LCFS Life Cycle Fuel Pathway Report

Method 2B Application: Element Markets Renewable Energy, LLC

LFG collected and processed in Davison, MI; delivered via pipeline for liquefaction to Topock, AZ; transported with trucks for use as LNG & L-CNG to CA.

1.) Overview

This document describes the Life Cycle Analysis and Carbon Intensity calculations- based on the CA-GREET model - for the Landfill Gas-to-Liquefied Natural Gas (LFG-to-LNG) and Landfill Gas-to-Compressed Natural Gas (pathway is hereinafter referred to as LFG-to-L-CNG, since the pathway involves re-vaporization of LNG and subsequent compression to CNG) pathways of Element Markets Renewable Energy, LLC (EMRE).

In our two pathways Landfill Gas is recovered from the Richfield Landfill in Davison, MI and processed at the onsite LFG to high-btu natural gas facility operated by Blue Skies Energy, Inc (BSE). EMRE takes title of the processed LFG that is injected into the gas transmission pipelines in Michigan and supplies biomethane for liquefaction to Applied Natural Gas Fuels, Inc. (ANGF) in Arizona. The withdrawn gas is liquefied in ANGF's Needle Mountain LNG Plant and LNG is transported to California customers using special LNG trailers pulled by diesel tractors. The LNG is used by ANGF's customers to fuel heavy-duty trucks either as LNG or – after re-vaporization and compression – as CNG.

The biomethane EMRE purchases from BSE is commingled with fossil natural gas when it enters the interstate pipeline system. EMRE will be obligated to retain records that demonstrate that the credits it earns under the pathways described in this document correspond directly with the volumes of biomethane purchased from the landfill and subsequently sold to ANGF.

The pathway is based on the existing ARB pathways for North-American LFG-to-CNG (CNG006[1]) and North-American LFG-to-LNG (LNG006[2]). In our application we provide facility-specific, updated information for all steps of the pathway. Unless specified otherwise, all assumptions of pathway CNG006 up to transportation via pipeline to the LNG facility apply. Similarly, assumptions of pathway LNG006 apply for steps downstream from NG transportation via pipeline.

Due to the fact that regional electricity source parameters for the two facilities involved in the pathway are different, two CA-GREET spreadsheets are included in EMRE's application package. This document includes information from both of the model results.

[1] Internal ARB-Developed Fuel Pathway - North American Landfill Gas to Compressed Natural Gas; posted on ARB website on 03/19/2013 - http://www.arb.ca.gov/fuels/lcfs/2a2b/internal/nalfg-cng-031513.pdf

[2] Internal ARB-Developed Fuel Pathway - LNG (from Landfill Gas); posted on ARB website on 09/23/2009; http://www.arb.ca.gov/fuels/lcfs/092309lcfs_lfg_lng.pdf

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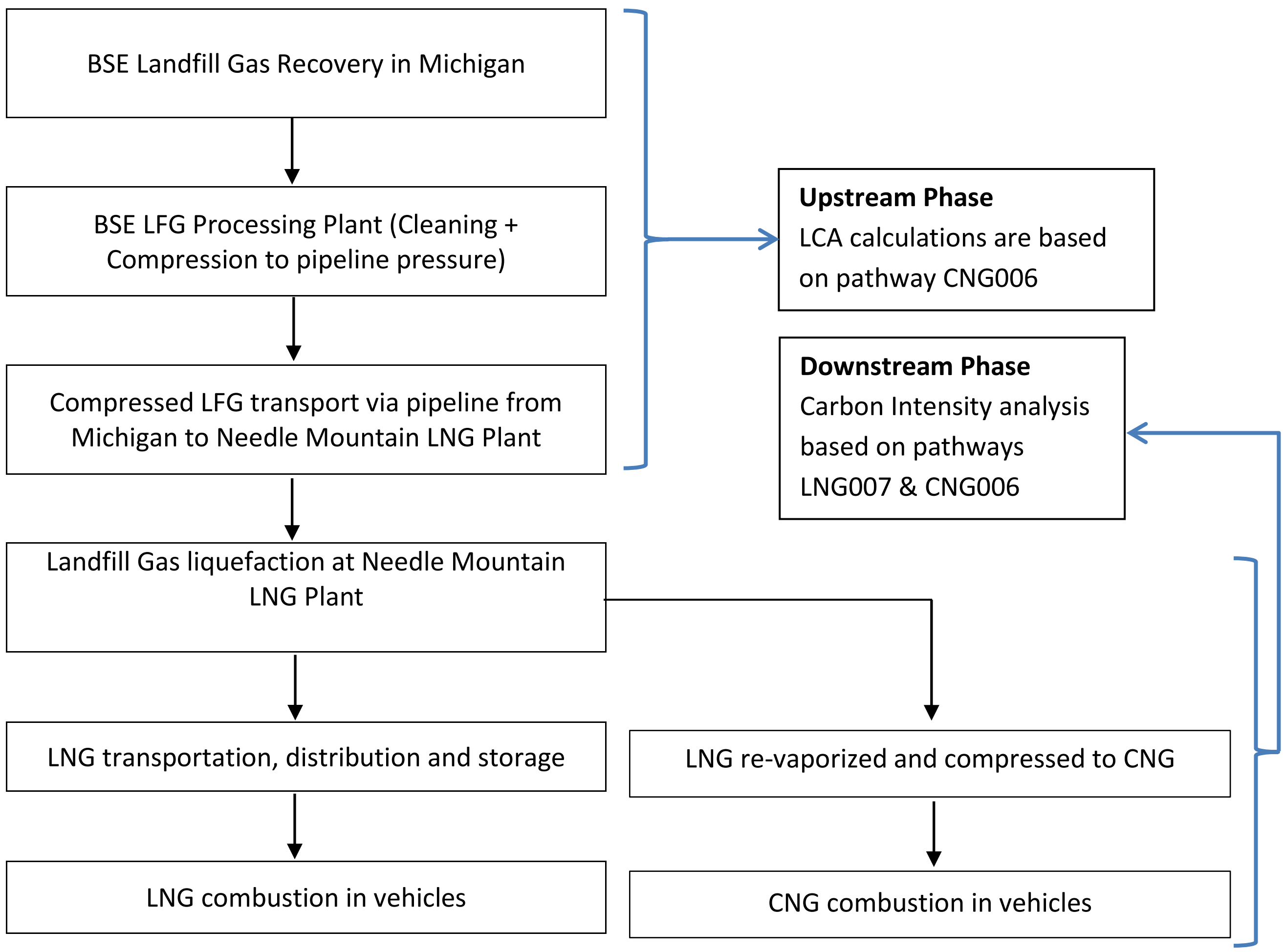
Following figure is intended to summarize the steps of the of EMRE's pathways:



2.) Pathway Description

Assumptions have been adjusted to better reflect the facility-specific operating parameters of BSE and the Needle Mountain LNG Plant. As stated above, this document focuses on adjustments made to the CNG006 and LNG006 pathways respectively; the assumptions of these pathways are not detailed.

2.1) Landfill Gas Recovery and Transport to Processing

The LFG-to-LNG and LFG-to-L-CNG pathways begin with the collection of raw landfill gas from [redacted] wells drilled into the Richfield Landfill. Gas is collected and then transported to the on-site processing facility via a negative pressure pipeline system, powered by the 1st stage compressor [redacted] The average transport distance from the wells to the LFG processing facility is [redacted] miles. According to the CA-GREET model, the energy necessary for these steps is approximately [redacted] Btu's for every 1 million Btu's collected and is provided entirely by electricity from the local grid. Likewise, because only electricity is used by the compressor, there are no direct emissions from this process, only upstream emissions associated with grid electricity of [redacted] **gCO_2e/MJ**.

Assumptions:

- Electricity generation mix parameters for LFG recovery, transportation to facility and processing have been adjusted according to Year 2009 eGRID Subregion Resource Mix – RFC Michigan values are used[3].
- LFG from the Richfield Landfill is collected from a series of [redacted] wells. Average transportation distance from landfill to processing plant is [redacted] miles.

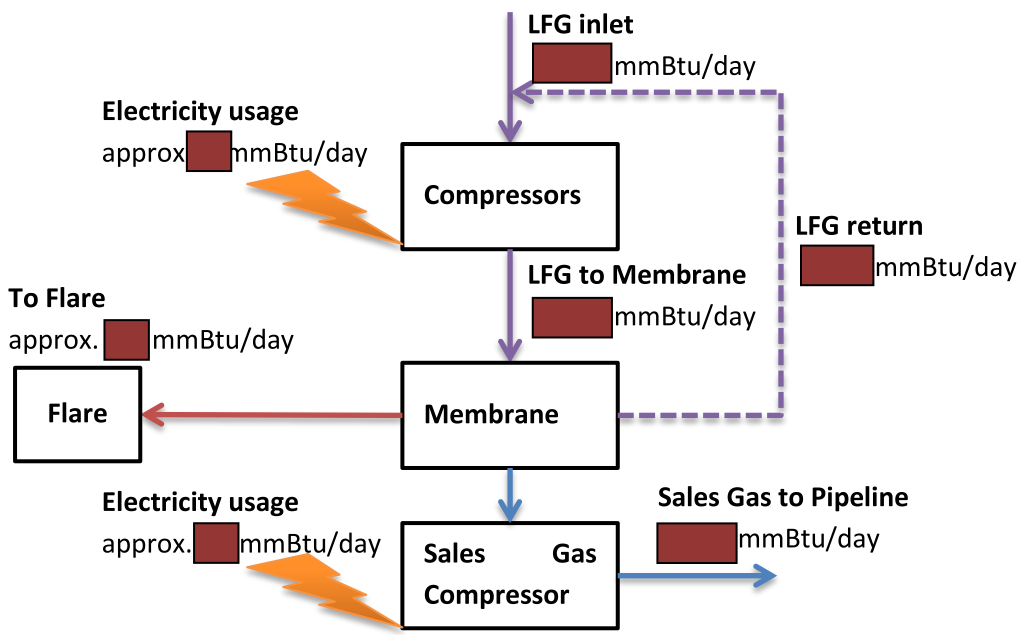
2.2) Landfill Gas Processing

The next step is cleaning the LFG to pipeline quality and pressure, via a compressor system feeding the gas through a membrane to separate usable methane from the LFG stream; BSE's processing plant utilizes [redacted] membrane system. Any remaining uncleaned landfill gas is combusted by a flare. The BSE facility draws [redacted] MMBtu/day of LFG from the landfill and requires [redacted] mmBtu of grid electricity. The flare uses LFG at a rate of [redacted] MMBtu/day.

With [redacted] MMBtu/day drawn from the landfill and [redacted] being used in the flair and [redacted] MMBtu/day sent to the pipeline, the overall efficiency of the LFG gas cleaning process is [redacted]%.

[3] See Appendix A - Year 2009 eGRID Subregion Resource Mix

An overview of BSE's inputs and outputs can be seen below:



After deducting direct energy usage of LFG recovery and transport from the electric power used in this step, using the [redacted] efficiency factor and the energy process shares between landfill gas and electricity, plus a flaring credit for all energy that is captured, the total energy consumed during the processing stage of the pathway is [redacted] **Btu/MMBtu** of energy captured and the total emissions are [redacted] **gCO_2e/MJ**.

Assumptions:

- The 1st stage compressor on the LFG processing plant's skid is equipped with [redacted] This solution allows the compressor to draw gas directly from the wells, without the need of and additional gathering blower. In our calculations we assume the LFG recovery step's energy usage and emissions to be identical with that of pathway CNG006 - except for the change in electricity mix used - in order to preserve the CA-GREET model's integrity (these values are needed to calculate upstream emissions of LFG as a fuel). The direct energy usage assumed for LFG recovery and transport to the facility ([redacted] Btu/mmBtu – 100% electricity) is deducted from the direct electricity used for LFG processing in order to avoid double-counting of energy used by the 1st stage compressor.
- LFG processing at the Richfield plant is at [redacted] % efficiency with processing fuels shares of [redacted] % LFG and [redacted] % electricity usage.
- The LFG processing plant uses [redacted] to destroy the separated waste gas stream. We have adjusted the CA-GREET model to use [redacted] emission factors in the appropriate calculations accordingly.

2.3) Natural Gas Transport

The third step in the LNG from LFG pathway is transport of the natural gas by pipeline from the LFG processing plant to the natural gas liquefaction plant in Topock, AZ. The Needle Mountain LNG Plant is located [redacted] miles from the LFG processing plant.

Based on assumptions in the GREET model for pathway CNG006, as well as the change in pipeline distance made above, the energy usage in transport and distribution stage is [redacted] **Btu/mmBtu** with emissions of [redacted] **gCO_2e/MJ**.

Assumptions

- A pipeline distance of [redacted] miles from the Richfield Landfill to Topock, AZ is used in the calculations.

2.4) NG Liquefaction at LNG Plant

Assumptions have been adjusted to better reflect the facility-specific operating parameters of the Needle Mountain LNG Plant. As stated above, this document focuses on adjustments made to the LNG006 pathway; the assumptions of that pathway are not detailed.

Natural gas delivered to the Needle Mountain LNG Plant in Topock, AZ is stripped of impurities until it is over 98% methane (CH4). CO_2, H_2S, other Sulfur components, moisture, mercury, and particles are stripped via acid gas removal and disposal, gas dehydration, mercury removal, and particle filtration. Stripping is powered by a natural gas-fueled turbine. Stripping prevents corrosion in the pipeline and crystallization of CO_2 during cryogenic processes. The emissions associated with these processes include CO, VOC, SOx, NOx, H_2S, particulates, and many toxic organic compounds. The purified quality NG then is cooled down to a -260^{o}F liquid in a heat exchanger that uses mixed refrigerant gas technology.

Total average annual electricity usage of the Needle Mountain LNG Plant is [redacted] MMBtu.

Following table contains annual average LNG Production and Feed Gas Withdrawal quantities. Both are converted to an LHV-MMBtu basis.

	Average Annual Quantity in LHV
LNG Production	[redacted]
Feed Gas Withdrawal	[redacted]

Based on electricity and gas usage as well as LNG production quantities, fuel shares are calculated as follows:

	Annual Usage [MMBtu]	Usage per gallon of LNG [Btu/gal]	Direct Usage per MMBtu of LNG [Btu/MMBtu]	Fuel Share
Electricity	[redacted]			
Natural Gas	[redacted]			
Total	[redacted]			

Total LNG production efficiency is: [redacted] **%**

After adjusting the CA-GREET model for fuel shares and the efficiency of the liquefaction process, the total energy usage of NG Liquefaction (including upstream energy): [redacted] **Btu/MMBtu** of LNG produced.

Accordingly, total GHG Emissions of NG Liquefaction is [redacted] **gCO2e/MJ**.

Assumptions:

- Electricity generation mix parameters for NG liquefaction have been adjusted according to Year 2009 eGRID Subregion Resource Mix – WECC Southwest (AZNM) values are used.
- Total average annual electricity usage of the Needle Mountain LNG Plant is [redacted] MMBtu
- Average Annual LNG production is [redacted] MMBtu, while average annual feed gas withdrawal is [redacted] MMBtu.
- [redacted] fugitive methane emissions are assumed, since the LNG plant is [redacted].
- Overall LNG production process efficiency of ANGF is [redacted] %.

2.5) LNG Storage

Fugitive methane emissions occur during LNG storage. The net emissions are a function of the methane boil-off and recovery rates.

Since [redacted] recovery system at the storage tank, [redacted] methane boil-off recovery was assumed. fugitive methane emissions from LNG storage are [redacted] **gCO_2e/MJ**.

2.6) LNG distribution

The finished LNG is offloaded into special LNG trailers and transported to wholesale customer tanks in CA and to the Ontario and Barstow refueling stations. Some methane boil-off occurs during transportation of the LNG, which is taken into account using the assumptions made in pathway LNG006.

In our LCA we calibrated the GREET model based on the amount of gallons delivered to each CA customer and the respective trip distance. Using this weighted average and taking into account the fugitive methane emissions, total energy usage of LNG distribution is [redacted] **Btu/MMBtu**, while emissions are [redacted] **gCO_2e/MJ**.

Assumptions:

- The weighted average of the round-trip transportation distance to CA clients in 2011 and 2012 is [redacted] miles.

2.7) Dispensing of LNG

ANGF also operates two vehicle refueling stations in Barstow and Ontario, California. These two stations dispense LNG and L-CNG to NG-powered vehicles.

Total energy used for the dispensing of LNG is [redacted], while emissions are [redacted] **gCO_2e/MJ**.

2.8) LNG Tank to Wheel

Tank to Wheel emissions for EMRE's LFG-to-LNG pathway are adapted without changes from ARB pathway LNG006.

Accordingly, Tank to Wheel energy usage is **1,000,000 Btu/MMBtu** and emissions are **58.5 gCO_2e/MJ**.

2.9) Re-vaporization and compression to CNG

Some of the LFG supplied by EMRE is re-vaporized and compressed to CNG before use as transportation fuel in heavy-duty vehicles.

Energy usage of this step is [redacted] and emissions are [redacted] **gCO_2e/MJ**

2.10) CNG Tank to Wheel

Tank to Wheel emissions for EMRE's LFG-to-L-CNG pathway are adapted without changes from ARB pathway CNG006[4].

Accordingly, Tank to Wheel energy usage is **1,000,000 Btu/MMBtu** and emissions are **57.73 gCO_2e/MJ**.

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[4] Internal ARB-Developed Fuel Pathway - North American Landfill Gas to Compressed Natural Gas; posted on ARB website on 03/19/2013 - http://www.arb.ca.gov/fuels/lcfs/2a2b/internal/nalfg-cng-031513.pdf

3.) Results From CA-GREET Model

The following table contains the total energy usage and Carbon Intensity of each steps of EMRE's pathway:

	Energy Required [Btu/MMBtu]	GHG Emissions [gCO2e/MJ]
Landfill Gas Recovery and Transport to Processing	[redacted]	
Landfill Gas Processing		
Natural Gas Transport		
NG Liquefaction at LNG Plant		
LNG Storage		
LNG distribution		
Dispensing of LNG		
LNG Tank to Wheel	1,000,000	58.50
Total	[redacted]	**24.90**

As seen above, EMRE's LFG-to-LNG pathway has a total energy usage of [redacted] **Btu/MMBtu** and a Carbon Intensity of **24.90 gCO2e/MJ.**

LFG-to-L-CNG Pathway

The following table contains the total energy usage and Carbon Intensity of each steps of EMRE's LFG-to-LNG pathway:

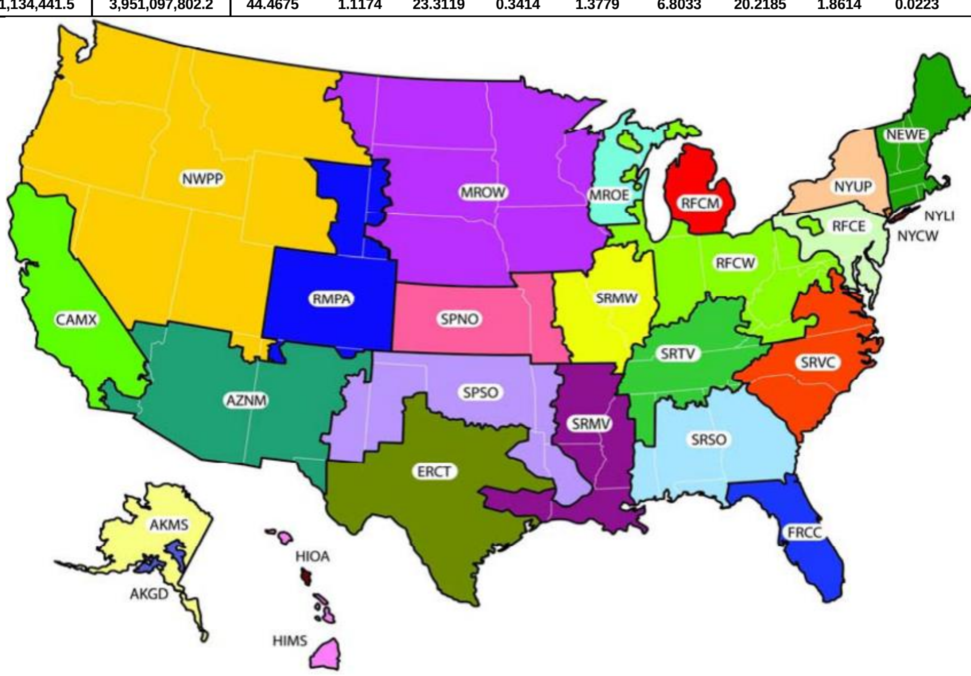
	Energy Required [Btu/MMBtu]	GHG Emissions [gCO_2e/MJ]
Landfill Gas Recovery and Transport to Processing	[redacted]	
Landfill Gas Processing		
Natural Gas Transport		
NG Liquefaction at LNG Plant		
LNG Storage		
LNG distribution		
Dispensing of LNG		
CNG Compression and Dispensing		
CNG Tank to Wheel	1,000,000	57.73
Total	[redacted]	**25.30**

As seen above, EMRE's LFG-to-LNG pathway has a total energy usage of [redacted] **Btu/MMBtu** and a Carbon Intensity of **25.30 gCO2e/MJ**

Appendix A - Year 2009 eGRID Subregion Resource Mix

http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_SummaryTables.pdf; page 5; downloaded: 08/10/2013

eGRID subregion acronym	eGRID subregion name	Nameplate capacity (MW)	Net Generatio	Generation resource mix (percent)										
				Coal	Oil	Gas	Other fossil	Biomass	Hydro	Nuclear	Wind	Solar	Geo-thermal	Other unknown/ purchased fuel
AKGD	ASCC Alaska Grid	1,514.9	5,337,982.5	11.8133	13.6743	66.0333	0.0000	0.0000	8.4791	0.0000	0.0000	0.0000	0.0000	0.0000
AKMS	ASCC Miscellaneous	701.1	1,364,176.9	0.0000	31.2972	3.8526	0.0000	0.4773	63.8578	0.0000	0.5151	0.0000	0.0000	0.0000
AZNM	**WECC Southwest**	**48,647.5**	**186,138,763.9**	**38.5979**	**0.0598**	**35.6808**	**0.0013**	**0.3166**	**6.0901**	**16.4726**	**0.5008**	**0.1012**	**2.1789**	**0.0000**
CAMX	WECC California	73,662.1	212,768,947.3	7.3284	1.3637	53.0498	0.2087	2.7167	12.7172	14.9288	2.7635	0.3003	4.3676	0.2553
ERCT	ERCOT All	101,910.6	337,031,899.7	32.9816	1.0518	47.8308	0.1257	0.1215	0.1539	12.3127	5.3314	0.0000	0.0000	0.0906
FRCC	FRCC All	65,716.1	208,123,783.6	23.6531	4.4222	54.8319	0.6348	1.7398	0.0099	13.9907	0.0000	0.0046	0.0000	0.7130
HIMS	HICC Miscellaneous	881.5	3,019,123.5	1.9907	69.8707	0.0000	7.1345	3.3481	3.7312	0.0000	8.3278	0.0460	5.5510	0.0000
HIOA	HICC Oahu	1,925.6	7,991,409.4	18.0201	77.6079	0.0000	2.2104	2.1615	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MROE	MRO East	8,881.2	29,587,725.5	68.9039	2.3652	4.9759	0.1206	3.2381	2.7096	15.2608	2.3228	0.0000	0.0000	0.1030
MROW	MRO West	53,894.9	190,640,178.1	69.0860	0.1515	2.3997	0.1600	1.1844	4.3578	13.9045	8.6647	0.0000	0.0000	0.0914
NEWE	NPCC New England	36,906.5	121,742,618.3	11.8606	1.5048	41.9731	1.6223	5.9158	7.0413	29.7601	0.3110	0.0000	0.0000	0.0109
NWPP	WECC Northwest	68,188.2	269,325,957.1	29.8340	0.3352	15.1503	0.1462	1.0927	46.5021	2.4632	3.8023	0.0000	0.5541	0.1199
NYCW	NPCC NYC/Westchester	13,914.0	40,501,288.1	0.0000	1.7869	55.8586	0.4808	0.5357	0.0185	40.8410	0.4784	0.0000	0.0000	0.0000
NYLI	NPCC Long Island	6,002.5	9,431,561.8	0.0000	12.9940	77.3406	4.5546	5.1108	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NYUP	NPCC Upstate NY	24,408.3	88,081,534.5	14.4853	0.9024	18.9282	0.3570	1.5950	30.7898	30.5892	2.3530	0.0000	0.0000	0.0000
RFCE	RFC East	73,537.6	261,151,661.8	35.3677	0.7271	17.1304	0.8437	1.3211	1.2358	42.9614	0.4050	0.0055	0.0000	0.0023
RFCM	**RFC Michigan**	**29,501.5**	**88,251,703.2**	**71.9861**	**0.4093**	**9.5071**	**0.5982**	**1.8820**	**0.0000**	**15.2782**	**0.3391**	**0.0000**	**0.0000**	**0.0000**
RFCW	RFC West	146,174.7	561,623,124.7	69.8826	0.4022	3.5051	0.3533	0.5057	0.7949	23.5563	0.9355	0.0000	0.0000	0.0644
RMPA	WECC Rockies	17,516.6	62,070,098.9	67.7689	0.0435	22.5989	0.0000	0.0911	4.3045	0.0000	5.0659	0.0412	0.0000	0.0860
SPNO	SPP North	21,159.4	65,008,815.6	73.8392	0.2559	7.8088	0.0368	0.0289	0.1377	13.4882	4.4044	0.0000	0.0000	0.0000
SPSO	SPP South	43,413.8	140,443,029.2	55.2342	0.1667	33.8651	0.2189	1.2052	5.5274	0.0000	3.7798	0.0000	0.0000	0.0027
SRMV	SERC Mississippi Valley	50,443.7	165,358,644.7	22.7319	1.4534	45.0929	0.8605	1.9253	1.7270	25.9742	0.0000	0.0000	0.0000	0.2347
SRMW	SERC Midwest	27,319.6	112,061,747.1	79.7879	0.0884	1.0399	0.0122	0.1270	1.7552	17.0754	0.1140	0.0000	0.0000	0.0000
SRSO	SERC South	70,962.7	252,713,667.3	52.1843	0.3499	22.3083	0.0748	2.9228	4.0925	18.0664	0.0000	0.0000	0.0000	0.0010
SRTV	SERC Tennessee Valley	67,069.4	238,173,939.7	58.8034	0.9387	8.6065	0.0087	0.7817	8.5808	22.1286	0.1516	0.0000	0.0000	0.0000
SRVC	SERC Virginia/Carolina	80,187.5	293,154,419.6	45.1039	0.6421	8.9501	0.1921	2.0466	1.6491	41.3467	0.0000	0.0016	0.0000	0.0678
U.S.		**1,134,441.5**	**3,951,097,802.2**	**44.4675**	**1.1174**	**23.3119**	**0.3414**	**1.3779**	**6.8033**	**20.2185**	**1.8614**	**0.0223**	**0.3799**	**0.0984**



This is a representational map; many of the boundaries shown on this map are approximate because they are based on companies, not on strictly geographical boundaries.

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