eGSE Energy Economy Ratio Development

Port of Portland

Portland, Oregon

Final Report

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1 Background

1.1 Proposed Project/Letter of Intent

The Port of Portland (Port) has been participating in Oregon's LCFS Clean Fuels Program (CFP) for approximately three years for CNG shuttle fleet and more recently for Electric Vehicles (based on charger use). The Port has targeted the electrification of the ground support equipment (GSE) that operate at Portland International Airport (PDX) as a key opportunity to reduce greenhouse gas emissions. GSE are non-road vehicles that operate on the airfield to service aircraft. Baggage tractors, belt loaders, and aircraft tractors are GSE types that are most easily converted to electric models. In general, baggage tractors transport luggage from the airport terminal to the aircraft for loading, belt loaders transfer baggage and cargo to and from the aircraft, while aircraft tractors (also referred to as pushbacks) push the aircraft backwards away from an airport gate. The Port is planning to install electric chargers throughout PDX to promote the airlines' conversion to electric GSE (eGSE).

The intent is to use the CFP to offset the investment and operating costs for both the Port and the airlines. GSE are not currently listed in Table 7 of the CFP's rules at Oregon Administrative Rule (OAR) 340-253-8010. Therefore, in order to receive credits through the CFP, the Port must apply for the addition of EERs for GSEs through the Tier 2 Pathway application process, which requires the documentation of the carbon intensity and EERs for the eGSE.

This report provides background on the low carbon fuel standard, describes the methodology used to calculate the EERs for eGSE, and provides recommendations for the EER for the replacement of diesel and gasoline powered GSE with electric. The intent is to use this report as a supplement to the letter of intent for the Tier 2 Pathway application.

1.2 Low Carbon Fuel Standard

Clean Fuels Programs with Low Carbon Fuel Standards have been enacted in several states and provinces in North America, including California, Oregon, and British Columbia, and are in process of being established in Washington. The purpose of a Low Carbon Fuel Standard (LCFS) is to reduce the carbon intensity (i.e. lifecycle greenhouse gases emissions per unit of energy) from transportation fuels. British Columbia's Renewable and Low Carbon Fuel Requirements Act became effective in 2010, which established a compliance process for meeting carbon intensity reduction limits. California adopted a LCFS in 2011 and Oregon's program began in 2016[1]. The State of Washington announced rulemaking for a Clean Fuels Program in 2021[2] and hope to complete the rulemaking process in 2022 with the program starting in 2023. Each state and

[1] Source: https://www.oregon.gov/deq/ghgp/cfp/Pages/CFP-Overview.aspx

[2] Source: https://ecology.wa.gov/Air-Climate/Climate-change/Reducing-greenhouse-gases/Clean-Fuel-Standard

province have implemented various approaches to applying, reporting, and verifying clean fuels and vehicles that tie to a market-based credit system. Differences in the development, administration, and enforcement of the various programs are evident, including varying timelines for carbon intensity (CI) reduction targets, as presented in **Table 1-1**.

Table 1-1 Published Carbon Intensity Reduction Targets

State or Province	Timelines for Carbon Intensity Reduction Targets
British Columbia:	20% by 2030 (no baseline published)
Washington (proposed):	20% by 2038 (below 2017 levels)
California:	20% by 2030 (below 2010 levels)
Oregon:	25% by 2035 (below 2015 levels)

A Congressional Briefing was published in July 2021 that discusses the potential for Congress to consider establishment of a national LCFS,[3] including a comparison of Renewable Fuel Standard (RFS) program to LCFS programs. Implementing a nationwide LCFS will need to take into consideration factors such as connections between an LCFS program and other incentives/programs that already exist, variability in regional needs/ability to produce low carbon fuels, equity, economic and environmental impacts, and other policy administration, regulation, and compliance concerns.

1.3 Oregon Clean Fuels Program

The Oregon Clean Fuels Program (CFP) is a market-based crediting program focused on reducing the carbon intensity (CI) of transportation fuels. The program is managed by their Department of Environmental Quality (DEQ) Environmental Quality Commission (EQC) with a goal to reduce the fuel carbon intensity (CI) in the State by 10% by 2025 and 25% by 2035. The credit program for cleaner fuels exists so that fleet owners/operators can buy credits on the market, which are approximately $120 per metric ton of GHG reduction at the time this report was prepared and has historically ranged from approximately $0 to $180 per ton.

The CFP is establishing Energy Economy Ratios (EERs) for petroleum-based fuels for various sectors. According to the Oregon DEQ legislation enacting the Clean Fuels Program,[4] an EER is defined as follows:

[3] Source: https://crsreports.congress.gov/product/pdf/R/R46835
[4] Source: https://secure.sos.state.or.us/oard/displayDivisionRules.action?selectedDivision=1560

Energy Economy Ratios are a dimensionless value that represent:

a) The efficiency of a fuel as used in a powertrain as compared to a reference fuel; or
b) The efficiency of a fuel per passenger mile, for fixed guideway applications.

Table 7 of the CFP’s rules at Oregon Administrative Rule (OAR) 340-253-8010 lists the EERs currently established for vehicle and fuel type combinations in the State of Oregon. In order to include additional vehicle types within this list, an entity must submit a Tier 2 Pathway Application to Oregon DEQ.

2 Methodology Development

2.1 Established EERs

2.1.1 Oregon

As mentioned in **Section 1.3**, the State or Oregon has established EERs for several equipment and fuel type combinations. These are included in Table 7 of the CFP's rules at Oregon Administrative Rule (OAR) 340-253-8010 which details the established EERs.

2.1.2 California

In addition to Oregon, California is one of the few states who has completed the rulemaking process and has recommended EERs for various light-duty, medium-duty, and heavy-duty vehicles for both diesel and gasoline models. EERs have been calculated through one of two ways:

(a) Comparing emissions of conventional fueled equipment to electric alternatives based on the average speed of the equipment. This methodology is typical of on-road trucks and yard tractors.
(b) Comparing CO_2 emissions and fuel consumption from conventional fueled equipment to electric alternatives, which was typically done for applications where the average speed does not properly characterize performance.

Of the vehicle types with EERs published in California, the closest match to GSE is the non-yard truck cargo handling equipment (CHE).

For electric CHE, the methodology is outlined in Attachment D to the "Notice of Public Availability of Modified Text and Availability of Additional Documents and Information".[5] The calculations based on this methodology resulted in an EER of 2.7 for CHE, which is an average of several EERs for various CHE, weighted by operational hours.

2.1.3 California Airports Council

The Port of Portland was provided with a preliminary memorandum by the California Airports Council, which averaged EERs for various types of mobile and portable eGSE using operational data provided in California's OFFROAD model. After weighting the EERs based on operating

[5] Attachment D – Analysis Supporting the Addition or Revision of Energy Economy Ratio Values for the Proposed LCFS Amendments.
https://ww3.arb.ca.gov/regact/2018/lcfs18/15dayattd.pdf?_ga=2.250286214.1099124258.1593455463-757701246.1551910355

hours, CAC recommended assigning eGSE an EER of 4.2 with a gasoline baseline, and an EER of 2.9 for eGSE with a diesel baseline.

2.2 Recommended Methodology

2.2.1 Description of the Fuel-Vehicle Technology

As described above, the Port is pursuing the calculation of EERs for three commonly used GSE types: baggage tractors, belt loaders, and aircraft tractors (pushbacks). Gasoline and diesel were both calculated since these fuel types are used at various airports, including PDX.

The Tier 2 Pathway application requires at least three months of operating data that represent typical usage for each individual vehicle. However, since the Port desires to calculate representative EERs for all airports in Oregon, it is recommended that representative operational data be used in lieu of operational data specific to PDX. Therefore, operational data for the GSE included in this analysis was taken from the available default data in FAA's most recent version of the Aviation Environmental Design Tool (AEDT), version 3d. This tool is recognized by the FAA and other members of the aviation sector as the accepted means of calculating emissions from aviation sources, such as aircraft and GSE. AEDT users have the ability to enter airport specific information, or utilize default data within the tool. The default values for horsepower (HP), hours of use, and load factors (LF) were used for the GSE included in this analysis.

The operational characteristics of pushbacks change based on the type of aircraft being moved, primarily split between smaller "narrow body" aircraft and larger "wide body" aircraft. Narrow-body pushbacks are primarily used at PDX, and other airports in Oregon. Therefore, the calculations within this report are for narrow body pushbacks, which should be considered representative for pushbacks in the State.

FAA's AEDT model provides one representative baggage tractor and belt loader, and two representative narrow body pushbacks. **Attachment A** includes screenshots of AEDT's default data for these vehicles. EERs were calculated for both gasoline and diesel versions of these four equipment types.

2.2.2 Calculation of EERs

In accordance with the definition of EERs from the State of Oregon, the recommended approach is to use engine efficiency as the basis for calculating EERs for eGSE. The formula used to calculate EERs based on engine efficiency is below:

$$EER_{Fuel} = \frac{Eff_{EV}}{Eff_{Fuel}}$$

Where:

EER_{Fuel} is the energy economy ratio for the conversion of GSE of a specific fuel type (either diesel or gasoline);
Eff_{Fuel} is the calculated efficiency of the engine of a specific fuel type (either diesel or gasoline); and
Eff_{EV} is the efficiency of the engine of an eGSE. Consistent with CARB's EER calculation methods, it is assumed that no energy loss would occur during battery charging or conversion to useful work, resulting in an engine efficiency of 1 for electric vehicles.

The efficiency of diesel and gasoline engines was calculated using the following formula:

$$Eff_{GSE,Fuel} = CF \times \left(\frac{E_{fuel} \times \sum_{GSE} \sum_{HP\ Bin} Fuel\ Use}{LF_{GSE,fuel} \times \sum_{GSE} \sum_{HP\ Bin} HPhr}\right)^{-1}$$

Where:

CF is the conversion factor of 2.6845 MJ/HP-hr;
E_{Fuel} is the energy density of the base fuel type (diesel or gasoline) in MJ/gallon[6];
Fuel Use is the annual fuel consumption for fuel type for each GSE (both diesel and gasoline);
$LF_{GSE,fuel}$ is the load factor for the combination of GSE type and fuel (diesel or gasoline);
HP-hr is the annual hours of operation multiplied by the horsepower of each GSE type; and
Eff_{EV} is the efficiency of the engine of an eGSE. Consistent with CARB's EER calculation

Fuel consumption is not a default parameter within AEDT. Therefore, fuel consumption was calculated using the following formula from FAA's Air Quality Handbook:

$$Fuel\ Usage\ (gal) = Fuel\ Flow\ Rate \times\ HP_{GSE,fuel} \times Hr_{GSE,fuel} \times LF_{GSE,fuel} \times \frac{1\ lb}{453.592\ g} \times d_{fuel}$$

Where:

Fuel Flow Rate is the amount of fuel used per horsepower-hour, in grams/HP-hr;
$HP_{GSE,fuel}$ is the horsepower power for each GSE and fuel type;
$Hr_{GSE,fuel}$ is the operational hours for each GSE and fuel type combination;
$LF_{GSE,fuel}$ is the load factor for the combination of GSE type and fuel (diesel or gasoline); and
d_{fuel} is the density of each fuel type

The fuel flow rate, HP, hours of use, and LF are all provided as default data within AEDT for each GSE and fuel type combination.

[6] Energy density was taken from values listed in Table 6 of the CFP's rules at Oregon Administrative Rule (OAR) 340-253-8010

Inputs for the formulas above as well as the calculated EERs are provided in **Table 2-1** for each combination of GSE and fuel types. It should be noted that AEDT provided two different horsepower options for narrow body pushbacks, both of which are provided in **Table 2-1**.

Table 2-1 Data Inputs and EER Results

Equation Parameters	Bag Tractor		Belt Loader		Narrow Body Pushback			
Fuel Type	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
Horsepower[a]	71	107	107	71	88	88	124	124
Hours of Use[a]	1,500		1,500		1,300			
HP-hr [c]	106,500	160,500	139,100	92,300	70,400	70,400	99,200	99,200
CF (MJ/hp-hr)[d]	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
E_{fuel} (MJ/gal)[b]	122.48	134.48	122.48	134.48	122.48	134.48	122.48	134.48
Load Factor[a]	0.55	0.55	0.50	0.50	0.80	0.80	0.80	0.80
Fuel Flow Rate (g/hp-hr) [a]	219.54	166.47	219.54	185.07	219.54	185.07	219.54	166.47
Fuel Use (Gal)[c]	4,572.63	4,562.95	5,429.39	2,652.00	4,396.60	3,236.42	6,195.20	4,102.13
Efficiency [c]	0.28	0.39	0.28	0.35	0.28	0.35	0.28	0.39
EER [c]	***3.56***	***2.59***	***3.56***	***2.88***	***3.56***	***2.88***	***3.56***	***2.59***

Notes:

a. Data provided by AEDT default values

b. Energy density provided by Table 6 of the CFP's rules at Oregon Administrative Rule (OAR) 340-253-8010

c. Values calculated based on formulas discussed earlier in this section

d. Standard conversion factor

3 Recommendations

Specific EERs for each fuel type and GSE combination are summarized in **Table 3-1** below. These EERs were calculated based on fuel type and represent the most utilized GSE at airports. The two calculated EERs for narrow body pushbacks were averaged to provide a representative EER for the two horsepower types.

Table 3-1 Recommended EER by Equipment Type

Equipment Type	Recommended EER (Diesel)	Recommended EER (Gasoline)
Baggage Tractor	2.59	3.56
Belt Loader	2.88	3.56
Narrow Body Pushback	2.73	3.56

The calculated EERs do not vary significantly between vehicle type, therefore it is recommended that the three EERs for each fuel type in **Table 3-1** be averaged to provide a generic EER for all GSE. This would result in an EER of 2.73 for diesel-powered GSE, and 3.56 for gasoline-powered GSE.

According to Table 7 of (OAR) 340-253-8010, Oregon has previously published EERs for similar replacement vehicles, including electric replacements for diesel cargo handling equipment (EER of 2.7) and gasoline vehicles (EER of 3.4). However, neither of these equipment are representative of the aviation sector. Therefore, it is recommended that the State of Oregon DEQ adopt the EER for GSE associated with aircraft operations of 2.73 for diesel-powered GSE, and 3.56 for gasoline-powered GSE.

Attachment A

AEDT Default Equipment Characteristics

AEDT Default Equipment Characteristics
Baggage Tractor

Diesel - Stewart & Stevenson TUG MA 50 - Baggage Tractor

Name:	Diesel - Stewart & Stevenson TUG MA 50 - Baggage Tractor
Category:	Ground Support Equipment
Subcategory:	Diesel - Stewart & Stevenson TUG MA 50 - Baggage Tractor
Fuel type:	Diesel
Default horsepower (hp):	71
Default load factor:	0.55
Useful life (years):	13
Default usage (hours/year):	1500
CO emission factor (g/HP-Hour):	5.423707
THC emission factor (g/HP-Hour):	1.145377
NOx emission factor (g/HP-Hour):	10.76608
SOx emission factor (g/HP-Hour):	...
PM-10 emission factor (g/HP-Hour):	1.383233

Gasoline - Stewart & Stevenson TUG MA 50 - Baggage Tractor

Name:	Gasoline - Stewart & Stevenson TUG MA 50 - Baggage Tractor
Category:	Ground Support Equipment
Subcategory:	Gasoline - Stewart & Stevenson TUG MA 50 - Baggage Tractor
Fuel type:	Gasoline
Default horsepower (hp):	107
Default load factor:	0.55
Useful life (years):	13
Default usage (hours/year):	1500
CO emission factor (g/HP-Hour):	178.943591
THC emission factor (g/HP-Hour):	5.947357
NOx emission factor (g/HP-Hour):	10.119165
SOx emission factor (g/HP-Hour):	...
PM-10 emission factor (g/HP-Hour):	0.068169

AEDT Default Equipment Characteristics

Belt Loader

Diesel - Stewart & Stevenson TUG 660 - Belt Loader

Name:	Diesel - Stewart & Stevenson TUG 660 - Belt Loader
Category:	Ground Support Equipment
Subcategory:	Diesel - Stewart & Stevenson TUG 660 - Belt Loader
Fuel type:	Diesel
Default horsepower (hp):	71
Default load factor:	0.5
Useful life (years):	11
Default usage (hours/year):	1300
CO emission factor (g/HP-Hour):	3.514467
THC emission factor (g/HP-Hour):	1.102756
NOx emission factor (g/HP-Hour):	11.647685
SOx emission factor (g/HP-Hour):	...
PM-10 emission factor (g/HP-Hour):	1.125455

Gasoline - Stewart & Stevenson TUG 660 - Belt Loader

Name:	Gasoline - Stewart & Stevenson TUG 660 - Belt Loader
Category:	Ground Support Equipment
Subcategory:	Gasoline - Stewart & Stevenson TUG 660 - Belt Loader
Fuel type:	Gasoline
Default horsepower (hp):	107
Default load factor:	0.5
Useful life (years):	11
Default usage (hours/year):	1300
CO emission factor (g/HP-Hour):	124.831932
THC emission factor (g/HP-Hour):	4.611003
NOx emission factor (g/HP-Hour):	10.130791
SOx emission factor (g/HP-Hour):	...
PM-10 emission factor (g/HP-Hour):	0.068776

AEDT Default Equipment Characteristics

Narrow Body Aircraft Tractor – 88 HP

"Diesel - Stewart & Stevenson TUG GT-35, Douglas TBL-180 - Aircraft Tractor"

Name:	"Diesel - Stewart & Stevenson TUG GT-35, Douglas TBL-180 - Aircraft Tractor"
Category:	Ground Support Equipment
Subcategory:	"Diesel - Stewart & Stevenson TUG GT-35, Douglas TBL-180 - Aircraft Tractor"
Fuel type:	Diesel
Default horsepower (hp):	88
Default load factor:	0.8
Useful life (years):	14
Default usage (hours/year):	800
CO emission factor (g/HP-Hour):	4.950583
THC emission factor (g/HP-Hour):	1.069282
NOx emission factor (g/HP-Hour):	11.938534
SOx emission factor (g/HP-Hour):	...
PM-10 emission factor (g/HP-Hour):	1.289938

"Gasoline - Stewart & Stevenson TUG GT-35, Douglas TBL-180 - Aircraft Tractor"

Name:	"Gasoline - Stewart & Stevenson TUG GT-35, Douglas TBL-180 - Aircraft Tractor
Category:	Ground Support Equipment
Subcategory:	"Gasoline - Stewart & Stevenson TUG GT-35, Douglas TBL-180 - Aircraft Tractor"
Fuel type:	Gasoline
Default horsepower (hp):	88
Default load factor:	0.8
Useful life (years):	14
Default usage (hours/year):	800
CO emission factor (g/HP-Hour):	177.973675
THC emission factor (g/HP-Hour):	5.922417
NOx emission factor (g/HP-Hour):	10.113689
SOx emission factor (g/HP-Hour):	...
PM-10 emission factor (g/HP-Hour):	0.067883

AEDT Default Equipment Characteristics

Narrow Body Aircraft Tractor – 124 HP

"Diesel - Stewart & Stevenson TUG GT-35, MC - Aircraft Tractor"

Name:	"Diesel - Stewart & Stevenson TUG GT-35, MC - Aircraft Tractor"
Category:	Ground Support Equipment
Subcategory:	"Diesel - Stewart & Stevenson TUG GT-35, MC - Aircraft Tractor"
Fuel type:	Diesel
Default horsepower (hp):	124
Default load factor:	0.8
Useful life (years):	14
Default usage (hours/year):	800
CO emission factor (g/HP-Hour):	4.950583
THC emission factor (g/HP-Hour):	1.069282
NOx emission factor (g/HP-Hour):	11.938534
SOx emission factor (g/HP-Hour):	...
PM-10 emission factor (g/HP-Hour):	1.289938

"Gasoline - Stewart & Stevenson TUG GT-35, MC - Aircraft Tractor"

Name:	"Gasoline - Stewart & Stevenson TUG GT-35, MC - Aircraft Tractor"
Category:	Ground Support Equipment
Subcategory:	"Gasoline - Stewart & Stevenson TUG GT-35, MC - Aircraft Tractor"
Fuel type:	Gasoline
Default horsepower (hp):	124
Default load factor:	0.8
Useful life (years):	14
Default usage (hours/year):	800
CO emission factor (g/HP-Hour):	177.973675
THC emission factor (g/HP-Hour):	5.922417
NOx emission factor (g/HP-Hour):	10.113689
SOx emission factor (g/HP-Hour):	...
PM-10 emission factor (g/HP-Hour):	0.067883