Well to Plug GHG Emissions for Electric Power Generation – Washington Electricity Mix

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Prepared by:
Stefan Unnasch
Love Goyal

Life Cycle Associates

DISCLAIMER

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Contact information:

Stefan Unnasch
Life Cycle Associates, LLC
1.650.461.9048
unnasch@LifeCycleAssociates.com
www.LifeCycleAssociates.com

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Terms and Abbreviations

ANL	Argonne National Laboratory
Btu	British thermal unit
CA	California
CARB	California Air Resources Board
CCCT	Combined cycle combustion turbine
CI	Carbon Intensity
CHP	Combined Heat and Power
EPA	Environmental Protection Agency
GHG	Greenhouse gas
GREET	Greenhouse gas, Regulated Emissions and Energy Use in Transportation (Argonne National Laboratory's well-to-wheels model)
GWP	Global warming potential
ICE	Internal combustion engine
IPCC	Intergovernmental Panel on Climate Change
J	Joule
LCA	Life cycle assessment
LCFS	Low Carbon Fuel Standard
LCI	Life cycle inventory
LHV	Lower heating value
MDT	Million dry tons
MJ	Mega Joule
mmBtu	Million Btu
NG	Natural gas
NREL	National Renewable Energy Laboratory
RBOB	Reformulated gasoline blendstock for oxygen blending
RFG	Reformulated gasoline
SCCT	Simple cycle combustion turbine
TTW	Tank-to-wheels
ULSD	Ultra low sulfur diesel
U.S.	United States
WA	Washington
WA CFS	Washington Clean Fuel Standard
WTT	Well-to-tank
WTW	Well-to-wheels

1. Electric Power Pathway in WA-GREET

Feedstock:	Natural Gas, Coal, Biomass, Biogas, Nuclear, Wind, Solar, Hydro
Products:	Electricity
Reference Documentation:	ARB 2009, ANL

Electricity is an intermediate source of energy used for fuel production and EV charging. Electricity is produced from a number of primary energy sources and via a number of different power generation technologies. Power generation in GREET is modeled based on the mix of natural gas, coal fuel oil, nuclear, biomass, and renewable resources. The Washington Clean Fuels Program (CFP) assigns electricity mix based on the average resource mix in each eGRID region shown in Figure 1.1.

Life cycle GHG emissions are based on the generation resource mix for each region. Direct emissions from power plants are based on estimated power plant types in each region. Upstream life cycle GHG emissions correspond to the specific resource extraction and processing as modeled in the GREET model for all fuel cycle pathways.

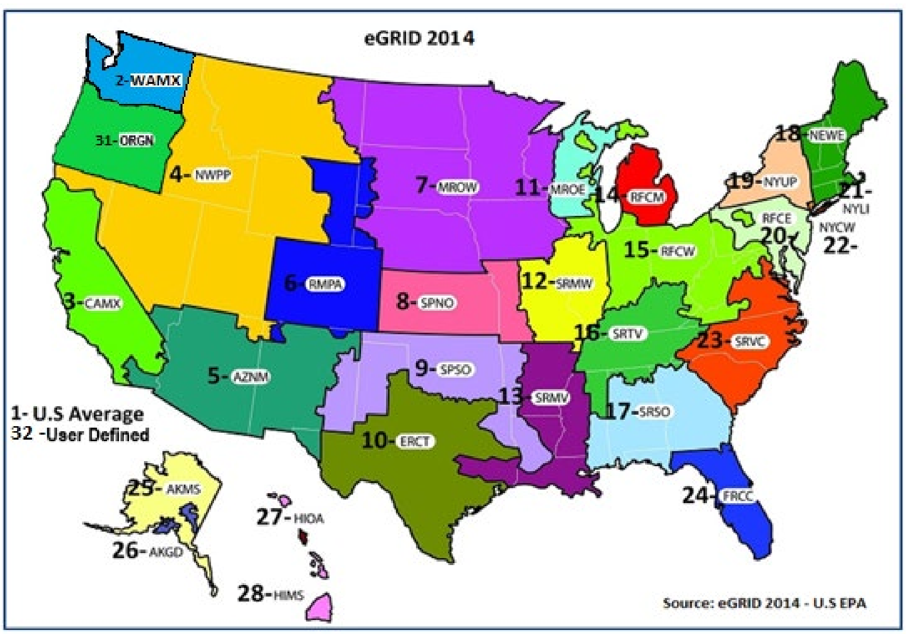

Figure 1.1. Electricity production regions in WA-GREET model

The U.S. Average Mix as well as eGRID values correspond to the power generation resource mix for the Megawatt-hours (MWh) generated in each region. Washington state average mix is developed based on the % contribution of various fuel types in total state electricity production over a given year, as reported under the annual Washington fuel mix disclosure reporting process.

In fuel cycle modeling, electricity is an intermediate fuel used in the recovery, processing, and production of other transportation fuels. Electricity is also a transportation fuel. Since electric vehicles do not emit any pollutants, fuel cycle emissions consist only of WTT emissions. When transmission losses included the emission are referred to as well to plug basis. The WTT emissions result from direct fuel combustion at the power plant and from upstream activities to recover, process, and transport fuels to the power plant. The system boundary for the electricity pathway, shown in Figure 1.2, includes the upstream activities of each fuel used to generate electricity, direct combustion of these fuels at the power plant, and losses through the transmission and distribution system. The following sections describe electricity generating resources and the WA-GREET electricity pathways. As is the case for other fuel pathways, the analysis framework excludes materials of construction for power plants and feedstock production equipment.

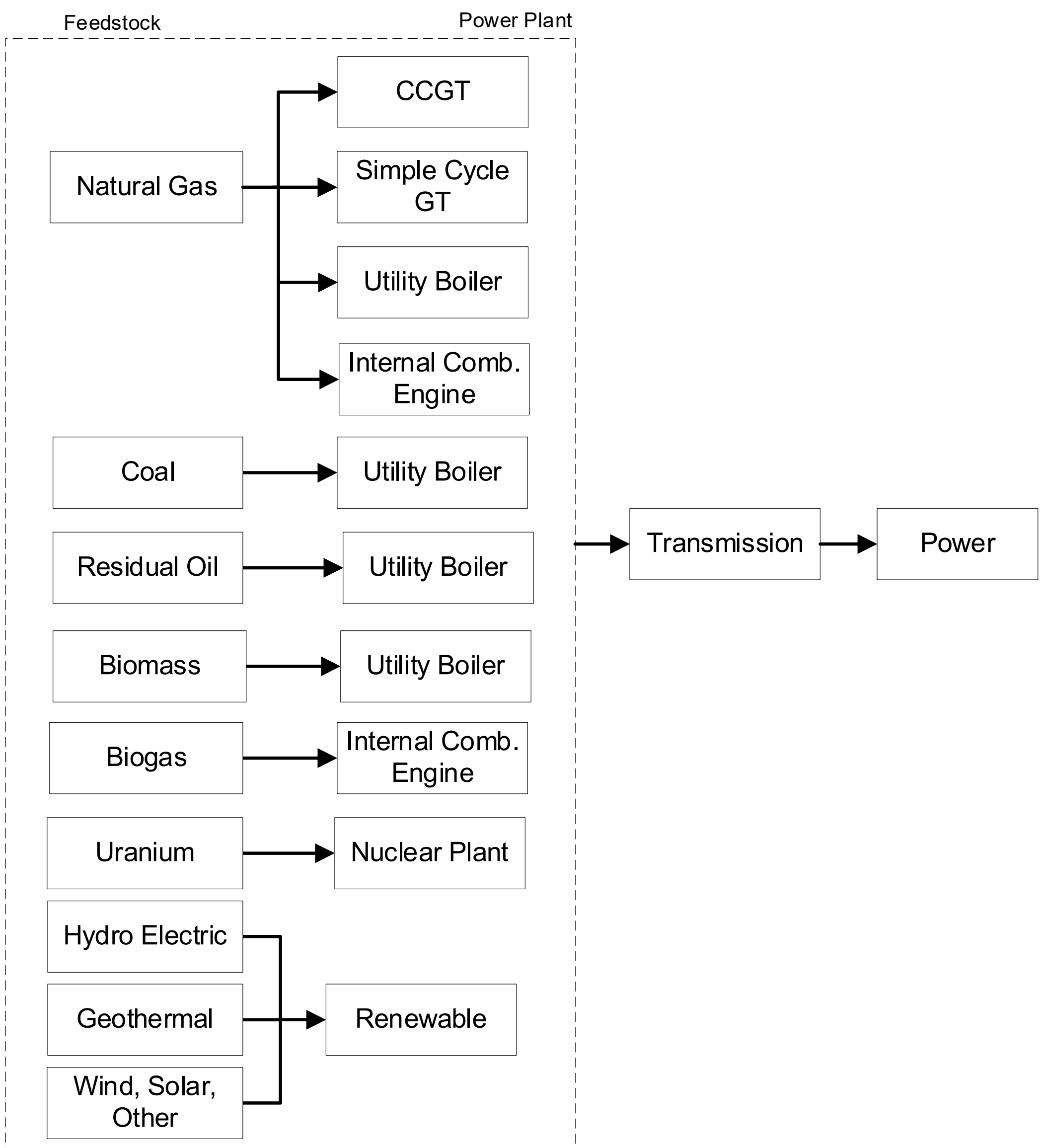

Figure 1.2. Electricity Production System Boundary Diagram

1.1 Sources of Electric Power

Emissions from electric power generation depend on the upstream feedstock as well as power generation emissions. Factors affection upstream emissions for each of the fuels described below are treated as default parameters in the WA-GREET model. A description of the power generation options in GREET follows.

Natural Gas to Electric Power

Natural gas provides a fuel for boiler/steam generators, simple cycle combustion turbines (SCCTs), combined cycle combustion turbines (CCCTs), and internal combustion engine (ICE) generation systems. In a steam generator, natural gas is burned in a furnace to raise steam which generates electricity as it passes through a steam turbine. In a simple cycle gas turbine, natural gas is burned in a combustor and then the hot combustion gases generate electricity as they flow through a gas turbine. A combined cycle plant is a combination of a simple cycle turbine and a steam generator. In a CCCT, the hot gases exiting the gas turbine are used to generate steam which then runs through a steam turbine to generate additional electricity. CCCTs are significantly more efficient than steam generators which are typically more efficient than simple cycle turbines.

Most new large capacity natural gas fired plants installed in the past few decades have been and will continue to be CCCTs because of their superior efficiency and lower cost. Historically, natural gas steam generators were base loaded facilities. However, with the advent of CCCTs over the past several decades, steam generators have been relegated to an intermediate cycling role, with SCCTs used as peaking units on hot summer afternoons. Natural gas-fired ICEs are also a generation resource, and are often used in combined heat at power (CHP) applications.

Coal to Electric Power

Despite strong head winds in the form of an aging fleet, increasingly stringent environmental regulations, and abundant new sources of domestic natural gas, coal is still used in much of the U.S. to generate electricity. Coal has traditionally been used in utility boiler/steam generators. A newer approach is to gasify the coal and then use the syngas in a combined cycle combustion turbine, or integrated gasification combined cycle (IGCC). IGCC is significantly more efficient than a steam generator and has lower emission rates though the adoption rate has not been significant due to competition from natural gas and other generation resources.

Fuel Oil to Electric Power

Once commonly used in utility boilers, residual oil is now only used in times of natural gas curtailment in Washington. Diesel oil is also used emergency generators and some combustion turbines, but again, this is generally only allowed in times of natural gas curtailment.

Nuclear Fuel to Electric Power

Nuclear power does not generate any power plant emissions, but does have upstream emissions associated with uranium mining, processing and transport. There are two main types of nuclear reactors in the U.S.: light water reactors and high temperature gas cooled reactors. All of the nuclear plants in the western United States are of the light water reactor design. The life cycle includes uranium mining, separation to fissile isotope, and processing.

Biogas to Electric Power

On-site power generation from landfills is a primary source of biogas-based power. Landfill gas (LFG) occurs from the decomposition of organic materials in landfills. The gas consists of a mixture of methane and CO_2. Absent the conversion of LFG to electric power, the gas would be flared. Internal combustion engines are the primary power generation equipment. GREET includes landfill gas pathways for fuel production but does not explicitly model biogas. Biogas power generation was added to the WA-GREET model.

Biomass to Electric Power

Biomass, such as farmed trees, perennial plants, or forest residue has long been used to generate electricity. Biomass is typically combusted boiler for steam production and power generation in a steam turbine. Boiler combustion methods range from stoker grates to fluidized beds. Biomass gasification is also an option for power generation, through the technology has not achieved widespread adoption. The direct carbon emissions from biomass are biogenic with upstream emissions associated with growing, harvesting and transporting the feedstock. Under the GREET model framework, the CO_2 emissions for power production are treated as carbon neutral since the carbon was recently removed from the atmosphere or in the case of forest residue and waste material it would decompose or be combusted as part of forest management operations.

Renewables to Electric Power

Resources that do not have any fuel cycle emissions (neither direct nor upstream) associated with them, including hydroelectricity, solar, wind, and geothermal. Under the WA-GREET framework, the renewable source derived electricity is considered to have zero CI.

Materials of Construction

Emissions associated with materials of construction are excludes from all of the fuel pathways analyzed in WA-GREET.

2. Fuel Pathway Calculations

This section describes the overall life cycle calculations for electric power pathway in WA-GREET. Examples are provided for the Washington average mix unless stated. The WA-GREET as well as an external calculator also calculate regional, and utility average CI values as described in Section 2.3.

The following describes the WTT calculations and factors that affect the carbon intensity for electric power. Upstream fuel cycle emissions are internally calculated in GREET. Some of the finished fuels, such as natural gas, diesel, and electric power are also inputs to other fuel production processes. This approach results in a recursive calculation within GREET to model the fuels used to make other fuels in turn used to make all the fuels in general.

2.1 Electric Power

Fuel cycle emissions from electric power include emissions at the power plant and the upstream emissions to produce feedstocks. WA-GREET calculates the WTT LCI data for electricity use in fuel production processes. The electricity sub-module calculates the fuel cycle emissions for electric power generation from a variety of generation resources. The following sections describe the general calculation methodology.

2.1.1 Calculation Method

For electricity pathways, all of the emissions occur in the fuel cycle and no emissions occur during vehicle operations[i]. The WTT emissions comprise the entire fuel life cycle. To estimate WTT emissions for electricity production, the typical GREET methodology is employed according to the following equation:

$$E_{Electricity,WTT} = \left(\sum_{i=1}^{n} \sum_{k=1}^{m} (F_i \times S_{i,k} \times (E_{Feed} + E_{Fuel})_{i,k}) \right) \div (1 - LF_{T\&D})$$

where,

$E_{Electricity}$ = GREET WTT result for upstream fuel cycle for electricity, a data array of life cycle greenhouse gas and criteria pollutant emissions for the electricity pathway per unit transportation fuel

E_{Feed} = data array of upstream emissions for the power plant fuel (for example, the emissions associated with natural gas recovery, processing and transport to the power plant per unit natural gas)

[i] Other emissions such as changes in brake wear and ozone from motors may be attributed to EVs, but are not discussed here. TTW emissions are treated as zero in this discussion.

E_{Fuel} = data array of direct emissions from the power plant (for example, the emissions associated with burning natural gas in a combined cycle combustion turbine per unit natural gas)

F_i = Fuel shares of generation mix

$S_{i,k}$ = Specific energy of i fuel type consumed by k power plant type per unit of fuel produced such that S = F_i × Technology share, k/η_k where η is the generation efficiency for each technology type (for example, the amount of natural gas burned in a utility boiler per unit of electricity produced)

i = different resources used to produce electricity (for example, natural gas, coal, oil, biomass, wind, etc.)

k = different types of combustion equipment used to generate power from a given fuel (for example boiler, combined cycle turbine, simple cycle turbine)

$LF_{T\&D}$ = Loss factor due to electrical losses along transmission and distribution lines

In general, the amount of each fuel type used in each different combustion device to produce a unit of electricity is an input ($S_{i,k}$). The WTT result is based on the weighted average for each fuel resource. The S is multiplied by the upstream and direct emissions per unit of fuel consumed. The resulting emissions from each fuel type and combustion device per unit of electricity produced are summed and then adjusted for transmission and distribution losses. The following sections describe in detail how the emissions are calculated, using the current WA CFP using Washington state average mix case as an example.

2.1.2 WTT Calculation

Fuel resource mix for the 2018 Washington average case is shown in Table 2.1 and compared to the U.S. Average mix. The Washington average fuel mix is an estimate of the share of each fuel consumed in Washington in 2018. The fuel mix was determined by allocating the fuel types as reported under the Washington fuel mix disclosure report to the fuel types compatible with the GREET model framework.

Table 2.1. Resource Mix for LCFS Washington Average Case

	Fuel Share (F_i)	
Resource Type	**Washington**	**U.S. Average**
Residual Oil	0.10%	1.2%
Natural Gas	20.26%	27.6%
Coal	10.22%	38.7%
Nuclear	4.75%	19.5%
Biomass	0.45%	0.45%
Biogas	0.2%	In Biomass
Non-combustion Renewables	64.03%	11.4%

Following the default assumptions for the WECC region in CA-GREET3.0, the residual consumption is distributed among utility boiler, internal combustion engine, and gas turbine. All of the coal and biomass are burned in utility boilers. The natural gas is distributed among boilers, combined cycle combustion turbines (CCCT), simple cycle combustion turbines (SCCT), and internal combustion engine. All of the nuclear power is assumed to come from light water reactors. The combustion technology shares for each fuel type and the associated energy efficiency are provided in Table 2.2. The technology shares for all technologies are directly based on CA-GREET3.0 and is specific to a given region as classified under the North American Electric Reliability Corporation (NERC) classification. Washington state electricity mix CI calculation uses the WECC region technology shares as this region incorporates the Washington.

Table 2.2. Combustion Technology Shares and Energy Efficiencies

Resource Type	**Fuel Share, F_i**	**Technology Share**	**Energy Efficiency**	**Energy Consumption (Btu/mmBtu)**	**WAMX Specific Energy, $S_{i,k}$ (Btu/mmBtu)**
Residual Oil-Fired Power Plants	0.10%		33.65%		
Boiler		72.4%	33.90%	2,949,853	2,156
Internal Combustion Engine		15.5%	39.00%	2,564,103	401
Gas Turbine		12.1%	27.60%	3,623,188	442
Natural Gas-Fired Power Plants	20.26%		48.12%		
Boiler		6.4%	32.00%	3,125,000	40,529
Simple-cycle gas turbine		3.3%	32.80%	3,048,780	20,388
Combined-cycle gas turbine		89.2%	51.10%	1,956,947	357,732
Internal Combustion Engine		1.1%	34.40%	2,906,977	6,480
Coal-Fired Power Plants	10.22%		34.70%		
Boiler		100.0%	34.70%	2,881,844	294,388
IGCC		0.0%	40.00%	2,500,000	0
Biomass Power Plants	0.45%		22.60%		
Boiler		100.0%	22.60%	4,424,779	19,770
IGCC		0.0%	40.00%	2,500,000	0
Biogas Power Plants	0.20%				
Internal Combustion Engine		100%	34.4%	2,906,977	5,745
Nuclear Power Plants	4.75%		100.0%	1,000,000	47,478
Other Power Plants (hydro, wind, geothermal, etc.)	64.03%		100.0%	1,000,000	640,274
Hydroelectric		92.4%			
Geothermal		0.0%			
Wind		7.2%			
Solar PV		0.4%			
Others (Biogenic Waste, Pumped Storage, etc.)		0.0%			

Energy Consumption is the inverse of energy efficiency, multiplied by 1,000,000.
WA average specific energy is the Energy Consumption multiplied by the fuel shares in the previous table for the 2018 Washington Average mix case

$S_{NG,\ Boiler} = F_i \times \text{Tech Share}_{Boiler} / \eta_{Boiler} = 1{,}000{,}000 \times 20.264\% \times 6.4\%/33.0\% = 40{,}529$

Before emissions can be estimated, the specific energy consumption for each fuel type must be determined. As mentioned above, specific energy is the amount of each type of fuel consumed per unit of electricity produced (Btu/mmBtu electricity) for each combustion device. The fuel resource mix, combined with efficiency of each generation device provides the basis to calculate the specific energy. The calculated average fuel use for each resource is then combined with the corresponding upstream factor associated with the resource extraction process modeled by other modules of the GREET model to calculate the total upstream emissions.

For each resource, the emissions from combustion for each given technology is combined with the corresponding technology share to calculate the emissions from electricity generation. Electricity generation emissions from all the resources are then combined with resource mix shares and added together to get the total electricity generation emissions from all the resources combined.

The upstream and the combustion emissions together represent the total emissions produced from the resource extraction as well as the combustion during the electricity generation at the outlet of the power plant.

2.1.3 Biogas Power

Biogas as a fuel type to produce electric power is not modeled in GREET1_2016. For the purposes of Washington CFS, this has been specially added in the WA-GREET framework. Following the consultation with Washington Department of Ecology, the public review process and the peer review process, and after input from Washington Department of Commerce, it was deemed necessary to represent the power generation in Washington from landfill gas as its own fuel type.

To that end, a new fuel type for electricity generation was added to WA-GREET specifically for the WA state grid mix CI calculation. Biogas was chosen as the most appropriate fuel type to represent the landfill gas used in the state to generate power.

The biogas to power pathway added to WA-GREET was considered to be carbon neutral for the CI calculation purpose. This was achieved by considering RNG flaring as the alternative fate of the biogas used to make power. This implied that the fully oxidized form of the carbon emissions in from RNG flaring were subtracted from the biogas combustion emissions in a stationary reciprocating engine.

This carbon neutral approach implies that CH_4 and N_2O emissions from biogas combustion were the primary form of GHG emissions from the biogas to power pathway, prior to the power conversion efficiency and transmission losses. This calculation approach however resulted in the net emissions from biogas to power showing up only in the power generation phase of the lifecycle.

Power conversion efficiency and technology shares for natural gas to power were also used for the biogas to power conversion efficiency and technology mix.

2.1.4 Transmission Losses

GREET WTT results include transmission losses. The total emissions from power generation including the upstream resource extraction are adjusted to include the losses during electricity transmission.

The loss factor is defined such that:

$$\text{Power at wall} = \text{Power at plant} \times (1 - LF_{T\&D})$$

Based on CA-GREET3.0, WA-GREET uses a transmission loss factor of 6.5%. After such adjustment, the final value represents the lifecycle emissions from the electricity at the wall outlet or consumption location.

2.2 Upstream and Direct Emission Data

Both the upstream and direct emission factors for power production pathway are based on the values in the WA-GREET model. Upstream emissions are referred to as well-to-tank or WTT emissions, and direct emissions or power plant emissions are referred to as tank-to-wheel or TTW emissions. The following sections describe the specific approach and data used to model both these phases for power production in WA-GREET, and how these data are affected by certain regional parameters in the GREET model.

2.2.1 WTT Emission Factors

Upstream life cycle data are calculated the GREET model using the procedure identified in Section 2.1.1 for each of the power generation resources. WTT emissions are based on the GREET model approach and corresponding fuel's upstream emissions as modelled within WA-GREET. The upstream life cycle approach is further discussed in detail in the original GREET documentation (Wang, 1999).

Table 2.3. WTT Emission Factors for Process Fuels

Upstream CI for Electricity Resources g/MMBtu of resource	Residual Oil	NG	Coal	Biomass	Nuclear	Other renewable energy sources
VOC	5.76	10.35	7.53	1.03	0.95	0
CO	12.25	32.21	3.04	4.31	3.95	0
CH_4	162.14	260.47	149.17	4.76	6.48	0
N_2O	0.21	1.43	0.04	0.03	0.05	0
CO_2	10,686	6,792	1,731	2,104	2,393	0
CO_2e	14,839	13,811	5,499	2,241	2,578	0

2.2.2 Power Plant Emissions

Power plant emissions depend on the efficiency for each fuel generation resource in combination with the emission factor for each fuel type. The emission factors on the EF sheet in GREET. The emission factors represent the combusted fuel based on its fuel properties. GREET calculates VOC and CO emissions as fully oxidized with the same GWP as CO_2 per g of carbon. Power plant emission factors for each fuel type also depend on the technology type which affects methane and N_2O emissions. Biomass and biogas are treated as biogenic carbon neutral.

Table 2.4. Power Plant Emissions on Electric sheet in GREET

Pollutant	User-Inputted Emission Factors (Default Data Here Are Emission Factors for EPA Database [g/kWh])						
	By Fuel-Type Plants						
	Oil Boiler	NG Boiler	NG SCCT	NG CCCT	NG ICE	Coal Boiler	Forest Residue Biomass Boiler
VOC	0.020	0.030	0.011	0.002	1.071	0.009	0.134
CO	0.158	0.458	0.414	0.090	3.684	0.056	4.733
CH_4	0.031	0.011	0.011	0.007	0.011	0.010	0.491
N_2O	0.006	0.001	0.001	0.001	0.001	0.015	0.065
CO_2	829	595	596	368	587	948	1,492
CO_2c							-1,501

2.2.3 Regional Parameters

WTT and power plant emissions are affected by the regional selection of power generation resources. WTT emissions for each fuel depend on the fuel cycle for a variety of fuels. WA-GREET allows for the separate calculation of feedstock and fuel phase GHG emissions.

Table 2.5. Regionalization in WA-GREET

Scenario Year	Feed	Fuel	Products
<u>2017 Baseline</u>			
2017	US	WA[a]	WA Gasoline, WA Diesel, WA Jet
2017	US	NWPP	UT Gasoline, UT Diesel
2017	US	NWPP	MT Gasoline, MT Diesel
2017	US	US	Corn Ethanol, Soy Biodiesel
<u>Look Up Table Pathways</u>			
2018	US	WA	WA, Utility Average Electricity, Hydrogen (SMR), Hydrogen (electrolytic), CNG, LNG
2018	US	US	LPG
<u>Upstream Data for Fuel Pathways</u>			
2018	US	WA	Corn, soybean oil, canola oil

[a]WA Fuel Mix corresponds the the WECC efficiency assumptions in GREET

2.3 Washington Specific Electricity Data

For the purposes of the Washington Clean Fuels Standards (CFS), the carbon intensity for electric power generated in Washington was modeled in the WA-GREET model. The Washington Department of Commerce regularly collects information and data from all electricity generators in the state to quantify the amount of electric power generated from various fuel sources. This data is published annually by the Washington Department of Commerce in the form of two specific disclosure reports[ii].

- Fuel Mix Aggregate Time Series
- [Utility Fuel mix] Disclosure Data report

The Fuel Mix Aggregate Time series is a spreadsheet that includes the MWh of power generated in the entire state by each fuel type in a yearly time-series form. The Disclosure Data report was retrieved directly in a spreadsheet format by Washington Department of Commerce, but contains the same data as the publicly-available PDF format report. This yearly report includes the MWh of power generated/purchased by each utility in the state in a given year broken down by each fuel type.

[ii] WA Fuel Mix Disclosure Data (https://www.commerce.wa.gov/growing-the-economy/energy/fuel-mix-disclosure/)

	A	B	C	D	E	F	G	H	I	J
1	**Electricity Consumption by Fuel Source**			**Updated Dec 2019**						
2	Washington State Aggregate Fuel Mix 2000-2018									
3	Megawatt Hours									
4										
5	**Fuel Source**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
6	**Landfill Gas**	68,978	70,807	220,705	75,125	134,122	80,500	57,858	49,041	23,043
7	**Other**	-	-	233,995	6,991	37,379	31,156	10,863	12,923	19,391
8	**Solar**	-	-	-	-	-	-	-	-	-
9	**Geothermal**	143,024	158,779	-	-	-	-	14,399	11,189	16,866
10	**Waste**	159,888	236,666	23,471	139,056	102,864	150,955	331,963	288,528	276,669
11	**Petroleum**	401,383	489,650	22,244	34,957	53,046	44,233	62,232	69,267	69,937
12	**Other Biogeni**	-	-	-	-	-	-	-	-	-
13	**Other Non-Bio**	-	-	-	-	-	-	-	-	-
14	**Biogas**	-	-	-	-	-	-	-	-	-
15	**Biomass**	1,100,469	937,515	392,378	434,700	536,643	587,085	392,712	460,983	415,226
16	**Wind**	-	23,822	163,134	320,540	346,470	432,667	867,392	545,622	1,010,928
17	**Nuclear**	4,285,939	3,975,371	3,858,716	3,726,175	4,591,072	4,403,537	4,513,216	4,326,265	5,083,665
18	**Natural Gas**	10,771,994	11,863,293	6,606,079	7,961,221	7,379,356	7,986,135	7,319,961	8,459,744	9,021,054
19	**Coal**	16,243,438	13,247,976	10,076,412	14,336,264	14,459,001	14,860,017	14,245,188	14,866,637	15,034,912
20	**Hydropower**	67,889,834	45,853,455	56,339,641	53,850,478	54,132,176	55,342,273	59,609,529	59,203,647	58,235,550
21	**Unspecified**									
22	**Total**	**101,064,948**	**76,857,334**	**77,936,775**	**80,885,507**	**81,772,129**	**83,918,558**	**87,425,313**	**88,293,846**	**89,207,239**
23	**Check**	**101,064,948**	**76,857,334**	**77,936,775**	**80,885,507**	**81,772,129**	**83,918,558**	**87,425,313**	**88,293,846**	**89,207,239**

Figure 2.1. Screenshot of the Fuel Mix Aggregate Time Series 2019 (CY2018) report

The above Figure 2.1 shows the screenshot of the "publish to web" sheet of the so far latest available state aggregate fuel mix report. The screenshot illustrates how the annual power generation is categorized into various fuel sources. Similarly, a screenshot of the "Report Extract" sheet of the latest available utility fuel mix disclosure report is present below in the Figure 2.2.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Report Year**	**Customer Served State**	**Claimant ID**	**Claimant Name**	**Fuel Type Category Name**	**BPA Unspecified Purchases MWh**	**BPA Claims on Plants MWh**	**Total BPA MWh**	**Adjusted WA PacifiCorp**	**Unspecified Purchases MWh**	**Plant Claims MWh**	**Total Unspecified Purchases MWh**	**Total Claims on Plants (Specified) MWh**	**Total MWh**
2	2020	WA	1	Alder Mutual Light	Biogas	0	0	0	0	0	0	0	0	0
3	2020	WA	1	Alder Mutual Light	Biomass	2	0	2	0	0	0	2	0	2
4	2020	WA	1	Alder Mutual Light	Coal	76	0	76	0	0	0	76	0	76
5	2020	WA	1	Alder Mutual Light	Geothermal	0	0	0	0	0	0	0	0	0
6	2020	WA	1	Alder Mutual Light	Hydro	97	4,616	4,713	0	0	0	97	4,616	4,714
7	2020	WA	1	Alder Mutual Light	Natural Gas	55	0	55	0	0	0	55	0	55
8	2020	WA	1	Alder Mutual Light	Nuclear	6	595	601	0	0	0	6	595	602
9	2020	WA	1	Alder Mutual Light	Other Biogenic	0	0	0	0	0	0	0	0	0
10	2020	WA	1	Alder Mutual Light	Other Non-Biogenic	2	0	2	0	0	0	2	0	2
11	2020	WA	1	Alder Mutual Light	Petroleum	1	0	1	0	0	0	1	0	1
12	2020	WA	1	Alder Mutual Light	Solar	0	0	0	0	0	0	0	0	0
13	2020	WA	1	Alder Mutual Light	Unknown	0	0	0	0	0	0	0	0	0
14	2020	WA	1	Alder Mutual Light	Waste	0	0	0	0	0	0	0	0	0
15	2020	WA	1	Alder Mutual Light	Wind	0	0	0	0	0	0	0	0	0
16	2020	WA	4	Benton County PUD #1	Biogas	0	0	0	0	0	0	0	0	0
17	2020	WA	4	Benton County PUD #1	Biomass	699	0	699	0	0	0	699	0	699
18	2020	WA	4	Benton County PUD #1	Coal	22,887	0	22,887	0	0	0	22,887	0	22,887
19	2020	WA	4	Benton County PUD #1	Geothermal	0	0	0	0	0	0	0	0	0
20	2020	WA	4	Benton County PUD #1	Hydro	29,257	1,389,416	1,418,673	0	0	13,769	29,257	1,403,185	1,432,442
21	2020	WA	4	Benton County PUD #1	Natural Gas	16,473	0	16,473	0	0	0	16,473	0	16,473
22	2020	WA	4	Benton County PUD #1	Nuclear	1,874	179,185	181,059	0	0	0	1,874	179,185	181,058

Figure 2.2. Screenshot of the 2020 Utility Fuel mix disclosure report

Both reports include the breakdown of the fuel sources used in the state to generate electric power. It should be noted that the list of fuel sources varies slightly between the two reports, which is a result of the data collection and compilation process employed by the Washington Department of Commerce to develop these two disclosure reports.

To be able to model and calculate the carbon intensity of WA state aggregate or a given utility power in WA-GREET, the first step is to re-map the fuel source types as present in the state aggregate/utility fuel mix disclosure data to fuel source types included in WA-GREET. This mapping, combined with the raw disclosure data forms the basis of calculating the grid mix for a given year before it is plugged into the WA-GREET model. Additionally, as this fuel mix disclosure data is available on a yearly basis, it may be required to be updated periodically for various purposes under the WA CFS.

2.3.1 Washington Average Electricity Pathway

The WA-GREET model has one additional electricity pathway in comparison to CA-GREET3: Washington Average mix. It is used as an intermediate fuel in the production of other transportation fuels. The Washington Average pathway is used to estimate energy and emissions from electricity used for biofuel production. Table 2.7 provides a summary of the 2017 and 2018 Washington state average electricity mix. The mix is based on the annual Washington aggregated fuel mix disclosure report.

As mentioned in the previous section, the GREET compatible grid mix is developed by remapping the fuel sources present in the state aggregated fuel mix disclosure report to GREET compatible fuel sources. This re-mapping for 2017 and 2018 is performed in a new sheet, called "WA-GREET," that was added to the aggregate time series spreadsheet specified previously. This new sheet uses the mapping table presented below in Table 2.6 to re-map the fuel sources in disclosure report to allow the calculation of GREET compatible grid mix.

Table 2.6. Fuel Source mapping table for the WA state aggregate fuel mix disclosure report

WA Fuel Mix Disclosure	GREET Categories									
	Residual oil	Natural gas	Coal	Nuclear power	Biomass	Biogas	Hydro electric	Geoth ermal	Wind	Solar PV
Hydropower							x			
Coal			x							
Cogeneration		x								
Natural Gas		x								
Nuclear				x						
Biomass					x					
Petroleum	x									
Waste	x									
Geothermal								x		
Landfill Gas						x				
Wind									x	
Other	x									
Solar										x
Unspecified		x								

The following Table 2.7 present the grid mix for 2017 and 2018 as calculated directly from the disclosure report and after re-mapping to WA-GREET compatible fuel sources.

Table 2.7. Washington Average Resource Mixes

Fuel Type	2017 WA Disclosure	2017 WAMX Mix	2018 WA Disclosure	2018 WAMX Mix
Residual oil	0.11%	0.33%	0.02%	0.10%
Other	0.18%	-	0.05%	-
Waste	0.04%	-	0.04%	-
Coal	13.39%	13.39%	10.22%	10.22%
Natural gas	10.83%	10.83%	7.33%	20.26%
Cogeneration	0.00%	-	0.00%	-
Unspecified	0.00%	-	12.93%	-
Landfill Gas (Biogas)	0.13%	0.13%	0.20%	0.20%
Nuclear power	4.19%	4.19%	4.75%	4.75%
Biomass	0.60%	0.60%	0.45%	0.45%
Hydroelectric	67.68%	67.68%	59.16%	59.16%
Geothermal	0.00%	0.00%	0.00%	0.00%
Wind	2.84%	2.84%	4.58%	4.58%
Solar PV	0.00%	0.00%	0.28%	0.28%

The grid mix resulted after the re-mapping can be plugged into WA-GREET model on the Inputs sheet as shown below in the Figure 2.3. Additional columns for new years can be added to the right with some adjustment to the lookup function implemented in the Active column.

	K	L	M	N	O	P
656	**10.2.b.1) Electric Generation Mix for Washington: Based on yearly data from Dept of Commerce**					
657						
658	Active Case selection:	2018				
659						
660	**WA Grid Mix**	**2017**	**Active**	**2018**	**2019**	**2020**
661	Residual oil	0.33%	0.10%	0.10%		
662	Natural gas	10.83%	20.26%	20.26%		
663	Coal	13.39%	10.22%	10.22%		
664	Nuclear power	4.19%	4.75%	4.75%		
665	Biomass	0.60%	0.45%	0.45%		
666	Biogas	0.13%	0.20%	0.20%		
667	Others	70.53%	64.03%	64.03%		
668	Total	100.00%	100.00%	100.00%	100.00%	100.00%
669						
670	**"Others" mix**	**2017**	**Active**	**2018**	**2019**	
671	Hydroelectric	95.96%	92.39%	92.39%		
672	Geothermal	0.00%	0.01%	0.01%		
673	Wind	4.03%	7.16%	7.16%		
674	Solar PV	0.00%	0.44%	0.44%		
675	Total	100.00%	100.00%	100.00%	100.00%	100.00%

Figure 2.3. Screenshot of Electric section of Inputs showing WA grid mix input data

Updating State aggregated mix

To perform this the CI results for state aggregate grid mix for a subsequent year, the following steps can be followed:

1. Copy the "WA-GREET" sheet from the modified aggregated fuel mix disclosure report (provided to Ecology) into a newer aggregated fuel mix disclosure report.
2. Update references in the sheet looking up to old file to the new file.
3. Add a section below existing data for the new year.
4. Copy the structure and formulas from the 2018 re-mapping table under the new year section.
5. Update the references in the new section from 2018 disclosure data to the new year's disclosure data.
6. Cross check results by matching the total produced power in the newly created section with the total power as calculated in the pre-existing sheet for the new year.
7. The resulting grid mix can be added to the WA-GREET model or potentially to the WA Utility CI calculator for calculating the CI results.

2.3.2 Washington Utility Specific Power

Within Washington, the WA CFS regulation includes provision to allow the use of utility specific CI for certain purposes outside of biofuel pathways, like credit generation from Electric Vehicle charging. To this end, Life Cycle Associates developed a new calculator external to the WA-GREET, referred to as "WA Utility CI Calculator," that models the carbon intensity for the power generated by an individual utility within Washington. This calculator is based on the well-to-plug lifecycle emission calculation methodology from WA-GREET described above and uses the utility specific electricity generation mix as reported under the Washington utility mix disclosure data.

Under the annual Washington utility mix disclosure report, the fuel types used to generate electricity by each specific utility in Washington is also reported annually. This data is included in the "Report Extract" sheet of the annual utility fuel mix disclosure report provided by Washington Department of Commerce. A screenshot of the "Report Extract" sheet showing such information structure is presented previously in the Figure 2.2. A copy of this sheet is pasted into the utility CI calculator, to be used as the direct data source for fuel mix for each utility. Each utility in the disclosure report is classified by its unique "Claimant ID" which is also associated to the utility name as the "Claimant name."

This annual report includes the self-reported amount of electricity production, in MWh, from a defined list of fuel types. The fuel type categories in the report include the following types of fuel used by a given utility for its electricity production:

- Biogas
- Biomass
- Coal
- Geothermal
- Hydro
- Natural Gas
- Nuclear
- Other Biogenic
- Other Non-Biogenic
- Petroleum
- Solar
- Unknown
- Waste
- Wind
- Unspecified (Plant use)
- Unspecified (BPA purchase)

These categories are matched with the resource categories as defined and used in the GREET model framework to calculate a WA-GREET compatible electricity resource mix for any given utility. In consultation with Ecology, a conservative approach was followed to perform this allocation as illustrated in the following Table 2.8.

Table 2.8 Allocation of Washington Fuel Mix Disclosure Resources Categories to WA-GREET Resources Categories

Energy Resources	Residual oil	Natural gas	Coal	Nuclear power	Biomass	Biogas	Hydroelectric	Geothermal	Wind	Solar PV
Biogas						1				
Biomass					1					
Coal			1							
Geothermal								1		
Hydro							1			
Natural Gas		1								
Nuclear				1						
Other Biogenic						1				
Other Non-Biogenic	1									
Petroleum	1									
Solar										1
Unknown		1								
Waste	1									
Wind									1	
Unspecified (Plant)		1								
Unspecified (BPA)		1								

The WA utility CI calculator allows the selection of the utility for which the lifecycle carbon intensity result is desired using its Claimant ID as reported under the Washington utility mix disclosure report due to its unique nature. The calculator includes the data directly extracted from the utility disclosure report for reference and also for use in CI calculation.

The utility selection is available on the “Utility_CI” sheet of the calculator using a combination of drop-down menus. The first drop-down menu allows the user to select between a pre-defined Washington utility or a User-Defined mix. The second drop-down menu allows the user to select a Claimant ID from the list of all the available claimant IDs under the utility mix disclosure data.

The utility selection is available on the "Utility_CI" sheet of the calculator using a combination of drop-down menus. The first drop-down menu allows the user to select between a pre-defined Washington utility or a User-Defined mix. The second drop-down menu allows the user to select a Claimant ID from the list of all the available claimant IDs under the utility mix disclosure data.

Upon selection of a claimant ID, the calculator shows the utility Claimant name of the corresponding ID from the utility mix disclosure report. Underneath the drop down menus, the calculator also includes a table showing the electricity generation mix for the selected utility as well as a section to input the custom user-defined mix.

Based on the selection of the first dropdown menu, the calculator activates the correct electricity generation mix as the active case. If User-defined mix is selected in the first drop-down menu, the second drop-down menu is functionally ignored, and the CI results correspond to the custom resource mix inputted by the user.

The drop-down menus and the generation mix table on the Utility_CI sheet on the Washington utility CI calculator is shown in the Table 2.9 below.

Table 2.9. Utility_CI sheet from the Washington Utility CI Calculator

1) Selection of Washington Utility or User Defined mix	2	1 - Washington Utility
		2 - 2018 Washington state grid mix
		3 - User Defined Mix
1.1) Selection of the WA Utility ID for CI Results		
Utility Claimant ID	1	*List of all Utility IDs and names available on Report Extract sheet
Name of the Selected Utility Mix	Alder Mutual Light	

2) Electric Generation Mix: Data Table — **Active Case for CI Calculation**

Fuel Type	**2018 WA state grid mix**	Alder Mutual Light	2018 WA state grid mix	User Defined Mix
Residual oil	0.10%	0.00%	0.10%	0.10%
Natural gas	20.26%	4.39%	20.26%	20.26%
Coal	10.22%	0.00%	10.22%	10.22%
Nuclear power	4.75%	10.92%	4.75%	4.75%
Biomass	0.45%	0.00%	0.45%	0.45%
Biogas	0.20%	0.00%	0.20%	0.20%
Others	64.03%	84.70%	64.03%	64.03%

"Others" category	**2018 WA state grid mix**	Alder Mutual Light	2018 WA state grid mix	User Defined Mix
Hydroelectric	92.39%	100.00%	92.39%	92.39%
Geothermal	0.01%	0.00%	0.01%	0.01%
Wind	7.16%	0.00%	7.16%	7.16%
Solar PV	0.44%	0.00%	0.44%	0.44%

Intro | Utility_CI | 2020 Fuel Share | Report Extract | 2020 Disclosure | EF_Tables

The calculator then follows the GREET methodology to calculate the lifecycle emissions from electricity produced at the selected Washington utility, or a user-defined mix, as selected by the user. The calculator shows the final well-to-plug electricity CI results for the selected source in gCO_2e/MJ as well as gCO_2e/kWh, as shown below in the Table 2.10.

Table 2.10. CI Results table in the WA Utility CI Calculator on Utility_CI sheet

3) CI Results for: User Defined Mix

Details Breakdown of CI for Electricity Resources: Upstream phase	Residual Oil	NG	Coal	Biomass	Nuclear	Other renewable energy sources	Total Upstream, g/MMBtu
VOC	0.02	4.65	2.37	0.02	0.04	0.00	7.106
CO	0.04	14.48	0.94	0.09	0.18	0.00	15.731
CH4	0.51	117.18	46.86	0.10	0.23	0.00	164.888
N2O	0.00	0.64	0.01	0.00	0.00	0.00	0.653
CO2	30.23	2980.35	484.76	43.69	63.21	0.00	3602.229
Convert to gCO2e/MMBtu	43.35	6138.10	1668.26	46.54	69.74	0.00	7965.982
g/MJ	0.04	5.82	1.58	0.04	0.07	0.00	7.55
g/kWh							27.18

Details Breakdown of CI for Electricity Resources: Electricity Production phase & Final WTW CI	Residual Oil	NG	Coal	Biomass	Biogas	Other renewable energy sources	Total Electricity Prod, g/MMBtu	Final WTW CI
VOC	0.00	0.95	0.48	0.18	0.39	0.00	2.002	
CO	0.04	10.52	4.07	6.46	1.68	0.00	22.771	
CH4	0.01	0.47	0.32	0.67	2.74	0.00	4.212	
N2O	0.00	0.06	0.51	0.09	0.01	0.00	0.673	
CO2	272.79	26738.97	31490.51	-12.57	-11.38	1.079	58479.410	
Convert to gCO2e/MMBtu	273.71	26789.18	31659.07	41.64	62.55	1.08	58827.227	
g/MJ	0.26	25.39	30.01	0.04	0.06		55.76	63.31
g/kWh							200.73	227.91

Updating Utility Specific Mix

A Washington Electric Utility CI calculator was developed with the intention to make it easy to update it and accommodate any subsequent years' data as provided by Washington Department of Commerce. The raw data, once imported into the utility CI calculator, is referenced in a progressive manner such that very few references are needed to be updated during this process.

The raw data from Washington Department of Commerce is included as its own sheet in the calculator, called "Report Extract." Data for each utility from this sheet is aggregated in its own single row, with different fuel sources in separate columns, on the "disclosure" sheet. One key aspect to this is the use the "Unique" formula available in Excel, in the Col A of this sheet, to remove the duplicate entries of the Claimant ID from the report extract sheet. As previously described, this claimant ID is used as the primary identifier for each utility.

The reorganized raw data on the disclosure sheet is then re-mapped on the "Fuel shares" sheet, using the mapping table available on the "EF_Tables" sheet. The fuel shares sheet primarily refers to the disclosure sheet and EF_Tables sheet, thus requiring minimal adjustment despite addition of a new raw data sheet.

Fuel shares sheet results in the remapped, GREET-compatible fuel mix for each utility which is then used for CI calculations on the "Utility" sheet. Utility sheet also does not directly refer to the raw data, requiring minimal changes to accommodate new raw data.

In order to update this calculator to use the utility fuel mix from a subsequent year, the following steps can be followed:

1. Collect the excel version of the utility mix disclosure report from Washington Department of Commerce for the given year.

2. Copy and paste the “Report Extract” sheet from the disclosure report into the utility CI calculator. The sheet may be renamed to “YYYY_Report Extract” for consistency.
3. At the bottom of the table on this sheet, add a sum formula to total all the rows for each column. This can be used to check the correctness of the subsequent data transformations.
4. On the “Disclosure” sheet, repoint the “Unique” formula in the column A to the new “Report Extract” sheet. Rename the year in the sheet’s name as necessary for consistency.
5. Similarly repoint the formulas in the remaining columns to new “Report Extract” sheet and update them as necessary to account for changes in number of rows on either sheet. Refer to the notes included in the top row for clarification on the included formula.
6. Go to the “Fuel Share” sheet. Adjust the formulas to accommodate any changes in the number of rows on the updated disclosure sheet. If new rows are needed, copy and paste the formulas from existing rows into the new rows and ensure correctness.
7. Go to the Utility tab, update the data validation on the utility selection pull down (cell C7) to include the correct number of rows on the updated fuel share sheet.
8. Also update the Vlookup formula in the utility name cell (cell C8) to include the correct set of rows on the updated fuel share sheet.
9. After selecting the correct values in the pull downs, the CI values for the selected utility for the new year should now be available in the section 3 of the Utility sheet.

3. Electric Power GHG Emission Results

The WA GREET model generates WTP GHG emission results for a range of power generation resources. The scope in WA GREET includes the upstream life cycle emissions plus emissions at the power plant. The sum of the upstream and power plant emissions is adjusted for a loss factor and available as an array of data from the electricity sheet as shown in Table 3.1. GREET identifies criteria pollutant and GHG emissions for the feedstock and fuel phase. Each phase represents the life cycle emissions adjusted for the transmission loss factor. The results are shown in energy and emissions power per mmBtu. The emissions per MJ are summarized at the bottom of each column along with the default result the selected grid mix.

Table 3.1. Well to Plug GHG Emissions for Power Generation

	Stationary Use: U.S. Mix			
	Total		Urban	
	Feedstock	Fuel	Feedstock	Fuel
Total energy	107,008	2,181,221	0.00	0.22
Fossil fuels	104,451	1,774,716	0.00	6.10
Coal	7,916	1,147,735	0.00	8.64
Natural gas	71,714	589,174	0.00	0.08
Petroleum	24,820	37,807	0.00	0.20
Water consumption	11.697	178.02		
VOC	15.231	3.00	0.538	0.933
CO	24.076	45.28	2.027	12.549
NOx	42.665	81.36	3.230	23.405
PM10	10.662	21.10	0.092	6.196
PM2.5	2.102	10.09	0.066	3.165
SOx	16.619	299.51	1.185	109.166
BC	0.237	0.81	0.007	0.229
OC	0.449	1.90	0.030	0.541
CH4	332.510	4.37		
N2O	0.901	2.23		
CO2	7,050	153,064		
CO2 (w/ C in VOC & CO)	7,135	153,144		
GHGs	15,562	153,756		
GHGs, gCO2e/MJ	14.90	145.88	160.78	

	Transportation Use: WAMX Mix			
	Total		Urban	
	Feedstock	Fuel	Feedstock	Fuel
Total energy	59,887	1,525,173.16		
Fossil fuels	59,043			
Coal	2,576			
Natural gas	48,781.84			
Petroleum	7,685.14			
Water consumption	4.194			
VOC	7.120	2.00	0.002	0.000
CO	15.795	22.77	0.003	0.000
NOx	23.121	63.34	0.007	0.000
PM10	3.058	17.53	0.000	0.000
PM2.5	0.694	11.46	0.000	0.000
SOx	7.779	35.90	0.005	0.000
BC	0.107	0.84	0.000	0.000
OC	0.163	1.89	0.000	0.000
CH4	165.234	4.21		
N2O	0.657	0.67		
CO2	3,804.254	58,484		
CO2 (w/ C in VOC & CO)	3,851	58,526		
GHGs	8,083	58,830		
GHGs, gCO2e/MJ	7.75	55.76	63.51	

The WA-GREET model also calculates the life cycle-based carbon intensity of electric power derived from individual fuel types, like residual oil or natural gas fired power plants. Such results are also affected by the power conversion efficiency as determind by the selected region in the model. The individual fuel to electric power CI results with the WAMX region selected from WA-GREET are shown below in the Table 3.2.

Table 3.2. Individual fuel type to power CI results

6) Power Plant Energy Use and Emissions: per mmBtu of Electricity Available at User Sites (wall outlets)

	Stationary Use: WAMX Mix		Transportation Use: WAMX Mix		Oil-Fired Power Plant		NG-Fired Power Plant		Coal-Fired Power Plant		Biomass-Fired Power Plant	
Energy Use: Btu	**Total**	**Urban**	**Total**	**Urban**	**Total**	**Urban**	**Total**	**Urban**	**Total**	**Urban**	**Total**	**Urban**
Residual oil	3,208		3,208		3,178,112		0		0		0	
NG	450,405		450,405		0		2,222,656		0		0	
Coal	314,854		314,854		0		0		3,082,187		0	
Biomass	21,144		21,144		0		0		0		4,732,384	
Nuclear	50,778		50,778		0		0		0		0	
Other energy sources	684,785		684,785		0		0		0		0	
Emissions: grams												
VOC	2.002	0.522	2.002	0.522	2.653	0.027	4.690	1.468	4.702	1.787	41.061	9.403
CO	22.771	6.318	22.771	6.318	43.329	0.433	51.910	16.248	39.808	15.127	1,446.235	331.188
NOx	63.339	22.052	63.339	22.052	1,983.430	19.834	46.750	14.633	467.973	177.830	880.780	201.699
PM10	17.527	5.975	17.527	5.975	32.891	0.329	2.992	0.937	125.065	47.525	908.677	208.087
PM2.5	11.461	3.854	11.461	3.854	18.232	0.182	2.992	0.937	77.421	29.420	643.503	147.362
SOx	35.897	12.851	35.897	12.851	1,705.898	17.059	1.351	0.423	323.162	122.801	198.653	45.492
BC	0.840	0.249	0.840	0.249	1.189	0.012	0.454	0.142	3.329	1.265	88.803	20.336
OC	1.895	0.550	1.895	0.550	0.960	0.010	1.448	0.453	6.271	2.383	209.782	48.040
CH4	4.212		4.212		10.101		2.326		3.134		150.140	
N2O	0.673		0.673		1.957		0.313		5.015		20.060	
CO2	58,479		58,479		270,294		131,951		308,269		-2,814	

3.1 Washington Utility CI Results

The results for the Washington power utilities for 2020 from the 2020 Washington Utility CI calculator are shown in the Table 3.3 below. The tables shows the specific mWh generated from each fuel type, % share of each fuel type, and, in the rightmost column, the CI for the given utility.

Table 3.3. Washington Utility CI Results

Claimant ID	Claimant Name	Residual oil	Natural gas	Coal	Nuclear power	Biomass	Hydroelectric	Geothermal	Wind	Solar PV	Total	Residual oil %	Natural gas %	Coal %	Nuclear power %	Biomass %	Hydroelectric %	Geothermal %	Wind %	Solar PV %	Total %	WTW CI g/kWh
1	Alder Mutual Light	0	239	0	595	0	4,616	0	0	0	5,450	0.00%	4.39%	0.00%	10.92%	0.00%	84.70%	0.00%	0.00%	0.00%	100.00%	24.86
85	Asotin County PUD #1	0	197	0	493	0	3,822	0	0	0	4,512	0.00%	4.37%	0.00%	10.93%	0.00%	84.71%	0.00%	0.00%	0.00%	100.00%	24.76
109	Avista (WA)	43,612	2,646,277	756,088	0	302,861	1,968,825	0	95,946	0	5,813,609	0.75%	45.52%	13.01%	0.00%	5.21%	33.87%	0.00%	1.65%	0.00%	100.00%	408.70
4	Benton County PUD #1	0	72,061	0	179,185	0	1,403,185	0	147,426	0	1,801,857	0.00%	4.00%	0.00%	9.94%	0.00%	77.87%	0.00%	8.18%	0.00%	100.00%	22.67
5	Benton Rural Electric Assn	0	23,495	0	58,420	0	452,998	0	0	0	534,913	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
6	Big Bend Electric Coop	0	62,203	0	61,815	0	479,324	0	0	0	603,342	0.00%	10.31%	0.00%	10.25%	0.00%	79.44%	0.00%	0.00%	0.00%	100.00%	57.68
18	Centralia City Light	42	8,254	37,303	20,523	0	199,125	0	0	0	265,247	0.02%	3.11%	14.06%	7.74%	0.00%	75.07%	0.00%	0.00%	0.00%	100.00%	174.37
19	Chelan County PUD #1	24	0	0	0	0	1,663,395	0	327	0	1,663,746	0.00%	0.00%	0.00%	0.00%	0.00%	99.98%	0.00%	0.02%	0.00%	100.00%	0.02
20	Cheney Light Department	0	14,577	0	14,463	0	112,151	0	0	0	141,191	0.00%	10.32%	0.00%	10.24%	0.00%	79.43%	0.00%	0.00%	0.00%	100.00%	57.76
21	Chewelah Electric Department	0	915	0	2,275	0	17,640	0	0	0	20,830	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
12	City of Blaine	0	3,535	0	8,789	0	68,150	0	0	0	80,474	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
22	Clallam County PUD #1	0	29,298	0	72,850	0	574,455	0	0	0	676,603	0.00%	4.33%	0.00%	10.77%	0.00%	84.90%	0.00%	0.00%	0.00%	100.00%	24.55
23	Clark County PUD #1	0	1,825,997	0	301,574	0	2,355,224	0	140,908	0	4,623,703	0.00%	39.49%	0.00%	6.52%	0.00%	50.94%	0.00%	3.05%	0.00%	100.00%	219.29
26	Clearwater Power (WA)	0	970	0	2,404	0	18,639	0	0	0	22,013	0.00%	4.41%	0.00%	10.92%	0.00%	84.67%	0.00%	0.00%	0.00%	100.00%	24.98
30	Columbia Rural Electric Assn (WA)	0	48,142	0	37,494	0	290,733	0	0	0	376,369	0.00%	12.79%	0.00%	9.96%	0.00%	77.25%	0.00%	0.00%	0.00%	100.00%	71.42
161	Consolidated Irrigation District #19	0	109	0	269	0	2,087	0	0	0	2,465	0.00%	4.42%	0.00%	10.91%	0.00%	84.67%	0.00%	0.00%	0.00%	100.00%	25.06
32	Coulee Dam, Town of	0	746	0	1,856	0	14,392	0	0	0	16,994	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.89
33	Cowlitz County PUD #1	127	439,736	2,622	387,284	67,647	3,156,681	0	348,336	558	4,402,991	0.00%	9.99%	0.06%	8.80%	1.54%	71.69%	0.00%	7.91%	0.01%	100.00%	57.54
35	Douglas County PUD #1	1	266,738	656	0	0	741,599	0	0	292	1,009,286	0.00%	26.43%	0.06%	0.00%	0.00%	73.48%	0.00%	0.00%	0.03%	100.00%	147.25
38	Eatonville Electric Department	0	1,220	0	3,030	0	23,494	0	0	0	27,744	0.00%	4.40%	0.00%	10.92%	0.00%	84.68%	0.00%	0.00%	0.00%	100.00%	24.93
41	Ellensburg Electric Division	0	8,858	0	22,027	0	170,796	0	0	0	201,681	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
39	Elmhurst Mutual Power & Light	0	12,354	0	30,719	0	238,201	0	0	0	281,274	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
160	Energy Northwest	0	1,051	0	2,615	0	20,276	0	0	0	23,942	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.89
162	Fairchild Airforce Base	0	1,933	0	4,806	0	37,262	0	0	0	44,001	0.00%	4.39%	0.00%	10.92%	0.00%	84.68%	0.00%	0.00%	0.00%	100.00%	24.91
44	Ferry County PUD #1	0	3,106	0	7,723	0	59,888	0	0	0	70,717	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
46	Franklin County PUD #1	0	73,860	0	113,472	0	893,085	0	0	0	1,080,417	0.00%	6.84%	0.00%	10.50%	0.00%	82.66%	0.00%	0.00%	0.00%	100.00%	38.43
82	Grant County PUD #2	0	4,016,058	0	5,371	0	1,172,023	0	33,610	0	5,227,062	0.00%	76.83%	0.00%	0.10%	0.00%	22.42%	0.00%	0.64%	0.00%	100.00%	425.99
47	Grays Harbor County PUD #1	0	39,168	0	97,394	8,040	755,205	0	0	0	899,807	0.00%	4.35%	0.00%	10.82%	0.89%	83.93%	0.00%	0.00%	0.00%	100.00%	25.28
48	Inland Power & Light	0	94,273	0	108,726	0	843,076	0	0	0	1,046,075	0.00%	9.01%	0.00%	10.39%	0.00%	80.59%	0.00%	0.00%	0.00%	100.00%	50.49
118	Jefferson County PUD #1	0	17,348	0	43,142	0	334,525	0	0	0	395,015	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
144	Kalispel Tribal Utility	0	1,220	0	3,030	0	23,497	0	0	0	27,747	0.00%	4.40%	0.00%	10.92%	0.00%	84.68%	0.00%	0.00%	0.00%	100.00%	24.93
51	Kittitas County PUD #1	0	5,104	0	12,233	0	94,855	0	0	0	112,192	0.00%	4.55%	0.00%	10.90%	0.00%	84.55%	0.00%	0.00%	0.00%	100.00%	25.77
Claimant ID	Claimant Name	Residual oil	Natural gas	Coal	Nuclear power	Biomass	Hydroelectric	Geothermal	Wind	Solar PV	Total	Residual oil %	Natural gas %	Coal %	Nuclear power %	Biomass %	Hydroelectric %	Geothermal %	Wind %	Solar PV %	Total %	WTW CI g/kWh
52	Klickitat County PUD #1	0	80,957	0	42,921	0	376,883	0	0	0	500,761	0.00%	16.17%	0.00%	8.57%	0.00%	75.26%	0.00%	0.00%	0.00%	100.00%	90.07
53	Kootenai Electric Coop	0	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00
54	Lakeview Light & Power	0	11,319	0	28,146	0	218,245	0	0	0	257,710	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
56	Lewis County PUD #1	0	38,598	0	95,975	0	748,174	0	59,989	0	942,736	0.00%	4.09%	0.00%	10.18%	0.00%	79.36%	0.00%	6.36%	0.00%	100.00%	23.21
111	Mason County PUD #1	0	3,233	0	8,038	0	67,503	0	0	0	78,774	0.00%	4.10%	0.00%	10.20%	0.00%	85.69%	0.00%	0.00%	0.00%	100.00%	23.27
89	Mason County PUD #3	0	29,262	0	72,761	0	573,771	0	18,628	210	694,632	0.00%	4.21%	0.00%	10.47%	0.00%	82.60%	0.00%	2.68%	0.03%	100.00%	23.88
59	McCleary Light & Power	0	1,351	0	3,361	0	26,063	0	0	0	30,775	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.89
63	Milton Electric Division	0	2,493	0	6,198	0	48,057	0	0	0	56,748	0.00%	4.39%	0.00%	10.92%	0.00%	84.68%	0.00%	0.00%	0.00%	100.00%	24.91
64	Modern Electric Water Company	0	10,219	0	25,412	0	197,048	0	0	0	232,679	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
66	Nespelem Valley Elec Coop	0	2,884	0	7,172	0	55,609	0	0	0	65,665	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
69	Northern Lights (WA)	0	5	0	13	0	104	0	0	0	122	0.00%	4.10%	0.00%	10.66%	0.00%	85.25%	0.00%	0.00%	0.00%	100.00%	23.26
71	Ohop Mutual Light	0	3,990	0	9,917	0	76,896	0	0	0	90,803	0.00%	4.39%	0.00%	10.92%	0.00%	84.68%	0.00%	0.00%	0.00%	100.00%	24.91
73	Okanogan County Electric Coop	0	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00
157	Okanogan County Electric Coop	0	6,712	0	6,934	0	53,768	0	0	0	67,414	0.00%	9.96%	0.00%	10.29%	0.00%	79.76%	0.00%	0.00%	0.00%	100.00%	55.72
72	Okanogan County PUD #1	0	42,645	113	43,783	0	525,057	0	22,034	0	633,632	0.00%	6.73%	0.02%	6.91%	0.00%	82.86%	0.00%	3.48%	0.00%	100.00%	37.86
75	Orcas Power & Light Coop	0	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00
158	Orcas Power & Light Coop	0	9,878	0	24,563	0	190,465	0	0	0	224,906	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
76	Pacific County PUD #2	0	28,884	0	32,135	0	249,175	0	0	0	310,194	0.00%	9.31%	0.00%	10.36%	0.00%	80.33%	0.00%	0.00%	0.00%	100.00%	52.15
130	Pacific Power (WA)	957	1,930,950	1,604,372	11,329	0	619,337	0	290,848	0	4,457,793	0.02%	43.32%	35.99%	0.25%	0.00%	13.89%	0.00%	6.52%	0.00%	100.00%	641.06
81	Parkland Light & Water	0	5,064	0	12,592	0	97,640	0	0	0	115,296	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
83	Pend Oreille County PUD #1	0	74,275	0	13,920	0	892,365	0	0	0	980,560	0.00%	7.57%	0.00%	1.42%	0.00%	91.01%	0.00%	0.00%	0.00%	100.00%	42.07
84	Peninsula Light	0	26,925	0	66,953	0	519,161	0	77,722	0	690,761	0.00%	3.90%	0.00%	9.69%	0.00%	75.16%	0.00%	11.25%	0.00%	100.00%	22.10
86	Port Angeles Light Operations	0	11,903	0	29,602	0	229,534	0	0	0	271,039	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
119	Port of Seattle	0	5,769	0	14,344	0	111,229	0	0	0	131,342	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
124	Port Townsend	0	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00
90	Puget Sound Energy	9,430	8,942,796	4,984,651	40,693	2,087	5,234,658	3,500	2,282,111	206,950	21,706,876	0.04%	41.20%	22.96%	0.19%	0.01%	24.12%	0.02%	10.51%	0.95%	100.00%	484.53
91	Richland Energy Services	0	107,961	0	93,718	0	726,699	0	0	399	928,777	0.00%	11.62%	0.00%	10.09%	0.00%	78.24%	0.00%	0.00%	0.04%	100.00%	64.95
92	Ruston, Town of	0	0	0	0	57	2,638	28	766	0	3,489	0.00%	0.00%	0.00%	0.00%	1.63%	75.61%	0.80%	21.95%	0.00%	100.00%	1.10
95	Seattle City Light	0	348,831	0	457,743	0	7,909,407	0	472,131	0	9,188,112	0.00%	3.80%	0.00%	4.98%	0.00%	86.08%	0.00%	5.14%	0.00%	100.00%	21.30
96	Skamania County PUD #1	0	6,254	0	15,552	0	120,589	0	0	0	142,395	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
97	Snohomish County PUD #1	0	249,576	0	617,771	65,472	4,896,819	0	722,952	80,280	6,632,870	0.00%	3.76%	0.00%	9.31%	0.99%	73.83%	0.00%	10.90%	1.21%	100.00%	21.99
143	Solar City (WA)	0	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00
99	Steilacoom Electric Utility	0	1,691	0	4,205	0	32,608	0	0	0	38,504	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
101	Sumas, City of	0	1,333	0	3,315	0	25,702	0	0	0	30,350	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
102	Tacoma Power	0	112,721	0	280,288	36,019	3,864,226	18,000	488,871	198	4,800,323	0.00%	2.35%	0.00%	5.84%	0.75%	80.50%	0.37%	10.18%	0.00%	100.00%	13.82
103	Tanner Electric Coop	0	4,297	0	10,683	0	82,838	0	0	0	97,818	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
106	Vera Water & Power	0	21,245	0	23,771	0	184,322	0	0	0	229,338	0.00%	9.26%	0.00%	10.37%	0.00%	80.37%	0.00%	0.00%	0.00%	100.00%	51.88
88	Wahkiakum County PUD #1	0	1,961	0	4,875	0	37,799	0	0	0	44,635	0.00%	4.39%	0.00%	10.92%	0.00%	84.68%	0.00%	0.00%	0.00%	100.00%	24.91
117	Whatcom County PUD #1	0	10,258	0	25,506	0	197,775	0	0	0	233,539	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90
120	Yakama Power	0	6,477	0	16,108	0	124,903	0	0	0	147,488	0.00%	4.39%	0.00%	10.92%	0.00%	84.69%	0.00%	0.00%	0.00%	100.00%	24.90

Utilities in Washington also report their GHG emissions to the Washington Department of Commerce as part of a state utility GHG emission reporting program. The carbon intensity results emissions results per this direct reporting are shown here in comparison with the utility CI results as modelled in WA-GREET. It should be noted that unlike the CI results from WA-GREET, the CI results from the self-reporting program only represent the power plant emissions, and do not appear to include the transmission losses. The comparison of the two dataset is shown below in the form of a state electric supply curve in the Figure 3.1 below.

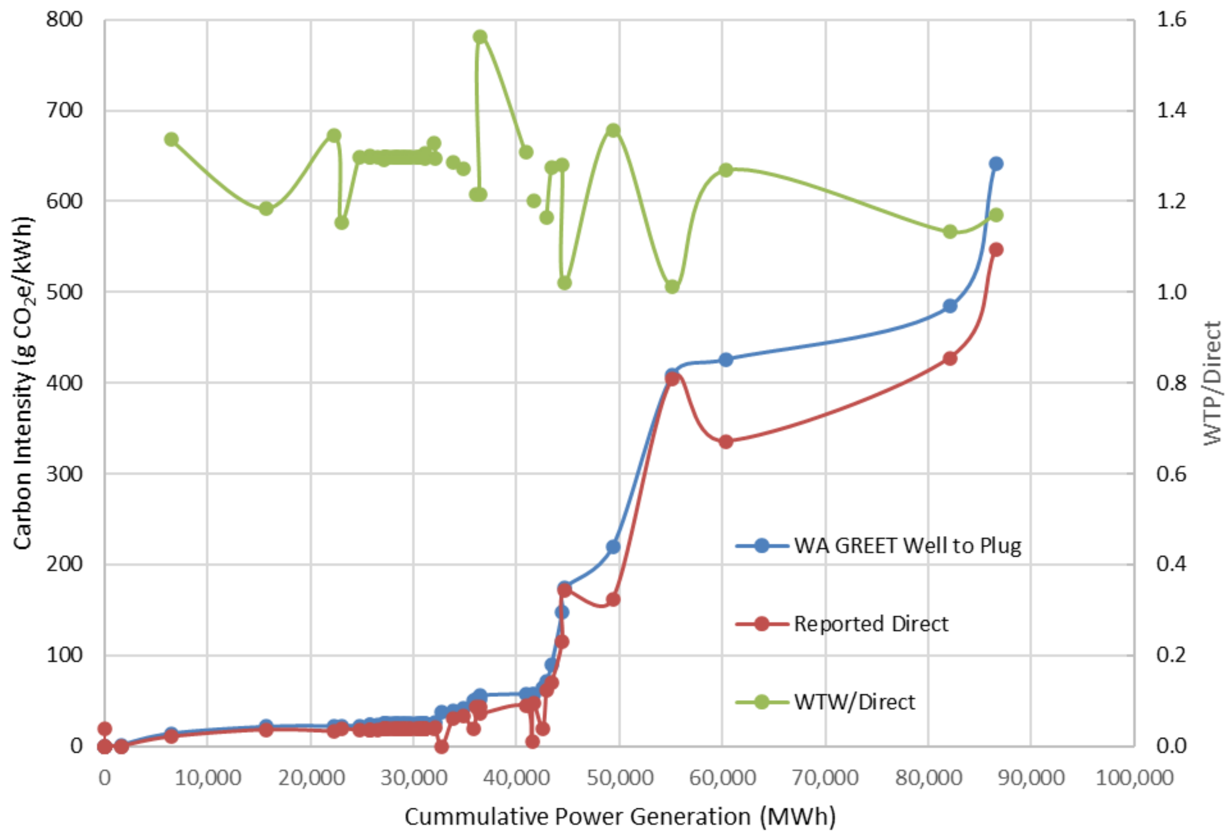

Figure 3.1. **Comparison of utility CI results from WA GREET and self reported data**

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