Nebraska Community Energy Alliance
Nebraska Solar Economic and Environmental Report
October 2021 Edition

- Central City
- City of Superior
- Fremont
- Gothenburg

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Executive Summary

The mission of the Nebraska Community Energy Alliance (NCEA) is to build and promote advanced technologies for housing and transportation that save energy, reduce CO_2 pollution and cut costs, (http://www.necommunity.energy/mission/). NCEA believes that demonstrating these technical advances ***at the local level*** is the best way to accelerate the market in Nebraska. Establishing the economic and environmental benefits of advanced technologies, such as solar energy projects, at this level will serve the mission of the NCEA and the mission of the Nebraska Environmental Trust (NET), a grant funder. NET aims "to conserve, enhance and restore the natural environments of Nebraska", (http://www.environmentaltrust.org/about/index.html).

In collaboration with the University of Nebraska-Lincoln, data from the AlsoEnergy PowerTrack™ solar monitoring system is being collected, processed, and analyzed to document the environmental and economic benefits of the photovoltaic solar systems installed in Central City, Superior, Fremont, and Gothenburg in Nebraska. A summary of the collected data is shown in Table 1. The energy savings is calculated based on the cost of electricity if it was provided through the local electricity provider. For Central City, Superior, Fremont, and Gothenburg, the rates of utility provided electricity are $0.0853/kWh, $0.09/kWh, $0.0985/kWh, and $0.0801/kWh, respectively.

Table 1. Cumulative Data Summary

Data Summary		Central City		Superior		Fremont		Gothenburg		TOTAL
		Oct 21	All time	Oct 21	All time	Oct 21	All time	Oct 21	All time	All Time
Energy Output (MWh)		55.67	3,459.24	150.00	5,535.18	107.93	5,784.02	132.68	5,216.69	19,995.13
Energy Savings		$4,749	$297,898	$12,795	$472,300	$10,631	$605,414	$10,627	$440,844	$1,816,456
Emissions Reductions	Emission Type	(lbs.)	(tons)	(lbs.)	(tons)	(lbs.)	(tons)	(lbs.)	(tons)	(tons)
	CO_2	83,751.94	2,196.06	225,663.9	3,683.66	158,100	4,645.33	199,604	3,422.43	13,947.48
	CO	56.21	1.55	151.46	2.79	145.38	5.47	133.97	2.52	12.3
	CH_4	6.75	0.14	18.19	0.28	22.60	0.74	16.09	0.25	1.41
	N_2O	0.98	0.030	2.65	0.049	3.57	0.112	2.34	0.046	0.24
	SO_2	153.05	4.24	412.37	7.01	256.74	7.24	364.75	6.54	25.02
	NOx	261.91	6.14	705.70	11.32	169.17	5.70	624.20	10.19	33.35
	VOC	1.47	0.032	3.97	0.056	1.67	0.061	3.51	0.051	0.20

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Economic and Environmental Report

I- Introduction

The Nebraska Community Energy Alliance (NCEA) was founded in June 2014 as an inter-local cooperative agency. Today, it has 37 members that span the entire state of Nebraska. Figure 1 shows these members and their locations across the state.

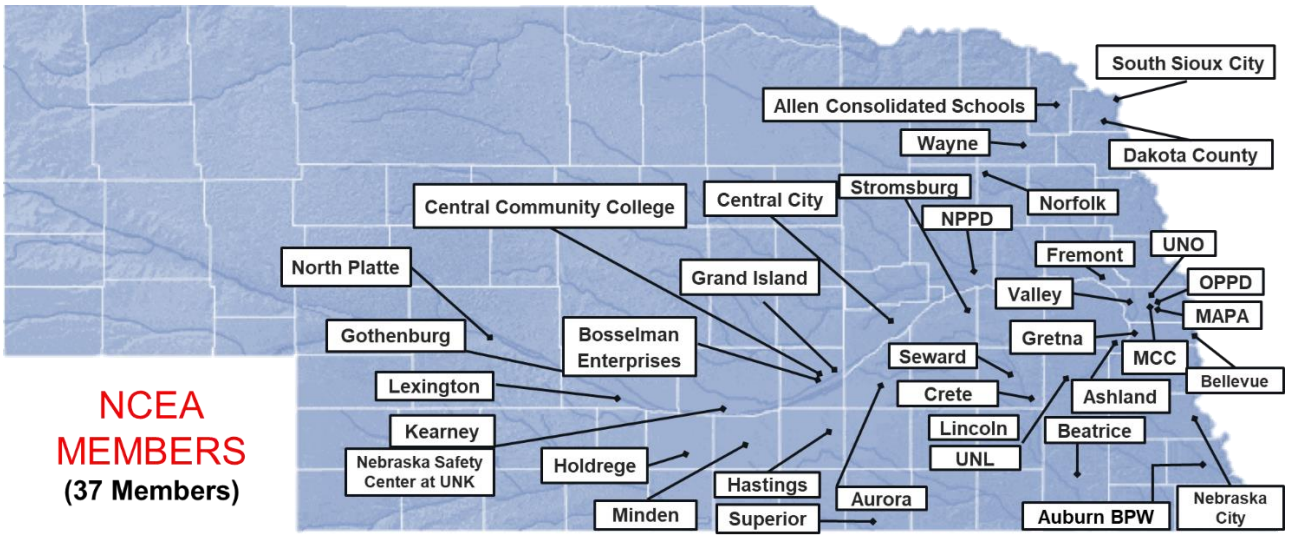


Figure 1. Nebraska Map Showing the 35 NCEA Participating Members

The mission of the Nebraska Community Energy Alliance (NCEA) is to build and promote advanced technologies for housing and transportation that save energy, reduce CO_2 pollution and cut costs, (http://www.necommunity.energy/mission/). This mission is clearly articulated by Mr. Lance Hedquist, City Administrator for South Sioux City and a founder of NCEA, "*Communities have a choice to simply exist or to lead. Our projects demonstrate leadership and help motivate and excite our citizens."*

NCEA believes demonstrating the economic and environmental air quality benefits of clean energy ***at the local level*** is the best way to accelerate the market in Nebraska. This mission is being achieved in part using grant funding from the Nebraska Environmental Trust (NET) and its own mission **"to conserve, enhance and restore the natural environments of Nebraska."** (http://www.environmentaltrust.org/about/index.html).

Table 2 shows the participating members and their involvement.

Table 2. Participating Members and their Involvement

Participating Members	Solar Energy System Size
Allen	6 kW
Central City	500 kW
Fremont	1 MW
Gothenburg	1 MW
Superior	1 MW

In collaboration with the Durham School of Architectural Engineering and Constructions (DSAEC) at the University of Nebraska-Lincoln, data is being collected, processed, and analyzed from the solar installations through AlsoEnergy PowerTrack™ solar monitoring system to document the environmental and economic benefits.

II- Detailed Data Analysis

Data analysis, tables and graphs for the solar system installed in Central City, Superior, Fremont, and Gothenburg are provided on the following pages. Detailed calculations are provided in the Appendix.

Central City

Central City is located in Merrick County, Nebraska, with an estimated population of 2,934 residents at the 2010 census. The electric service for the city was established in 1909 and is owned and operated by Central City [1]. Power is purchased in partnership with the Nebraska Public Power District (NPPD). The city currently has approximately 1,693 customers, including 1,393 residential customers. In their partnership with NPPD, Central City provides assistance with incentive programs, technical assistance, and economic development support. For example, Central City offers assistance to low-income property owners with heating and air-conditioning replacement projects.

Data Analysis

The Mesner Solar Development, Inc.[2]–[4] developed the 500 kW single axis tracking photovoltaic solar installation system in Central City. The installation became operational toward the end of August 2017. Table 3 provides data analysis for the month of October 2021 and since August 2017. Figures 2, 3 and 4 provide detailed information about the daily and monthly generation. The energy savings is calculated based on the cost of electricity if it was provided through the local electricity provider. For Central City, electricity costs $0.0853/kWh.

Table 3. Monthly and Total Savings

		October 2021	All Time
Energy Output (MWh)		55.67	3,459.24
Energy Savings		$4,749	$297,898
Emissions Reductions	Emission Type	(lbs.)	(tons)
	CO_2	83,751.94	2,196.06
	CO	56.21	1.55
	CH_4	6.75	0.14
	N_2O	0.98	0.030
	SO_2	153.05	4.24
	NOx	261.91	6.14
	VOC	1.47	0.032

Equivalencies:

If the generated power is used as a fuel for electric cars, the cars will drive the following miles

October: 189,946.04 miles
All time: 11,793,242.30 miles

Average monthly electricity consumption for a U.S. residential customer is 877 kWh per month [5], [6]**, and 1,004 kWh per month for residential customers in Nebraska** [6]**. Generated electricity can deliver power to the following number of houses**

October: 58 Houses

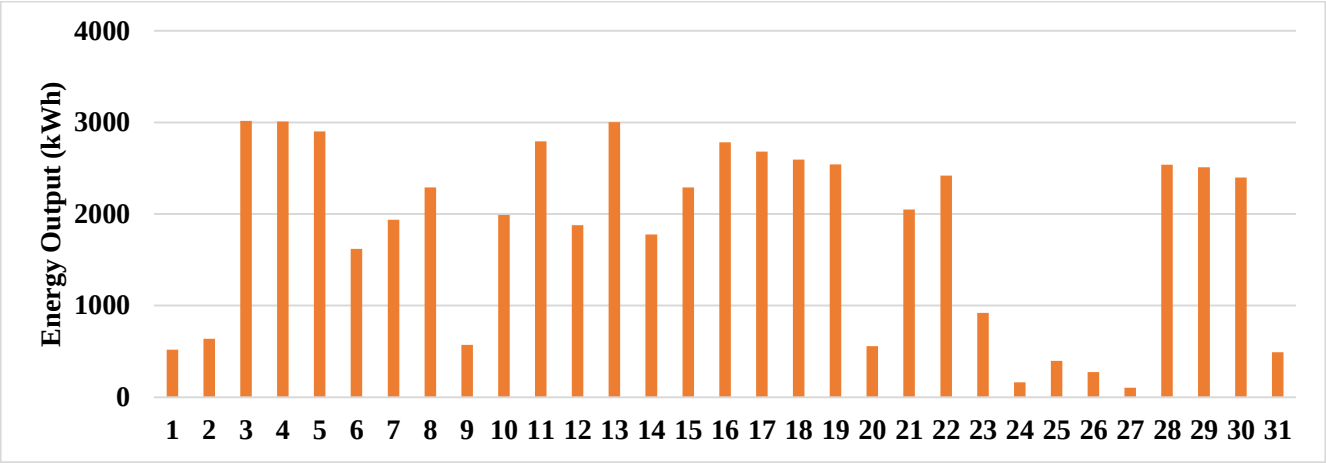


Figure 2. Daily Power Output for the Month of October 2021

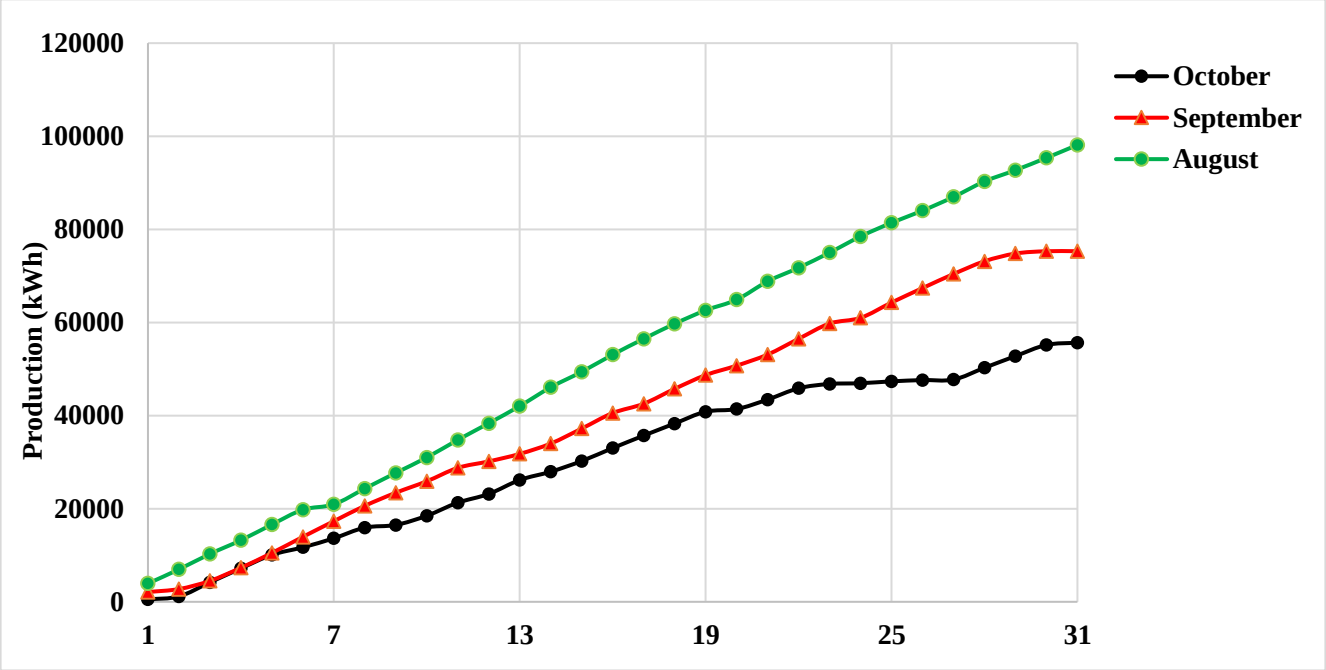


Figure 3. Cumulative Daily Production Data for August, September, and October 2021

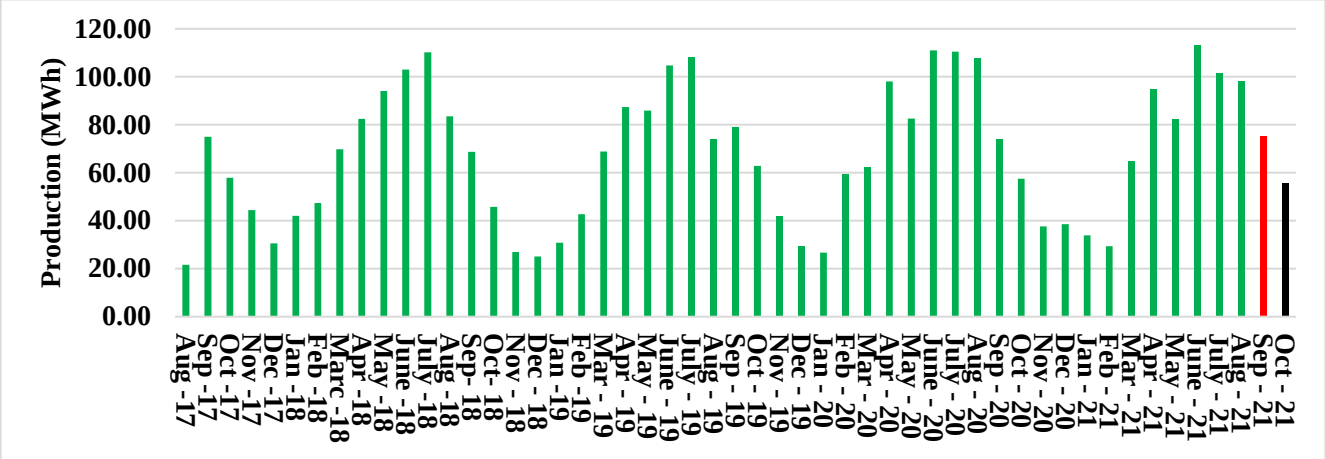


Figure 4. Monthly Production Data for the System since Installation in August 2017

City of Superior

The city of Superior is in Nuckolls County, Nebraska, with a population of 1,957 residents at the 2010 census. Power is currently purchased with wholesale power supply agreements with the Nebraska Public Power District (NPPD) [7] and American Electric Power (AEP) Inc. Superior owns its distribution system with 2 substations accumulating to 10 MVA [8]. The city uses an average of approximately 72 MWh of power per day. The solar array could produce 8-10% of the city's average daily use.

Data Analysis

AEP Onsite Partners LLC, a subsidiary of American Electric Power (AEP) Inc., developed the 1 MW fixed axis photovoltaic solar installation system in Superior [9]. The installation became operational toward the end of December 2018. Table 4 provides data analysis for the month of October 2021 and since December 2018. Figures 5, 6 and 7 provide detailed information about the daily and monthly generation. The energy savings is calculated based on the cost of electricity if it was provided through the local electricity provider. For Superior, the rate of utility provided electricity is $0.09/kWh [10].

Table 4. Monthly and Total Savings

		October 2021	All Time
Energy Output (MWh)		150.00	5,535.18
Energy Savings		$12,795	$472,300
Emissions Reductions	Emission Type	(lbs.)	(tons)
	CO_2	225,663.9	3,683.66
	CO	151.46	2.79
	CH_4	18.19	0.28
	N_2O	2.65	0.049
	SO_2	412.37	7.01
	NOx	705.70	11.32
	VOC	3.97	0.056

Equivalencies:

If the generated power is used as a fuel for electric cars, the cars will drive the following miles

October: 511,796.59 miles
All time: 18,591,986.6 miles

Average monthly electricity consumption for a U.S. residential customer is 877 kWh per month [5], [6]**, and 1,004 kWh per month for residential customers in Nebraska** [6]**. Generated electricity can deliver power to the following number of houses**

October: 156 Houses

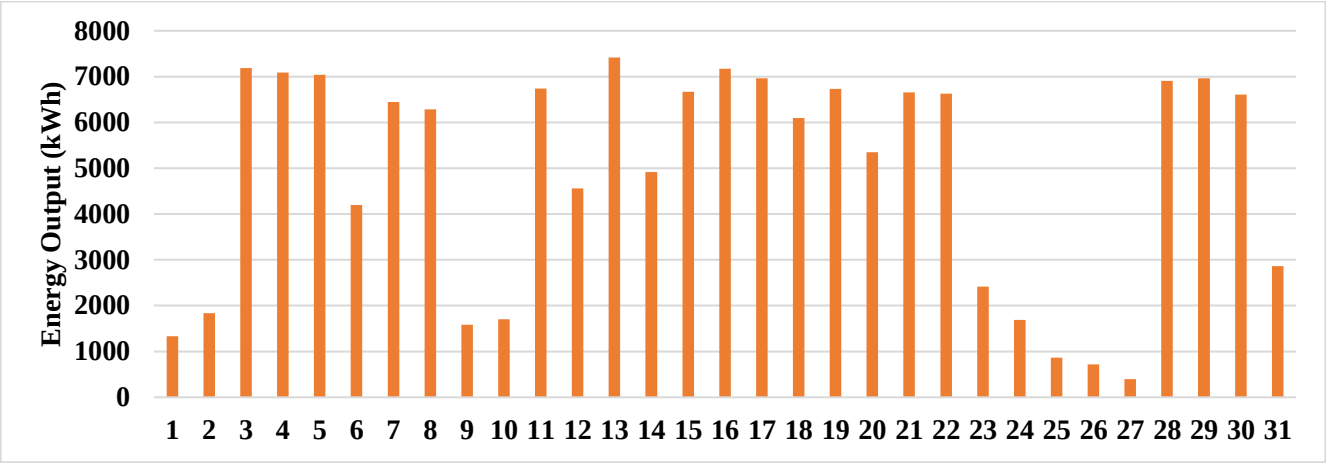


Figure 5. Daily Power Output for the Month of October 2021

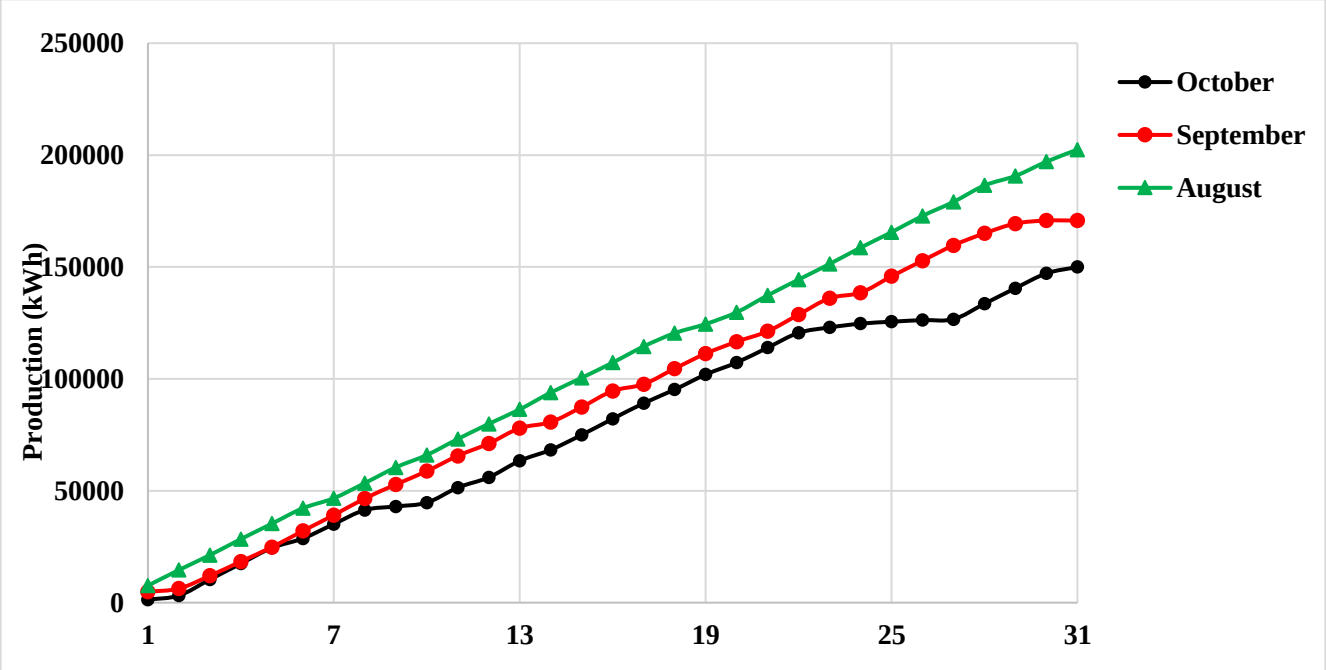


Figure 6. Cumulative Daily Production Data for August, September, and October 2021

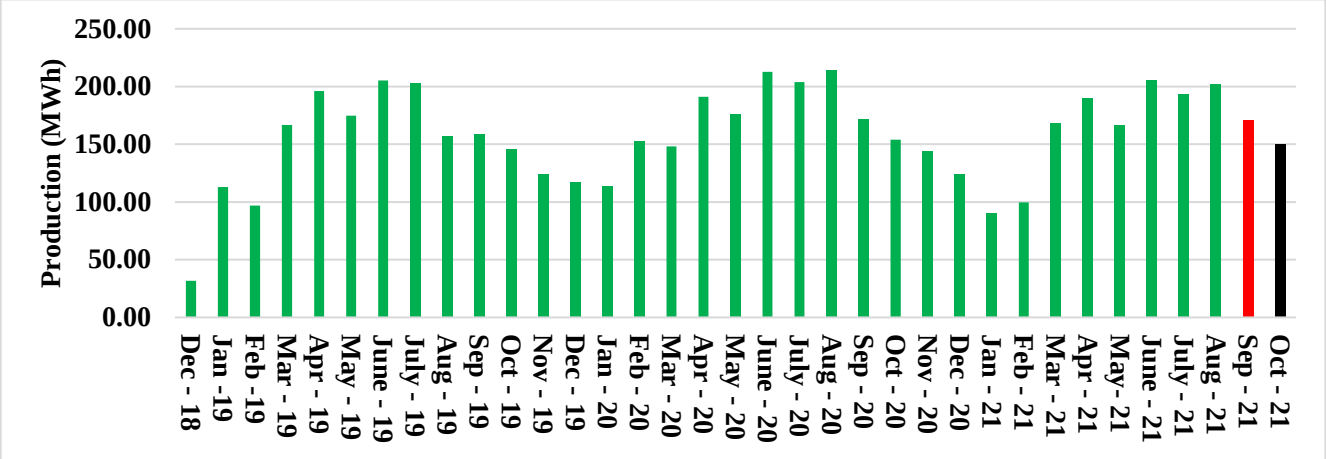


Figure 7. Monthly Production Data for the System since Installation in December 2018

Fremont

Fremont is located in Dodge County, Nebraska, with an estimated population of 26,397 residents at the 2010 census. The Fremont Department of Utilities Electrical System was established in 1895 and it covers 60 square miles including the city of Fremont and the surrounding area [11]. The Electric Service maintains approximately 394 miles of cabling that includes 261.69 miles of overhead and 132.06 miles of underground. The city currently has approximately 14,210 customers.

Data Analysis

The installed (Phase II) system in Fremont is a 1 MW photovoltaic solar system and it is being built by GenPro Energy Solutions [12]. The Phase II installation became operational from the mid of September 2018. Table 5 provides data analysis for the month of October 2021 and since installation in September 2018. Figures 8, 9 and 10 provide detailed information about the daily and monthly generation. The energy savings is calculated based on the cost of electricity if it was provided through the local electricity provider. For Fremont, electricity costs $0.0985/kWh [13].

Table 5. Monthly and Total Savings

		October 2021	All Time
Energy Output (MWh)		107.93	5,784.02
Energy Savings		$10,631	$605,414
Emissions Reductions	Emission Type	(lbs.)	(tons)
	CO_2	158,100	4,645.33
	CO	145.38	5.47
	CH_4	22.60	0.74
	N_2O	3.57	0.112
	SO_2	256.74	7.24
	NOx	169.17	5.70
	VOC	1.67	0.061

Equivalencies:

If the generated power is used as a fuel for electric cars, the cars will drive the following miles

October: 368,246.92 miles
All time: 19,409,289.90 miles

Average monthly electricity consumption for a U.S. residential customer is 877 kWh per month [5], [6]**, and 1,004 kWh per month for residential customers in Nebraska** [6]**. Generated electricity can deliver power to the following number of houses**

October: 107 Houses

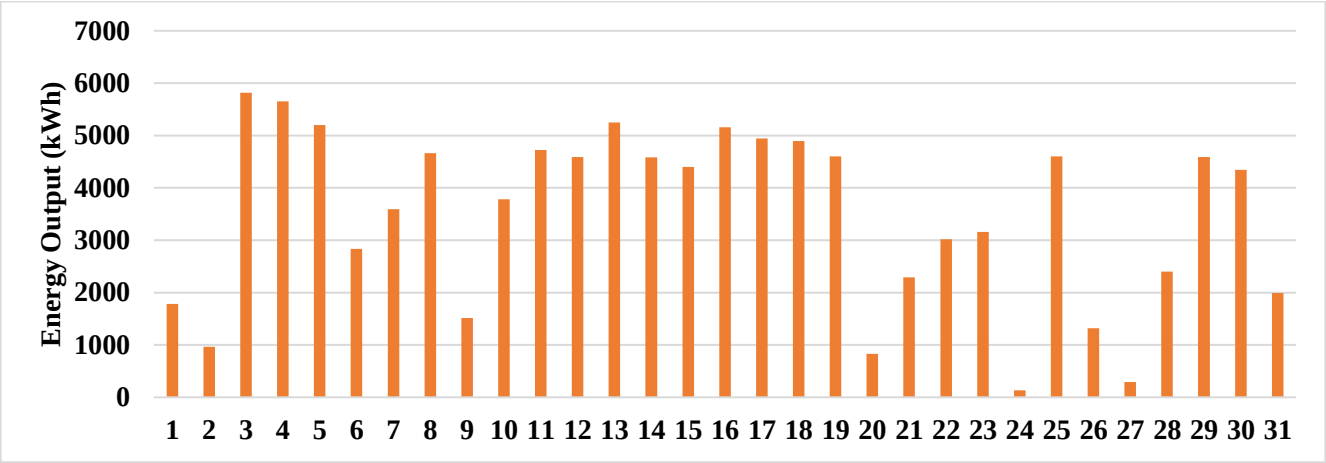


Figure 8. Daily Power Output for the Month of October 2021

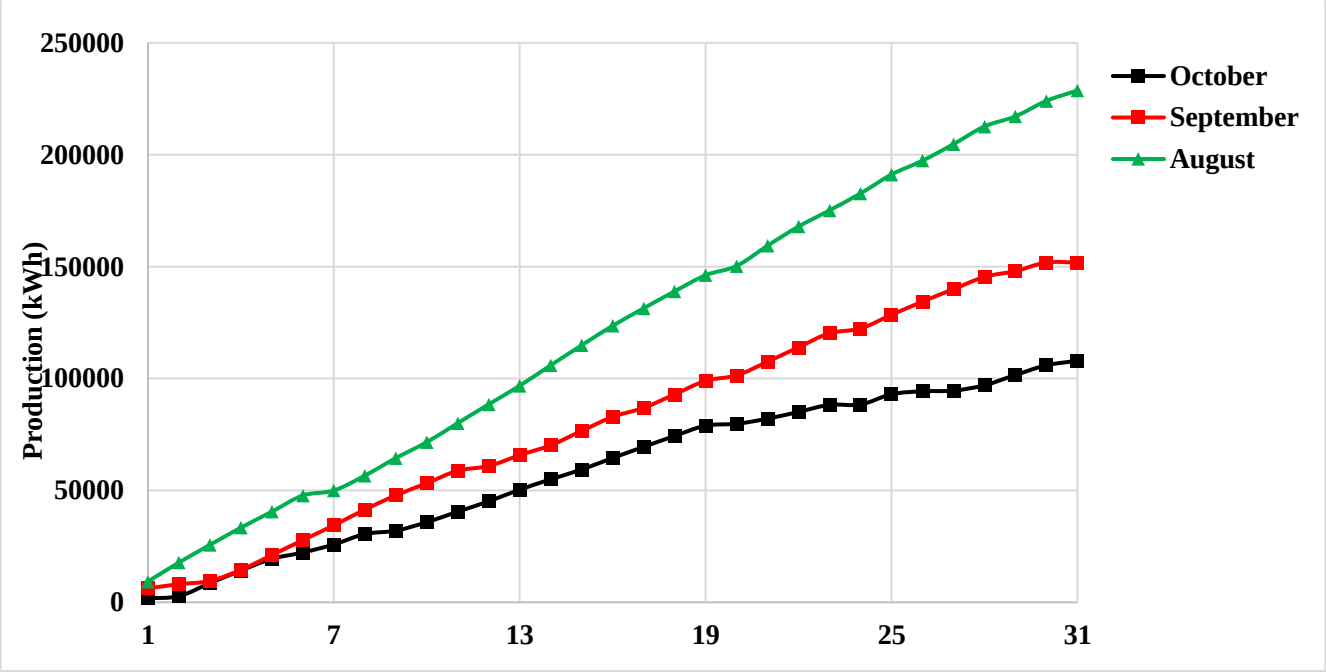


Figure 9. Cumulative Daily Production Data for August, September, and October 2021

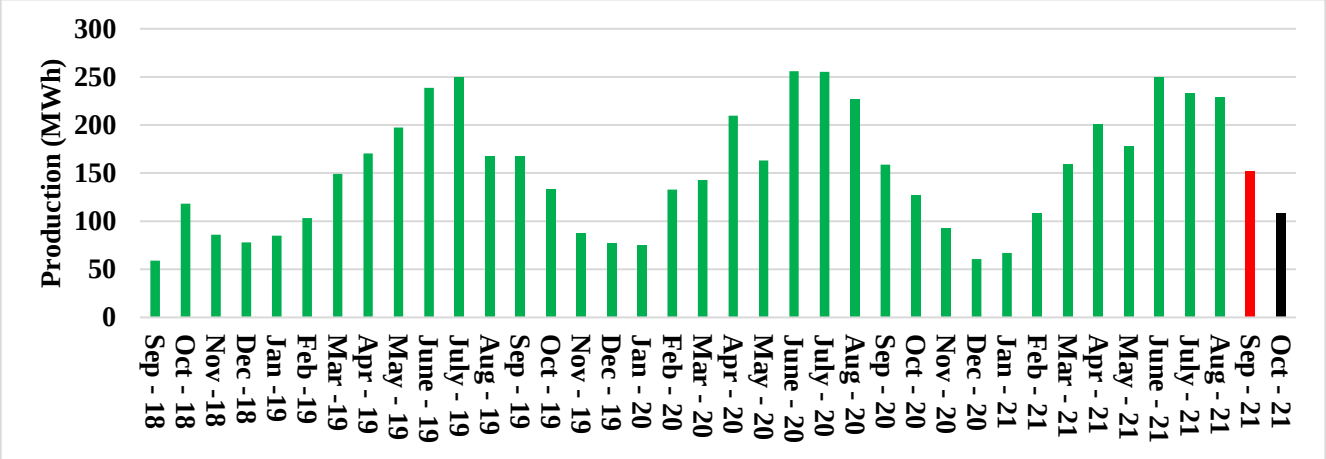


Figure 10. Monthly Production Data for the System since Installation in October 2018

Gothenburg

Gothenburg is located in Dawson County, Nebraska, with an estimated population of 3,574 residents at the 2010 census. Gothenburg is a municipally owned distribution system with four substations accumulating to 13,750 KVA [14]. Power is purchased from a wholesale power supply agreement with the Nebraska Public Power District (NPPD). Gothenburg also encourages their residents to increase their energy efficiency by using the Home Energy Calculator to make comparisons to similar homes.

Data Analysis

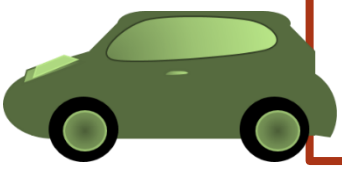
The installed system (Phase-I and Phase-II) in Gothenburg is a 1MW single axis tracking photovoltaic solar system. Phase-I became operational toward the end of January 2018 and Phase-II installation became operational in mid of June 2019. Table 6 provides data analysis for the month of October 2021 and since installation in January 2018. Figures 11(a), 11(b), 12(a), 12(b), 13(a), and 13(b) provide detailed information about the daily and monthly generation. The energy savings is calculated based on the cost of electricity if it was provided through the local electricity provider. For Gothenburg, electricity costs $0.0801/kWh.

Table 6. Monthly and Total Savings

		October 2021		All Time
		Phase-I	Phase-II	Phase-I + Phase-II
Energy Output (MWh)		61.74	70.94	5,216.69
Energy Savings		$4,946	$5,682	$440,844
Emissions Reductions	Emission Type	(lbs.)	(lbs.)	(tons)
	CO_2	92,887	106,717.15	3,422.43
	CO	62.34	71.62	2.52
	CH_4	7.49	8.60	0.25
	N_2O	1.09	1.251	0.046
	SO_2	169.74	195.01	6.54
	NO_x	290.48	333.73	10.19
	VOC	1.63	1.877	0.051

Equivalencies:

If the generated power is used as a fuel for electric cars, the cars will drive the following miles



October: Phase-I: 210,663.70 miles
Phase-II: 242,030.22 miles
All time: 17,619,190.82 miles

Average monthly electricity consumption for a U.S. residential customer is 877 kWh per month [5], [6]**, and 1,004 kWh per month for residential customers in Nebraska** [6]**. Generated electricity can deliver power to the following number of houses**

October: Phase-I: 61 Houses
Phase-II: 70 Houses

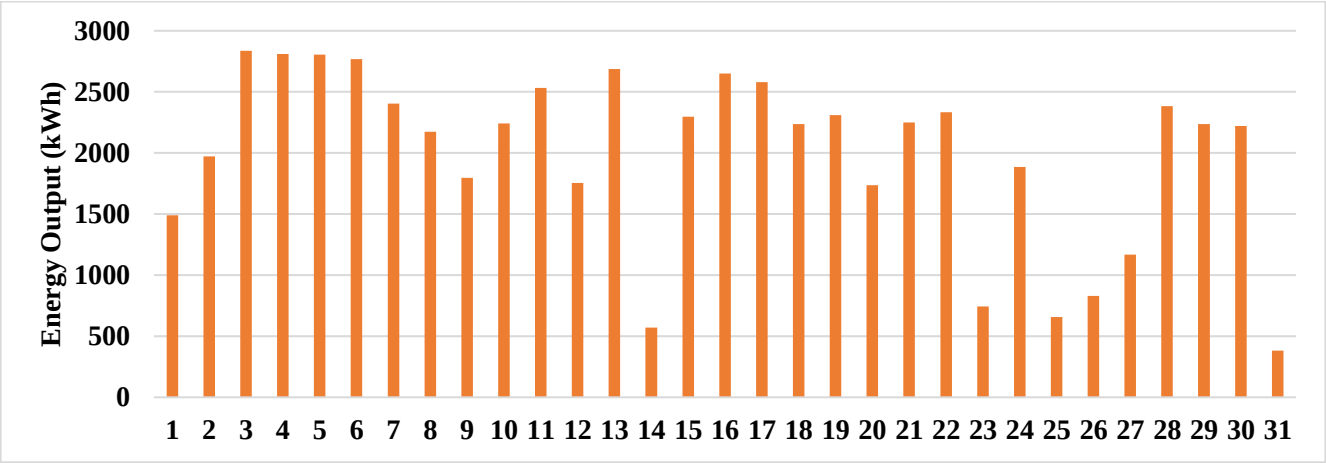


Figure 11.a. Daily Power Output for the Month of October 2021. (Phase-I)

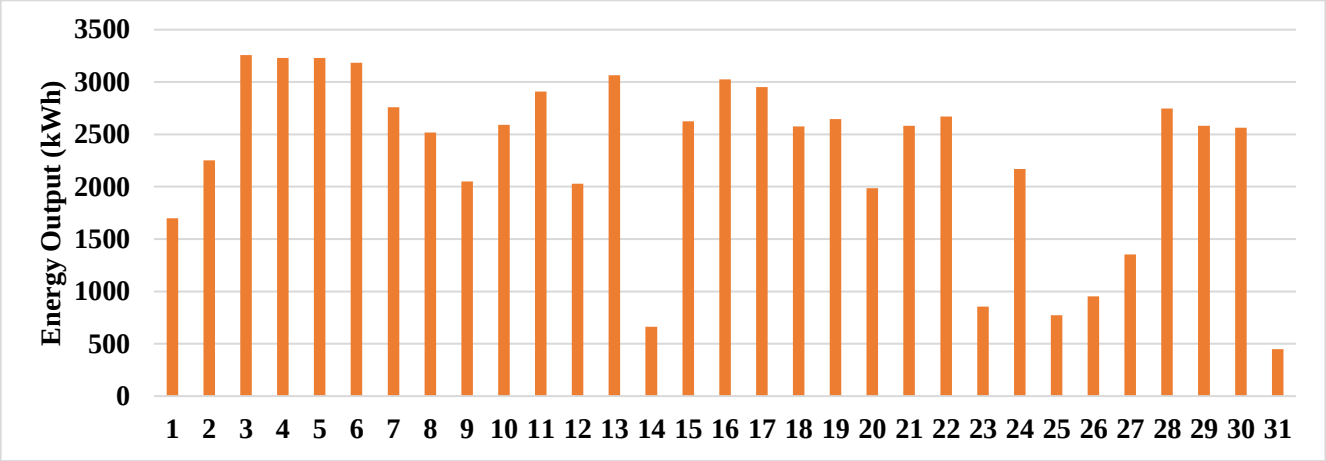


Figure 11.b. Daily Power Output for the Month of October 2021. (Phase-II)

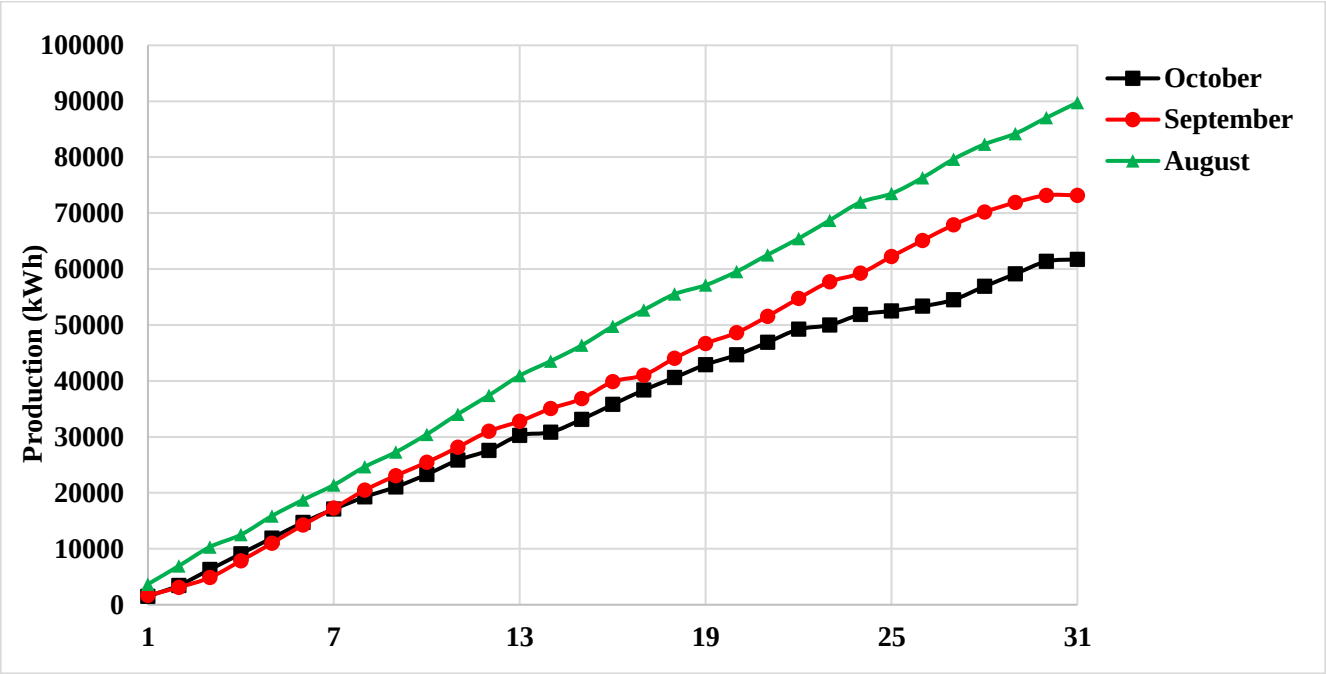


Figure 12.a. Cumulative Daily Production Data for August, September, and October 2021. (Phase-I)

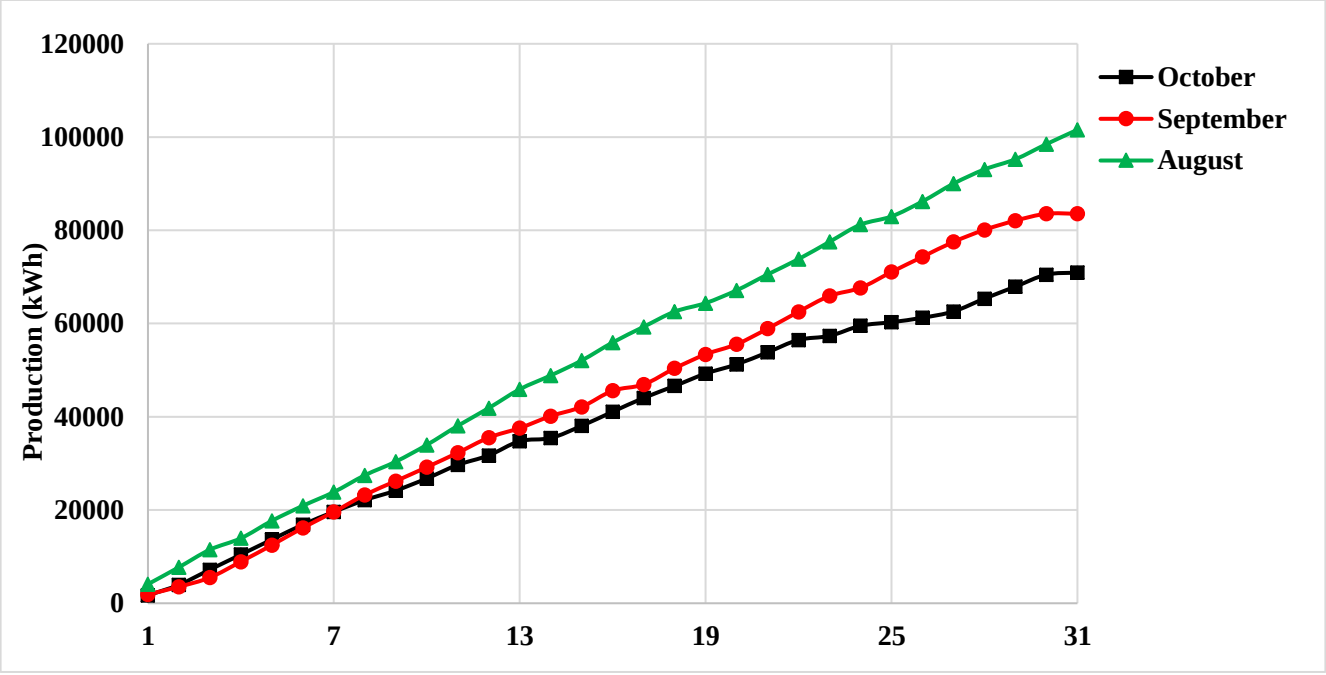


Figure 12.b. Cumulative Daily Production Data for August, September, and October 2021. (Phase-II)

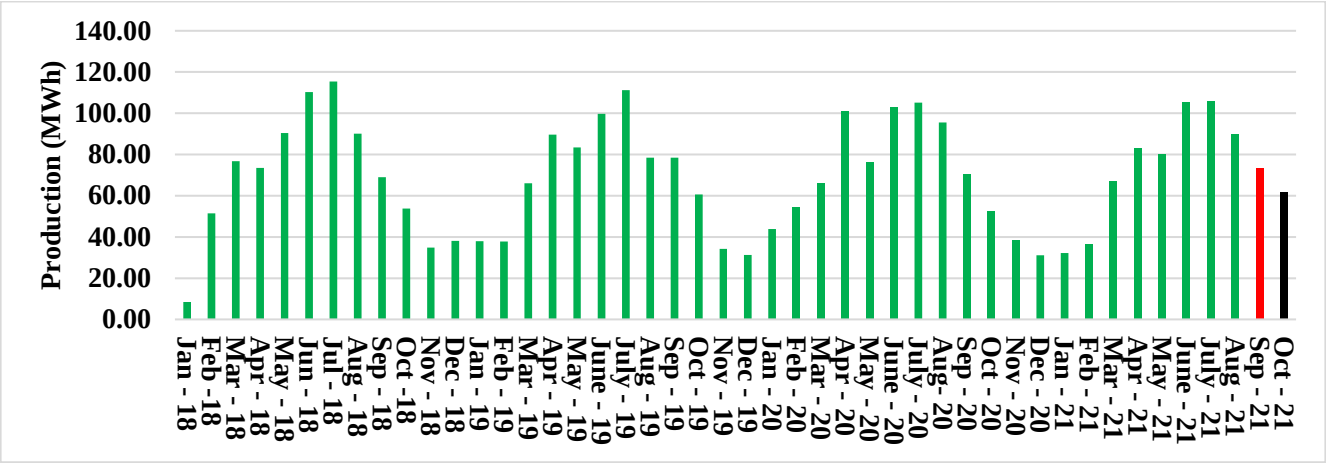


Figure 13.a. Monthly Production Data for the System since Installation in January 2018. (Phase-I)

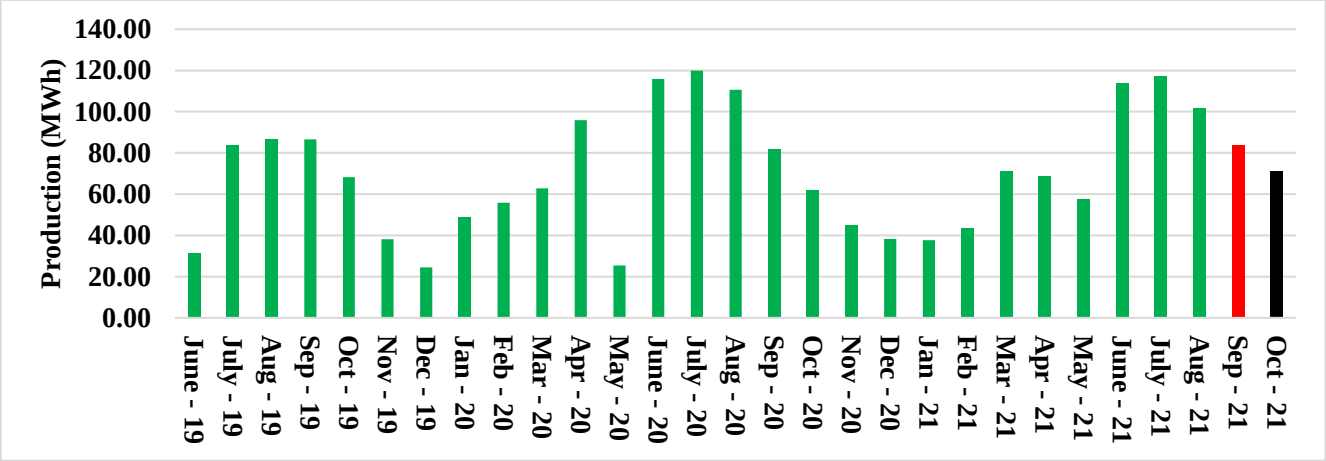


Figure 13.b. Monthly Production Data for the System since Installation in June 2019. (Phase-II)

APPENDIX

A. Emission and Economy Analysis Calculation

$$\text{Total Energy Saving per month, ES} = \sum_{i=1}^{m} E_i \times C, \quad (1)$$

$i = 1{:}\,m, m \textit{ equals to the length of month}$

where E_i is energy in a given day (kWh) and C is the energy price $\left(\frac{\$}{\text{kWh}}\right)$.

$$\text{Total number of houses that can be powered} = \frac{ES}{HC} \quad (2)$$

where ES is the total saved energy in a month and HC is the average residential monthly electricity consumption constant $(957 \frac{\text{kWh}}{\text{month}})$

$$\text{Electric Vehicle (EV) total equivalent miles} = \sum_{i=1}^{m} E_i \times V \quad (3)$$

where V is the EV equivalent miles per kWh that is 3.412 $\left(\frac{mi}{kWh}\right)$.

$$\text{Total } CO_2 \text{ Emission} = \sum_{i=1}^{m} E_i \times \alpha \quad (4)$$

where α is the equivalent amount of CO_2 per kWh $\left(\frac{lbs.}{kWh}\right)$.

$$\text{Total } CO \text{ Emission} = \sum_{i=1}^{m} E_i \times \beta \quad (5)$$

where β is the equivalent amount of CO per kWh $\left(\frac{lbs.}{kWh}\right)$.

$$\text{Total } CH_4 \text{ Emission} = \sum_{i=1}^{m} E_i \times \gamma \quad (6)$$

where γ is the equivalent amount of CH_4 per kWh $\left(\frac{lbs.}{kWh}\right)$.

$$\text{Total } N_2O \text{ Emission} = \sum_{i=1}^{m} E_i \times \eta \quad (7)$$

where η is the equivalent amount of N_2O per kWh $\left(\frac{lbs.}{kWh}\right)$.

$$Total\ SO_2\ Emission\ = \sum_{i=1}^{m} E_i \times \lambda \quad (8)$$

where λ is the equivalent amount of SO_2 per kWh $\left(\frac{lbs.}{kWh}\right)$.

$$\text{Total } NO_x \text{ Emission } = \sum_{i=1}^{m} E_i \times \rho \quad (9)$$

where ρ is the equivalent amount of NO_x per kWh $\left(\frac{lbs.}{kWh}\right)$.

$$\text{Total } VOC \text{ Emission } = \sum_{i=1}^{m} E_i \times \phi \quad (10)$$

where ϕ is the equivalent amount of VOC per kWh $\left(\frac{lbs.}{kWh}\right)$.

B. Greenhouse Gas Definitions

A greenhouse gas (GHG) is a gas that contributes to the greenhouse effect by infrared radiation produced by solar warming of the earth's surface. The following information provides a definition of each type of GHG emission and detailed analysis of how these GHG emissions are calculated along with supporting references.

Carbon Dioxide Equivalent (CO_2 Equiv.)

The CO_2 equivalent gives a total emissions factor for the three most dominant greenhouse gasses, CO_2, CH_4, and N_2O. Each of the three gasses is multiplied by its global warming potential (GWP) shown below which accounts for the overall effect of each gas on global warming [15]. For example, CH_4 has a GWP of 25 which means that one gram of CH4 has the same effect on global warming as 25 grams of CO2 over a period of a hundred years. Certain gasses are more harmful in the short term or in the long term, so the 100-year value is usually used as a good average. The equation below shows the formula for calculating CO_2 equivalent emissions.

Table A.1. Global warming potential (GWP) values relative to CO_2 [15]

Emission	100-year GWP value
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298

$$CO_2 \text{ Equivalent} = 1*CO_2 \text{ emissions} + 28*CH_4 \text{ emissions} + 265*N_2O \text{ emissions}$$

Carbon Dioxide (CO_2)

Carbon dioxide is the most common greenhouse gas and makes up 81% of all GHG emissions [16]. The majority of CO_2 emissions come directly from electricity generation, transportation, and industry; a smaller fraction comes indirectly from deforestation, increased agriculture, and other activities that reduce the amount of natural land.

Methane (CH_4)

Methane is the second most common greenhouse gas at 10% of all emissions [16], and is also the main component of natural gas. When released into the atmosphere, it reacts to form CH_3 and water vapor, which is the most potent of greenhouse gasses. Methane is far worse in the short term with a 20-year GWP of 84. The long term GWP of methane is 28.

Nitrous Oxide (N_2O)

Nitrous oxide is the third most common greenhouse gas at 6% of all GHG emissions [16]. N_2O reacts with the air to produce nitric oxide (NO), which then reacts with the ozone layer. N_2O is extremely potent and has a GWP factor 265 times that of CO_2.

C. Other Harmful Gases Emitted as a By-product of Electricity Generation

Carbon Monoxide (CO)

Carbon monoxide is a very weak direct greenhouse gas but has important indirect effects on global warming. CO reacts with hydroxyl (OH) radicals in the atmosphere, reducing their abundance.

Sulfur Dioxide (SO_2)

Exposure to sulfur dioxide can have significant impacts to the human respiratory system. Short term exposure to SO_2 can make breathing difficult and the effect is worse for children, the elderly, and those with asthma. SO_2 also contributes to formation of acid rain.

Nitrogen Oxides (NO_x)

Nitrogen oxides can also cause breathing problems for healthy people and especially for those with asthma. The EPA measured that NO_x concentrations inside vehicles can be 2-3 times higher than at locations away from roadways. Nitrogen oxides also react in the air to produce smog and acid rain.

Volatile Organic Compounds (VOC)

Volatile organic compounds cause many problems as indoor and outdoor air pollutants. Outdoor VOC emissions can create photochemical smog. VOCs are any compound of carbon, not including carbon dioxide, carbon monoxide, carbonic acid, metallic carbides, and ammonium carbonate.

D. Emission Calculations – Nebraska Public Power District

Nebraska Public Power District's (NPPD) revenue is mainly derived from wholesale power supply agreements with 46 municipalities and 24 rural public power districts and rural cooperatives who rely totally or partially on NPPD's electrical system. NPPD also serves about 80 communities at the retail level. Approximately 5,352 miles of transmission lines make up the NPPD electrical grid system, which delivers power to about 600,000 Nebraskans [17]. NPPD owns or has operating control of 29 generating facilities, and their current fuel sources include coal, nuclear, natural gas and oil, hydropower, wind and solar. They have two low-sulfur coal stations including Gerald Gentleman Station and Sheldon Station. Their natural gas facilities include the Beatrice Power Station, Canaday Station, and three peaking units located in Hallam, Hebron, and McCook. Wind is supplied from eight facilities located in Nebraska. NPPD operates three hydroelectric generators located in North Platte, Kearney, and Spencer.

The energy mix is estimated from eGRID 2018 power plant data tool [18]. Table C.1 and Table C.2 provide a summary of GHG emissions for each vehicle type based on the primary energy source used for driving one mile and for driving 11556 miles annually.

TABLE C.1. Greenhouse Gas Emissions Factors (grams per mile) for NPPD utility company

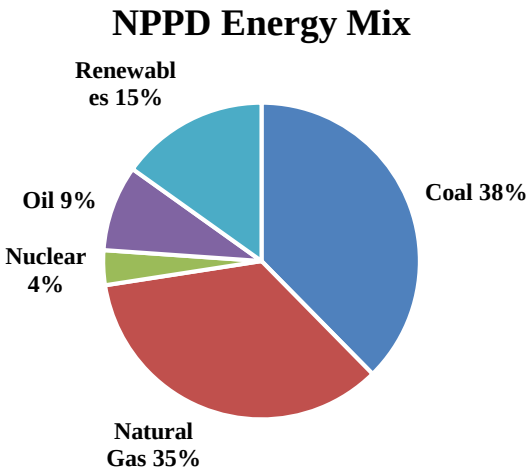
	BEV
Emissions (grams per mile)	**NPPD 2018 (15% Renewable)**
CO_2 Equiv.	201.044
CO_2	199.933
CO	0.1343
CH_4 (Methane)	0.0161
N_2O	0.0024
NOx	0.6252
SO_2	0.3654
VOC	0.0035

TABLE C.2. Greenhouse Gas Emissions in lbs. for one year using an average driving distance of 11,556 miles. (1 lb. = 453.592 g).

	CV	**DV**	**CNG**	**BEV**
Emissions per year (lbs.)				**NPPD 2018 (15% Renewable)**
CO_2 Equiv.	9036.309	8820.522	9282.668	7265.428
CO_2	9020.259	8749.697	9109.682	7135.497
CO	72.891	68.787	69.709	68.787
CH_4 (Methane)	0.171	0.255	0.754	2.611
N_2O	0.041	0.217	0.517	0.217
NOx	3.057	3.057	5.921	3.057
SO_2	0.107	0.015	0.051	0.031
VOC	4.290	5.605	1.839	4.331

Detailed Calculations

The energy mix has been estimated as per the eGRID 2018 power plant data tool [18]. The tables below show the emission calculations.



Carbon Dioxide (CO_2) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of CO_2 Emission per kWh [18]		Contribution to Total Grams of CO_2 Emitted per kWh
Coal	37.63%	x	999.1	=	376.0
Natural Gas	34.92%	x	644.1	=	224.9
Nuclear	3.55%	x	0	=	0
Oil	8.77%	x	929.3	=	81.46
Renewables	15.13%	x	0	=	0
			Total	**grams/kWh**	**682.4**
				grams/mile	**199.93**

Carbon Monoxide (CO) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of CO Emission per kWh[19]		Contribution to Total Grams of CO Emitted per kWh
Coal	37.63%	x	1.0006	=	0.377
Natural Gas	34.92%	x	0.195	=	0.068
Nuclear	3.55%	x	0	=	0.000
Oil	8.77%	x	0.155	=	0.014
Renewables	15.13%	x	0	=	0.000
			Total	**grams/kWh**	**0.458**
				grams/mile	**0.134**

Methane (CH_4) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of CH_4 Emission per kWh[18]		Contribution to Total Grams of CH_4 Emitted per kWh
Coal	37.63%	x	0.126	=	0.0474
Natural Gas	34.92%	x	0.013	=	0.0044
Nuclear	3.55%	x	0	=	0
Oil	8.77%	x	0.037	=	0.0032
Renewables	15.13%	x	0	=	0
			Total	**grams/kWh**	**0.055**
				grams/mile	**0.0161**

Nitrous Oxide (N_2O) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of N_2O Emission per kWh [18]		Contribution to Total Grams of N_2O Emitted per kWh
Coal	37.63%	x	0.018	=	0.007
Natural Gas	34.92%	x	0.002	=	0.0006
Nuclear	3.55%	x	0	=	0
Oil	8.77%	x	0.007	=	0.0006
Renewables	15.13%	x	0	=	0
			Total	**grams/kWh**	**0.008**
				grams/mile	**0.0024**

Sulfur Dioxide (SO_2) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of SO_2 Emission per kWh [18]		Contribution to Total Grams of SO_2 Emitted per kWh
Coal	37.63%	x	2.616	=	0.985
Natural Gas	34.92%	x	0.152	=	0.0532
Nuclear	3.55%	x	0	=	0
Oil	8.77%	x	2.390	=	0.2095
Renewables	15.13%	x	0	=	0
			Total	**grams/kWh**	**1.247**
				grams/mile	**0.3654**

Nitrogen Oxides (NO_x) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of NOx Emission per kWh [18]		Contribution to Total Grams of NOx Emitted per kWh
Coal	37.63%	x	0.931	=	0.350
Natural Gas	34.92%	x	2.574	=	0.8989
Nuclear	3.55%	x	0	=	0
Oil	8.77%	x	10.093	=	0.8847
Renewables	15.13%	x	0	=	0
			Total	**grams/kWh**	**2.134**
				grams/mile	**0.6252**

Volatile Organic Compound (VOC) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of VOC Emission per kWh[19]		Contribution to Total Grams of VOC Emitted per kWh
Coal	37.63%	x	0.011	=	0.004
Natural Gas	34.92%	x	0.017	=	0.0059
Nuclear	3.55%	x	0	=	0
Oil	8.77%	x	0.020	=	0.0017
Renewables	15.13%	x	0	=	0
			Total	**grams/kWh**	**0.012**
				grams/mile	**0.0035**

Carbon Dioxide Equivalent (CO_2) Emissions

Contributing Gas	grams/mile		GWP		Contribution to Total CO_2e Emission
CO_2	199.93	x	1	=	199.9327846
CH_4	0.016	x	25	=	0.403446221
N_2O	0.0024	x	298	=	0.707721896
			Total	**grams/mile**	**201.04**

E. Emission Calculations – Fremont Utilities

The Fremont electric service area covers 60 square miles including the city of Fremont and the surrounding area. The electric division provides power to over 14,210 homes and businesses. The Lon D. Wright Power Plant at First and Luther Road is the utility's power production facility, and it is staffed by three shifts 24-hours a day to provide our customers economical, safe, and reliable electric service.

The coal fired plant located on the east side of Fremont has three units producing 16.5, 22, and 91.5 megawatts, respectively. Each year, the plant uses approximately 370,000 ton of coal to produce about 620,128 megawatt hours of electricity [20].

The energy mix is estimated from eGRID 2018 power plant data tool [18]. Table D.1 and Table D.2 provide a summary of GHG emissions for each vehicle type based on the primary energy source used for driving one mile and for driving 11556 miles annually.

TABLE D.1. Greenhouse Gas Emissions Factors (grams per mile) for Fremont utility company

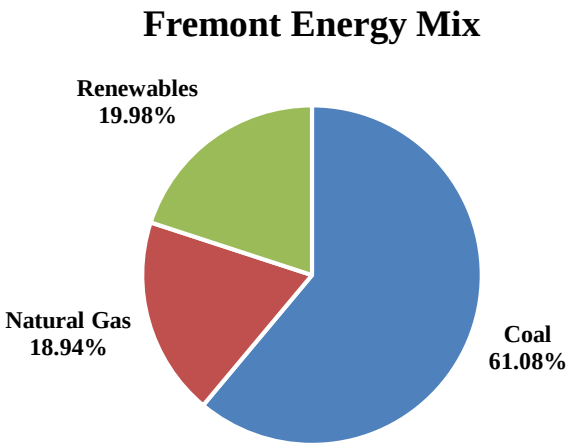
	BEV
Emissions (grams per mile)	**Fremont 2018 (20% Renewable)**
CO_2 Equiv.	196.683
CO_2	194.684
CO	0.1791
CH_4 (Methane)	0.0280
N_2O	0.0044
NOx	0.2082
SO_2	0.3163
VOC	0.0020

TABLE D.2. Greenhouse Gas Emissions in lbs. for one year using an average driving distance of 11,556 miles (1 lb. = 453.592 g).

	CV	**DV**	**CNG**	**BEV**
Emissions per year (lbs.)				**Fremont 2018 (20% Renewable)**
CO_2 Equiv.	9036.309	8820.522	9282.668	7265.428
CO_2	9020.259	8749.697	9109.682	7135.497
CO	72.891	68.787	69.709	68.787
CH_4 (Methane)	0.171	0.255	0.754	2.611
N_2O	0.041	0.217	0.517	0.217
NOx	3.057	3.057	5.921	3.057
SO_2	0.107	0.015	0.051	0.031
VOC	4.290	5.605	1.839	4.331

Detailed Calculations

According to the official city of Fremont website, The Lon D. Wright Power Plant at First and Luther Road is the utility's power production facility. The coal fired plant located on the east side of Fremont has three units producing 16.5, 22, and 91.5 megawatts, respectively. Each year the plant uses approximately 370,000 ton of coal to produce about 620,128 megawatt hours of electricity [20]. The energy mix has been estimated as per the eGRID 2018 power plant data tool [18].



Carbon Dioxide (CO_2) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of CO_2 Emission per kWh [18]		Contribution to Total Grams of CO_2 Emitted per kWh
Coal	61.08%	x	830.3	=	507.2
Natural Gas	18.94%	x	830	=	157.3
Renewables	19.98%	x	0	=	0
			Total	**grams/kWh**	**664.456**
				grams/mile	**194.684**

Carbon Monoxide (CO) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of CO Emission per kWh [19]		Contribution to Total Grams of CO Emitted per kWh
Coal	61.08%	x	1.0006	=	0.611
Natural Gas	18.94%	x	0	=	0.000
Renewables	19.98%	x	0	=	0
			Total	**grams/kWh**	**0.611**
				grams/mile	**0.1791**

Methane (CH_4) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of CH_4 Emission per kWh [18]		Contribution to Total Grams of CH_4 Emitted per kWh
Coal	61.08%	x	0.1	=	0.0781
Natural Gas	18.94%	x	0	=	0.0174
Renewables	19.98%	x	0	=	0
			Total	**grams/kWh**	**0.095**
				grams/mile	**0.0280**

Nitrous Oxide (N_2O) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of N_2O Emission per kWh [18]		Contribution to Total Grams of N_2O Emitted per kWh
Coal	61.08%	x	0.0	=	0.0114
Natural Gas	18.94%	x	0	=	0.0035
Renewables	19.98%	x	0	=	0
			Total	**grams/kWh**	**0.015**
				grams/mile	**0.0044**

Sulfur Dioxide (SO_2) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of SO_2 Emission per kWh [18]		Contribution to Total Grams of SO_2 Emitted per kWh
Coal	61.08%	x	1.3	=	0.824
Natural Gas	18.94%	x	1	=	0.2555
Renewables	19.98%	x	0	=	0
			Total	**grams/kWh**	**1.079**
				grams/mile	**0.3163**

Nitrogen Oxides (NO_x) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of NOx Emission per kWh [18]		Contribution to Total Grams of NOx Emitted per kWh
Coal	61.08%	x	0.9	=	0.542
Natural Gas	18.94%	x	1	=	0.1682
Renewables	19.98%	x	0	=	0
			Total	**grams/kWh**	**0.711**
				grams/mile	**0.2082**

Volatile Organic Compound (VOC) Emissions

Energy Source	Percentage of Total Energy Production [18]		Grams of VOC Emission per kWh [19]		Contribution to Total Grams of VOC Emitted per kWh
Coal	61.08%	x	0.011	=	0.007
Natural Gas	18.94%	x	0	=	0.0000
Renewables	19.98%	x	0	=	0
			Total	**grams/kWh**	**0.007**
				grams/mile	**0.0020**

Carbon Dioxide Equivalent (CO_2) Emissions

Contributing Gas	grams/mile		GWP		Contribution to Total CO_2e Emission
CO_2	194.68	x	1	=	194.6837675
CH_4	0.028	x	25	=	0.69943229
N_2O	0.0044	x	298	=	1.299399135
			Total	**grams/mile**	**196.68**

References

[1] "Central City, NE Community Profile," 2017. http://www.cc-ne.com/ccne (accessed Jul. 02, 2018).

[2] "Mesner Development :: Solar Development," 2015. http://www.mesnerdevelopment.com/solar_development.shtml (accessed Jul. 02, 2018).

[3] "SOLAR EXAMPLES | Nebraskans for Solar." http://www.nebraskansforsolar.org/solarexamples/ (accessed Jul. 05, 2018).

[4] "Nebraska's Solar Energy Generation." http://www.neo.ne.gov/statshtml/198.htm (accessed Jul. 05, 2018).

[5] U.S. Energy Information Administration (EIA), "How much electricity does an American home use?," 2018. https://www.eia.gov/tools/faqs/faq.php?id=97&t=3 (accessed Mar. 27, 2019).

[6] U. S. E. I. A. (EIA), "2019 Average Monthly Bill-Residential (Data from forms EIA-861-schedules 4A-D, EIA-861S and EIA-861U)." https://www.eia.gov/electricity/sales_revenue_price/pdf/table5_a.pdf (accessed Oct. 10, 2020).

[7] Nebraska Public Power District, "Who We Serve." https://www.nppd.com/about-us/who-we-serve/ (accessed Jan. 07, 2019).

[8] I. JEO Consulting Group, "Superior, Nebraska Comprehensive Development Plan 2024." Accessed: Jan. 13, 2019. [Online]. Available: http://www.cityofsuperior.org/cityCodes/Comp Plan/SuperiorCompPlan.pdf.

[9] Donna Christensen, "Superior buys into solar power with AEP contract | News | hastingstribune.com," *Hastings Tribune*, 2017. http://www.hastingstribune.com/news/superior-buys-into-solar-power-with-aep-contract/article_0e4fbcf2-d60b-11e7-a1d5-0399726834ac.html (accessed Jan. 07, 2019).

[10] City of Superior, "Resolution NO. 10-24," 2010. http://www.cityofsuperior.org/images/utilityRates/electricrates.pdf (accessed Jan. 07, 2019).

[11] City of Fremont, "Utilities | Fremont, NE - Official Website." https://www.fremontne.gov/23/Utilities (accessed Oct. 17, 2018).

[12] Nebraskans for Solar, "Fremont's Community Solar Farms | Nebraskans for Solar." http://www.nebraskansforsolar.org/tag/fremonts-community-solar-farms/ (accessed Oct. 17, 2018).

[13] "An ordinance of the city of Fremont, Nebraska." https://www.fremontne.gov/DocumentCenter/View/5437/2019-Electric-Ordinance-5511-CC-10-29-19-REV (accessed Oct. 10, 2020).

[14] N. P. P. District, "Utilities- Gothenburg, NE," 2009. https://www.ci.gothenburg.ne.us/utilities.asp (accessed Jul. 05, 2018).

[15] C. for Corporate Climate Leadership, "Emission Factors for Greenhouse Gas Inventories," 2018. Accessed: Oct. 10, 2020. [Online]. Available: https://www.ecfr.gov/cgi-bin/text-idx?SID=ae265d7d6f98ec86fcd8640b9793a3f6&mc=true&node=pt40.23.98&rgn=div5#ap40.23.98_19.1.

[16] O. US EPA, "Overview of Greenhouse Gases | Greenhouse Gas (GHG) Emissions | US EPA," 2015. https://www.epa.gov/ghgemissions/overview-greenhouse-gases (accessed Oct. 10, 2020).

[17] "About Us." https://www.nppd.com/about-us (accessed Oct. 10, 2020).

[18] US EPA OAR, "Emissions & Generation Resource Integrated Database (eGRID) | US EPA." https://www.epa.gov/egrid (accessed Oct. 10, 2020).

[19] California Environmental Protection Agency Air Resources Board, "Detailed California-Modified GREET Pathway for California Average and Marginal Electricity," *Station. Source Div.*, 2009, Accessed: Jul. 02, 2018. [Online]. Available: https://www.arb.ca.gov/fuels/lcfs/022709lcfs_elec.pdf.

[20] "Electric Generation | Fremont, NE - Official Website." https://www.fremontne.gov/423/Electric-Generation (accessed Oct. 10, 2020).