that lasts for a fixed period of time. This allows snapshot evaluations of measure impact at any given point in time in a manner that incorporates the fixed and variable expenses and savings over the full time period applicable to implementation of the measure. Levelization also allows for comparing the results of different measures on a common financial basis. The levelization formula to be used in the analysis is as follows:

$$LC = \frac{[PV * D_r * (1 + D_r)^t]}{((1 + D_r)^t) - 1}$$

Where:

LC	=	Levelized costs of a technology or best practice, $ or $/activity unit
PV	=	Present value of discounted cost stream
D_r	=	Real discount rate, dimensionless (5% used for this project)
t	=	Levelization period, or number of years over which payments are to be made

%20Analysis%20of%20Measures%20to%20Meet%20the%20Requirements%20of%20Californias%20Assembly%20Bill%2032.pdf.

Time Period of Analysis

For each measure, incremental emission reductions and incremental costs and savings will be calculated relative to the characteristics of the baseline that would otherwise prevail in Oregon up through the end of the 2035 planning period, as well as the lifetime of the measure in question. The NPV of the cumulative net costs of each measure and the cumulative emission reductions of each measure will be reported starting with the initial year of the phase-in of the measure up through the target period for analysis (2035). For example, if a measure includes a complete phase-in over time, the annual GHG reductions and the NPV of the incremental costs and the cumulative emission reductions will be reported for the entire period from the beginning of the phase-in up through 2035. The earliest year of measure phase-in for this project should be 2013. Annual GHG reductions will also be reported for an interim year of 2020.

Geographic Inclusion

GHG impacts of activities that occur within Oregon will be estimated, regardless of the actual location of emission reductions. This is most obvious for electricity consumption, where emissions are accounted for using a consumption-basis (emission reductions occur both within and outside of the state). Since the baseline I&F presents these emissions on a consumption-basis, no distinction is generally made to the location of the generation sources involved.

The rest of the baseline is not constructed on a consumption basis. Therefore, measures that result in lower fuel or materials consumption can also result in upstream GHG impacts that occur out of state. An example of where this occurs is solid waste recycling of aluminum. The associated reduction in upstream material extraction and processing (e.g., bauxite mining and primary smelting) results in lower energy use and GHG emissions. While a measure may increase recycling in the region, the reduction in emissions may occur where the virgin inputs for the recycled materials are produced (due to lower demand). Where significant emission impacts are likely to occur outside the State, these will be estimated but kept apart from the known direct in-State reductions.

When cost curves are constructed during scenario analysis, CCS will consult with ODOE on whether to include both the in-State and potential out-of-State reductions. More on this issue is included in the next section on energy-cycle coverage. [In most projects supported by CCS, these emissions reductions have been counted towards the achievement of the jurisdiction's emissions goal, since they result from actions taken within the jurisdiction]

Energy-Cycle Coverage

GHG reductions for each measure will be based on an energy-cycle and net energy impact analysis wherever possible, based on best available data and priority need. Tracking the full range of fuel use inputs is preferred, and in some cases essential, for accurately tracking of full energy-cycle carbon emissions for technology options and best practices displaying very different performance characteristics from the standard practices they are replacing. The approach involves identifying all the possible stages of the energy-cycle, for instance, and quantifying the fuel input per unit of energy or material produced (electricity or fossil fuel). The focus, however, will be on those energy-cycle elements where there are significant differences in greenhouse gas emissions between the business or reference case (standard practice) and the measure.

Energy-cycle impacts will be reported for each source for which information is available to support an energy-cycle analysis. Where net energy-cycle emission reductions are captured, there can often be two sets of emission reductions estimated: the total energy-cycle reductions; and those estimated on just a direct basis (e.g., tailpipe emissions). In some cases, these will be difficult to separate these geographically based on available information. Therefore, by default, the in-State reductions will often be those estimated on a direct basis (e.g. differences in fuel combustion tailpipe emissions between standard practice and measure cases for in-region processes).

Similar to fuels consumption, changes in materials management and consumption also have important energy-cycle implications. For example, in municipal solid waste management, baseline emissions from in-State processes typically include only those processes that are known to occur within Oregon (e.g., landfill or waste combustion emissions). However, these ignore potentially significant upstream GHG emissions embedded in each of the waste components being managed. CCS will estimate these upstream emission reductions for relevant measures (e.g. source reduction, recycling) and assume that all upstream reductions occur out-of-State.

Examples of Direct/Indirect Net Cost and Benefit Metrics

Note: These examples are meant to be illustrative and are not necessarily comprehensive.

1. **Transportation and Land Use (TLU) Sector**
   a. Direct Costs and/or Savings
      i. Incremental cost of more efficient vehicles net of fuel savings, net of fuel savings.
      ii. Incremental cost of implementing Smart Growth programs, net of saved infrastructure and service costs.
      iii. Incremental cost of mass transit investment and operating expenses, net of any saved infrastructure and service costs (e.g., roads)
      iv. Incremental cost of alternative fuel, net of any change in maintenance costs
      v. Net effects of carbon sequestration from land use measures
   b. Indirect Costs and/or Savings
      i. Net value of employment and income impacts, including differential impacts by socio economic category
      ii. Re-spending effects on the economy from financial savings
      iii. Net changes in the prices of goods and services in the region
      iv. Health benefits of reduced air and water pollution
      v. Ecosystem benefits of reduced air and water pollution
      vi. Value of quality-of-life improvements
      vii. Value of improved road and community safety
      viii. Energy security
2. **Residential, Commercial, and Industrial (RCI) Sectors**
   a. Direct Costs and/or Savings
      i. Net capital costs or savings (or incremental costs or savings relative to standard practice) of improved buildings, appliances, equipment (cost of higher-efficiency refrigerator versus refrigerator of similar features that meets standards)
      ii. Net operation and maintenance (O&M) costs or savings (relative to standard practice) of improved buildings, appliances, equipment, including avoided/extra labor costs for maintenance (less changing of compact fluorescent light (CFL) or light-emitting diode (LED) bulbs in lamps relative to incandescent)
      iii. Net fuel (gas, electricity, biomass, etc.) costs (typically as avoided costs from a societal perspective)

iv. Cost/value of net water use/savings

v. Cost/value of net materials use/savings (for example, raw materials savings via recycling, or lower/higher cost of low-global warming potential (GWP) refrigerants)

vi. Direct improved productivity as a result of industrial measures (measured as change in cost per unit output, for example, for an energy/GHG-saving improvement that also speeds up a production line or results in higher product yield)

b. Indirect Costs and/or Savings

i. Net value of employment and income impacts, including differential impacts by socio economic category

ii. Re-spending effect on economy

iii. Net value of health benefits/impacts

iv. Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)

v. Net embodied energy of materials used in buildings, appliances, equipment, relative to standard practice

vi. Improved productivity as a result of an improved working environment, such as improved office productivity through improved lighting (though the inclusion of this as indirect might be argued in some cases)

3. Energy Supply (ES) Sector

a. Direct Costs and/or Savings

i. Net capital costs or savings (or incremental costs or savings relative to reference case technologies) of renewables or other advanced technologies resulting from policies

ii. Net O&M costs or savings (relative to reference case technologies) renewables or other advanced technologies resulting from policies

iii. Avoided or net fuel savings (gas, coal, biomass, etc.) of renewables or other advanced technologies relative to reference case technologies resulting from policies

iv. Total system costs (net capital + net O&M + avoided/net fuel savings + net imports/exports + net transmission and distribution (T&D) costs) relative to reference case total system costs

b. Indirect Costs and/or Savings

i. Net value of employment and income impacts, including differential impacts by socio economic category

ii. Re-spending effect on economy

iii. Higher cost of electricity in the region

iv. Energy security
v. Net value of health benefits/impacts
vi. Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)

4. Agriculture, Forestry, and Waste Management (AFW) Sectors

a. Direct Costs and/or Savings
   i. Net capital costs or savings (or incremental costs relative to standard practice) of facilities or equipment (e.g., manure digesters and associated infrastructure, generator; ethanol production facility; composting facility; land purchases/easements; opportunity costs; tree planting programs; etc.)
   ii. Net O&M costs or savings (relative to standard practice) of equipment or facilities
   iii. Net fuel (gas, electricity, biomass, etc.) costs or avoided costs
   iv. Cost/value of net water use/savings
   v. Net cost or avoided costs of reduced nutrient application
   vi. Reduced VMT and fuel consumption associated with land use conversions (e.g., as a result of forest/rangeland/cropland protection policies), where data exist to quantify these
   vii. Net embodied energy and emissions of water use in equipment or facilities relative to standard practice
   viii. Net embodied energy and emissions of solid waste management changes (recycling), source reduction, or re-use.

b. Indirect Costs and/or Savings
   i. Net value of employment and income impacts, including differential impacts by socio economic category
   ii. Net value of human health benefits/impacts
   iii. Net value of ecosystem health benefits/impacts (wildlife habitat; reduction in wildfire potential; nutrient run-off; etc.)
   iv. Value of net environmental benefits/impacts (value of damage by air or water pollutants on structures, crops, etc.)

List of Common Factors for Measure Quantification (needed across sectors)

1. Energy price forecasts: covering electricity, as well as each fuel type; sources could include US Department of Energy's Energy Information Administration (US DOE EIA) forecasts;
2. Forecasts for electricity and gas sales in Oregon over the modeling period;
3. Information on current (most recent year) utility sales of gas and electricity in Oregon, preferably by utility, especially if different goals are to apply to different utilities. To the extent that utilities serving the Oregon also serve areas outside the region, information would be needed on the fraction of sales of each relevant utility inside the Oregon;
4. Carbon intensity of grid electricity: should be taken from Oregon's GHG I&F. These values may change over the modeling period, and will be needed for many ES and RCI options and potentially TLU and AFW options as well;
5. Estimates of the average current and projected gas and electricity avoided costs (in $/MMBtu and $/MWh) in Oregon;
6. Energy-cycle emission factors: for electricity, as well as each fuel type; sources could be ANL GREET model or a specific set developed for the OR Low Carbon Fuel Standard;
7. Oregon population forecasts (e.g., county-level, if possible;
8. Forecasts for the number of new residential buildings to be constructed over the planning period (by year), and of the commercial floor space to be constructed annually (or, for example, forecasts for these parameters in five-year increments);
9. Estimates of current total water use, preferably by sector, for the most current year available (and, preferably, for recent years) in the State. If water use data are unavailable, water production (volume of water treated of water for domestic, commercial, and industrial uses) in the State would be a good proxy; embedded energy/carbon content of water deliveries in Oregon.
10. Estimates of future water use in Oregon. These may be available from water treatment/distribution authorities, or may need to be created by extrapolating trends in use per person and applying them to demographic projections;
11. Estimates of current and future volumes of wastewater treated;
12. Regional economic forecast (employment, gross domestic product (GDP)); and
13. Biomass supply and demand assessment: a common need for energy and GHG planning where strategies target in-region fuel supplies. This will be developed by the AFW sector analysts from a variety of sources.

Appendix F:
Index of Files Delivered to ODOE

The following identifies the files used to prepare the quantification of mitigation measure emissions reductions and costs and the marginal abatement cost curve charts and tables delivered to ODOE. It also identifies files supporting the foundational macroeconomic modeling effort.

File Name	Sector	Format	Description
Task 1. Greenhouse Gas Abatement Curve Components			
07-30-12_ODOE_ Scenario_Cost_Curve.xlsx	All	Excel	Excel workbook file containing all of the measure-level results and the marginal abatement cost curves used in the report. Also includes the measures used for the foundational modeling of the least-cost scenarios and the chart comparing the emission reductions (after adjusting for overlaps) for Scenarios 2 and 3 to Oregon's baseline emissions inventory and forecast and GHG reduction goals.
07-30-12_ODOE_Scenario_Cost_Curves_by_Sector.xlsx	All	Excel	Excel workbook file containing sector specific measure-level cost curves formatted for the report. This file contains the same sector-specific spreadsheets as the "07-30-12_ODOE_ Scenario_Cost_Curve.xlsx" file except that the cost curve charts are formatted differently.
7-09-12 ODOE Micro-Analysis Common Data.xlsx	All	Excel	Contains common assumptions for data used across all sectors, including energy prices and emission intensities.
FINAL Oregon PS cost curve analysis - combustion e-factors.xlsx	PS	Excel	Contains all of the worksheets used to prepare the microeconomic analysis of the PS options, using point-of-combustion CO2e emission factors. The first worksheet in this file provides an index to the worksheets included in the file.
FINAL Oregon PS cost curve analysis – fuel cycle e-factors.xlsx	PS	Excel	Contains all of the worksheets used to prepare the microeconomic analysis of the PS options, using fuel cycle CO2e emission factors. The first worksheet in this file provides an index to the worksheets included in the file.
Input spreadsheets for FINAL Oregon PS cost curve analysis – combustion e-factors.xlsx and FINAL Oregon PS cost curve analysis – fuel cycle e-factors.xlsx	PS	Excel	• 07-24-12_Overlap_Analysis.xlsx • 7-09-12 ODOE Micro-Analysis Common Data.xlsx • OR LCFS Cost Curve Summaries Draft - ext to 2050 072512.xlsx

File Name	Sector	Format	Description
			• OR_RPS_Approved_Generators.xlsx • 2010_FINAL_GEN_Emissions_Summary.xlsx • 2009_final_Gen_Emissions_Summary.xlsx • 2008_final_Gen_Emissions_Summary.xlsx • Resource_Mix_2008-2010_Small_v_large (corrected).xlsx • or_retail_rps_size_class_2008_2010.xlsx • meters in oregon - 2009.xlsx • Oregon population projection.xlsx
ODOE-RCI-Options-Final.xlsx	RCI	Excel	Contains all of the worksheets used to prepare the microeconomic analysis of the RCI measures. The first worksheet in this file provides an index to the worksheets included in the file.
ODOE Ag Measures Quantification.xlsx	AFW	Excel	Contains all of the worksheets used to prepare the microeconomic analysis of the Agriculture options, using fuel cycle CO2e emission factors. The first worksheet in this file includes a summary of all measures analyzed within this file.
ODOE Forestry Measures Quantification.xlsx	AFW	Excel	Contains all of the worksheets used to prepare the microeconomic analysis of the Forestry options, using fuel cycle CO2e emission factors. The first worksheet in this file includes a summary of all measures analyzed within this file.
ODOE Waste Measures Quantification.xlsx	AFW	Excel	Contains all of the worksheets used to prepare the microeconomic analysis of the Waste options, using fuel cycle CO2e emission factors. The first worksheet in this file includes a summary of all measures analyzed within this file.
GHG model for ODOE 7 side calcs for CCS.xlsx	AFW	Excel	File supplied by ODEQ that includes data used to develop the waste management sector GHG I&F. Data used to develop quantification of AFW-5 and AFW-10.
waste generation model for GWC.xlsx	AFW	Excel	File supplied by ODEQ that contains waste composition and management data for Oregon. Used to develop quantification for AFW-4a, AFW-4b, and AFW-10.
Cosnt and Remodel alternatives.xlsx	AFW	Excel	File supplied by ODEQ that contains analysis from the Oregon Global

File Name	Sector	Format	Description
			Warming Commission Interim 2020 Roadmap. Data used to develop baseline data and GHG reduction estimates for AFW-9.
OR LCFS Cost Curve Summaries Draft – Extended to 2050.xlsx	TLU	Excel	Contains all of the worksheets used to prepare microeconomic analyses of LCFS scenarios, as well as macroeconomic modeling inputs to REMI modeling effort. See colored tabs (green & red) for macro inputs.
Oregon TARGGET Transit and Land Use Data.xlsx	TLU	Excel	Contains full transit and land use analysis for land-use, bus transit, and rail transit scenarios. Data used to develop microeconomic impacts, GHG reduction estimates and inputs to REMI models for macroeconomic analysis.
ODOT Greenstep Scenario Outputs Summary.xlsx	TLU	Excel	Contains ODOT Greenstep Scenario Outputs.
ODOT Scenario Freight Emissions Reductions Quantities	TLU	Excel	Contains ODOT Scenario Freight Emissions Reductions Quantities
Task 2. Foundational Modeling			
ODOE REMI Inputs and Assumptions.xlsx	Macro	Excel	Contains inputs to the REMI PI+ model and mapping from Micro Analysis to the REMI PI+ model
ODOE REMI Results.xls	Macro	Excel	Contains output data in raw form and summarized for 2022 and 2035