Technical Appendix - City of Nome

Wind Resource Measurement

NJUS is surrounded to the east and north by hilly terrain and hence has several wind site options but two stand out: Banner Ridge, five miles north-northwest of city center, home to two existing EWT DW52-900 wind turbines; and Cape Nome, 13 miles east-southeast of city center, where modeling indicates an excellent wind resource and where NJUS plans to route new distribution to power a communications tower and mining development.

Nome, Banner Ridge, and Cape Nome, Google Earth image

Banner Ridge

Since 2008, NJUS has been operating two EWT DW52-900 wind turbines on Banner Ridge. To update the wind flow model of the ridge, NJUS condensed eight years of high-resolution DW52 turbine anemometer data to 10-minute time steps for a 2022 siting analysis (the anemometers and wind vanes are located on top of the nacelles, 52 meters above ground level). The data sets were analyzed using Windographer software, which included manual filtering for electrical outages and apparent icing events. The data was combined into a single file and is viewable as two individual turbines or a combined turbine. Banner Ridge winds are seasonally variable with strong winds in the winter and lighter winds in the summer. This mirrors Nome's seasonal electric load profile of higher winter loads and lower summer loads. The wind resource is documented in a Feb. 2022 technical memorandum to NJUS from V3 Energy LLC, subject: *Banner Ridge Site Recommendations for New EWT Wind Turbines.*

Banner Ridge wind resource summary table

Variable	EWT1--WIND-SPEED	EWT2--WIND-SPEED	Speed 52m cmb
Measurement height (m)	52	52	52
Mean wind speed (m/s)	6.48	6.36	6.40
Max 10-min avg. wind speed (m/s)	34.2	35.1	33.6
Weibull k	1.39	1.38	1.40
Weibull A (m/s)	7.03	6.94	6.98
Mean power density (W/m^2)	535	507	508
Mean energy content ($kWh/m^2/yr$)	4,689	4,444	4,448
Data recovery rate (%)	91.2	92.9	95.2

Cape Nome

The winds on Cape Nome have not yet been measured with specialized wind resource assessment instrumentation, but EMD GASP modeling (windPROSPECTING), a widely used and highly respected online wind mapping resource for the wind power industry, predicts a robust wind resource on Cape Nome, with a 7.5 m/s mean wind speed at 50 meters above ground level and a predicted annual energy production of 2.9 GWh/yr (33% capacity factor) for a generic 1 MW wind turbine. The Cape Nome wind resource will be confirmed with met tower or Lidar measurement commencing summer 2024.

EMD GASP model of Cape Nome wind resource

Wind resource details at Cape Nome summit from EMD GASP modeling

Turbine Array Modeling

Wind turbine siting in complex terrain is aided by wind flow modeling such as WAsP software, developed by Technical University of Denmark, which is the world's premier wind flow modeling tool for the wind power industry. The software works by insertion of wind data into a digital elevation map of the prospective site and surrounding area. Individual wind turbines or a wind farm are added to predict energy production for turbines displaced from the wind data source. A feature of the software is calculation of wake loss in multi-turbine arrays, which aids in selecting turbine locations to minimize inter-turbine interference.

Banner Ridge

NJUS commissioned a WAsP modeling report in 2022 with the intention of adding two new EWT turbines on Banner Ridge to complement the existing two EWT DW52-900 models. The modeling and an on-the-ground site inspection confirmed that one of the two intended sites is well suited to locate a new wind turbine but the other intended site location, noted in the table below as EWT 3, is ideal with anticipated annual energy production comparable to the average of the original two.

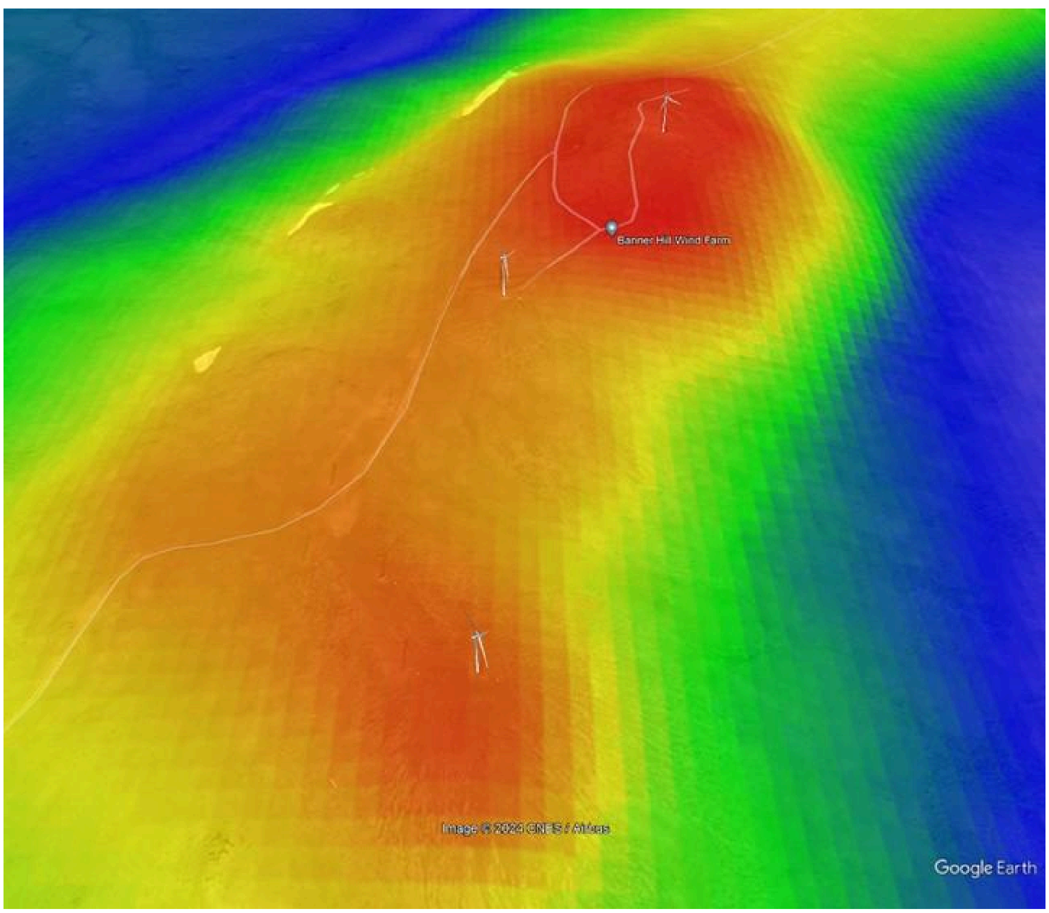
WAsP modeling site results, Banner Ridge

Site	Location	Turbine	Elevation	Height	Net AEP	Wake loss

	[m]		[m a.s.l.]	[m a.g.l.]	[GWh]	[%]
EWT 1	(479331.2,7160242.0)	EWT52-900	174.8	50	2.389	1.58
EWT 2	(479560.6,7160641.0)	EWT52-900	200	50	2.573	1.0
EWT 3	(479315.1,7159754.0)	EWT58-1000	150	46	2.447	0.56

The Google Earth image below shows an overlay of modeled wind speed on Banner Ridge with. Note that the two upper (or northernmost) turbines are existing, the bottom (or southernmost) turbine is "EWT 3", the proposed location for the new EWT DW58-1000 turbine.

WAsP modeling map of Banner Ridge and wind turbines, view north



Cape Nome

Because there is not yet detailed wind reference (met tower) data for Cape Nome, it has not yet been modeled with WAsP software to demonstrate array options for the planned four EWT DW58-1000 wind turbines there. But, the Cape Nome is very long (over 1 km) and broad (approximately ½ km) and will easily accommodate four 1 MW turbines with considerable room for future expansion. Because the orientation of the Cape Nome is principally north-south and the prevailing winds northeast, the planned four new wind turbines can be placed relatively near each other in a north-south alignment and experience little shadowing or wake effect.

Note that wind turbines on Banner Ridge will generate approximately (net with wake loss) 2.4 GWh/year each (note that the existing turbines presently underperform this benchmark due to curtailment requirements to maintain system stability; this will be corrected with installation of a BESS) and turbines on Cape Nome are expected to generate approximately (gross) 2.9 GWh/year each per EMD GASP modeling, or 20% higher. The third Banner Ridge turbine however can be installed immediately while the Cape Nome wind turbines require completion of a wind study, construction of electrical distribution connection to the cape, and construction of a suitable access road to the summit plateau in order to complete that aspect of the project.

Solar Resource

Nome's solar resource for a flat-panel PV array was derived from solar Global Horizontal Irradiation (GHI) data obtained automatically from Homer software (see below). This is accomplished automatically using site location, which determines latitude and enables referencing NASA and NWS databases of average cloud cover for clearness. Homer's help menu states that GHI is the sum of beam radiation (also called direct normal irradiance), diffuse irradiance, and ground-reflected irradiance.

Static Energy Balance Modeling

A companion analysis to wind turbine array design and annual energy production estimation is a static energy balance model using Homer software ([HOMER - Hybrid Renewable and Distributed Generation System Design Software (homerenergy.com)]) to demonstrate how renewable energy assets, such as wind and solar power, will operate within an existing or future isolated (or islanded) grid power system, such as in Nome. For this, recent several year electric load data collected by the Secondary Control and Data Acquisition System (SCADA) in the Snake River Power Plant are combined to create a representative year in one hour time steps.

To this are added the four Power House diesel generators that burn #2 diesel fuel and two wind generators. They are:

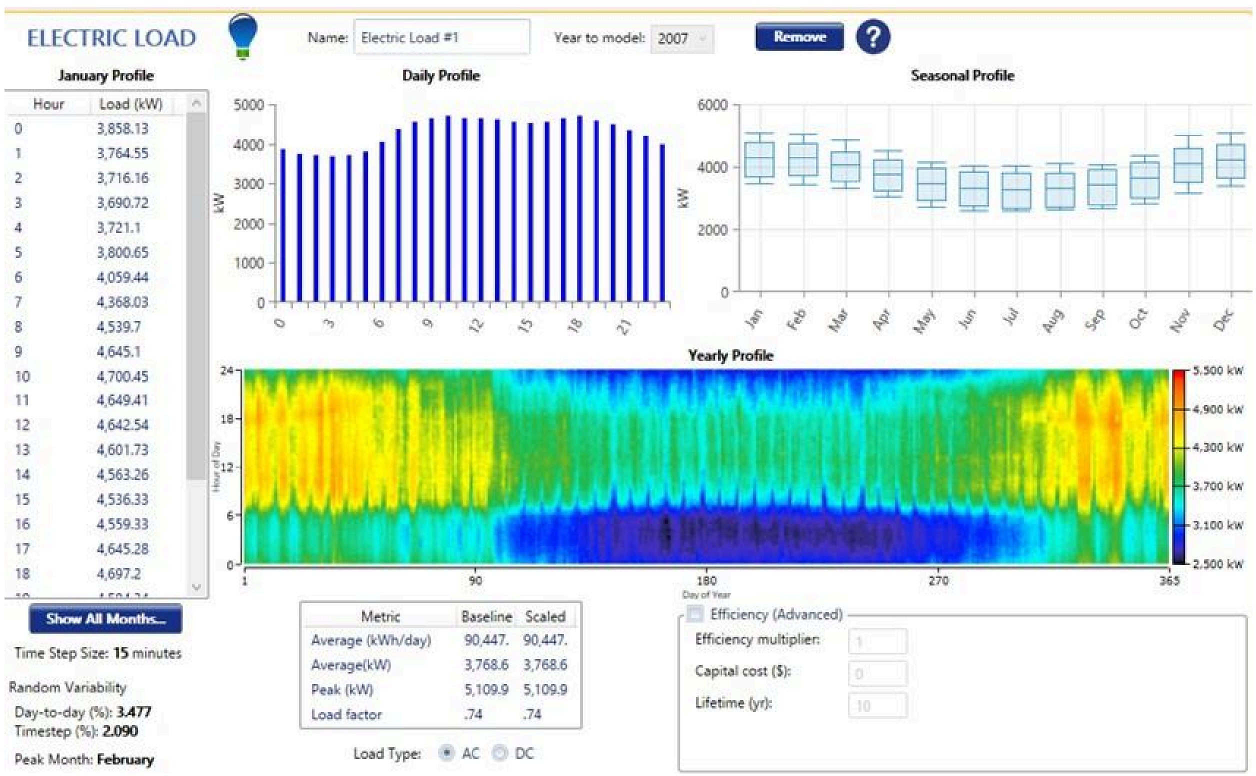
- Unit 15: Wartsila 12V32 – 5.2 MW
- Unit 16: Wartsila 12V32 – 5.2 MW
- Unit 12: Caterpillar 3616 – 3.5 MW
- Unit 14: Caterpillar 3516 – 1.9 MW
- EWT 1 on Banner Ridge (DW52-900 HH50)
- EWT 2 on Banner Ridge (DW52-900 HH50)

Additional wind and solar resources were, respectively, added to the Homer model using measured and internet-accessed data. The former was accomplished for the wind resource using EWT 1 and EWT 2 nacelle anemometer data as noted above. For the solar resource, Homer software was programmed to access a NASA database that combines solar irradiance at Nome's latitude with satellite-measured temporal clearness data.

Homer software also enables one to model a battery energy storage system to demonstrate the benefit of diesel-off operation, which was accomplished in the modeling effort for this grant application. Storage capacity of 7.75 MWh with Saft Intensium Max +20, combined with a 7.5 MW converter, was modeled by EPS, Inc. as suitable for NJUS' planned renewable energy expansion project. Note that battery modeling is a highly complex task and potentially the energy storage and/or converter capacities will be modified during final design, though EPS, Inc. has expressed confidence that these capacities will best serve NJUS' needs.

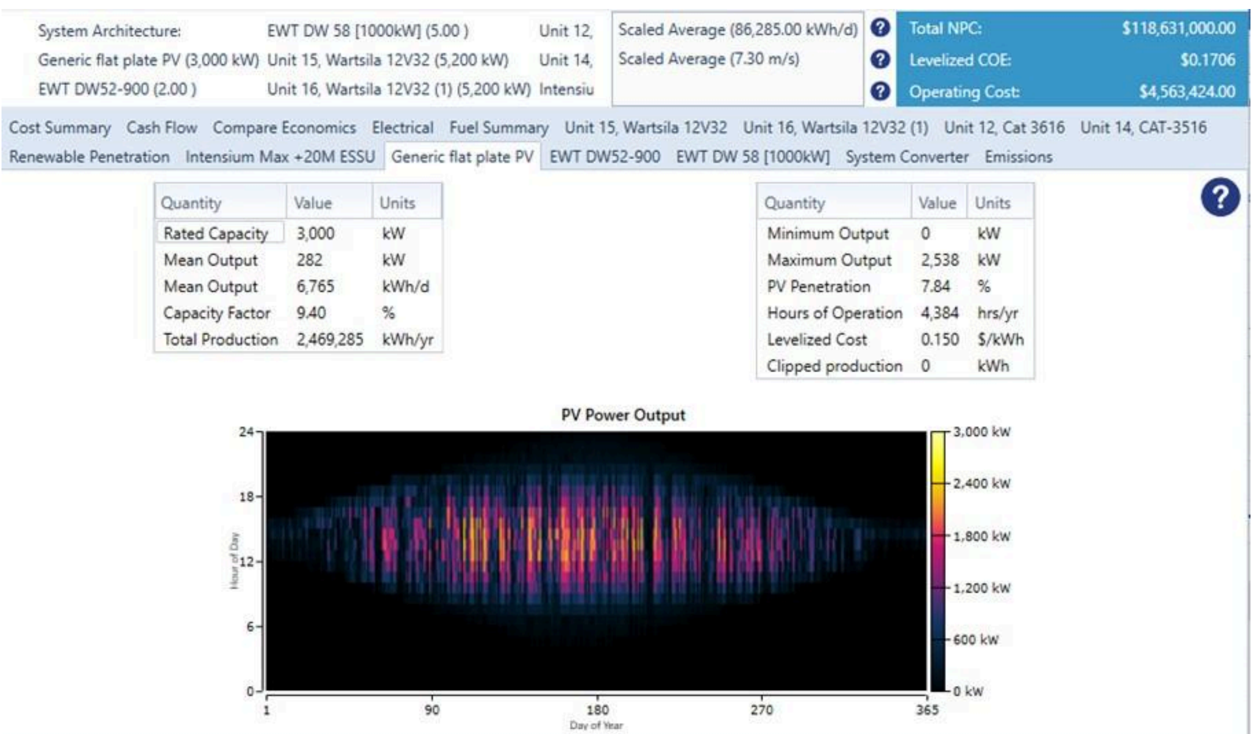
The most power feature of Homer software is its economic optimization model and while for this grant application it was partially set up for that purpose, Homer was mostly used for its energy balance features in order to predict fuel savings from the three planned project iterations: construction of 3 MW solar power capacity in year 1, installation of 1 MW wind power capacity on Banner Ridge in year 2, and construction of an additional 4 MW wind power capacity on Cape Nome in year 3. Homer modeling results are shown below:

Nome electric load, Homer software

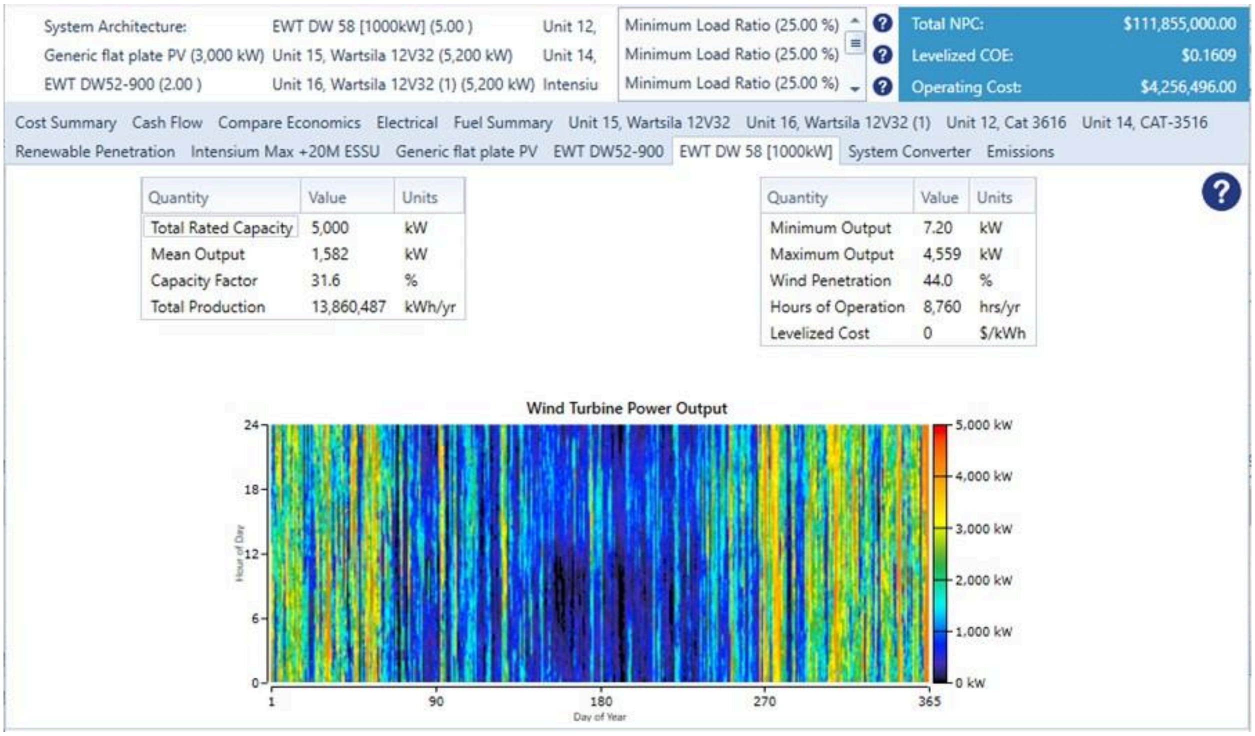


Electrical generation by production source, Homer software

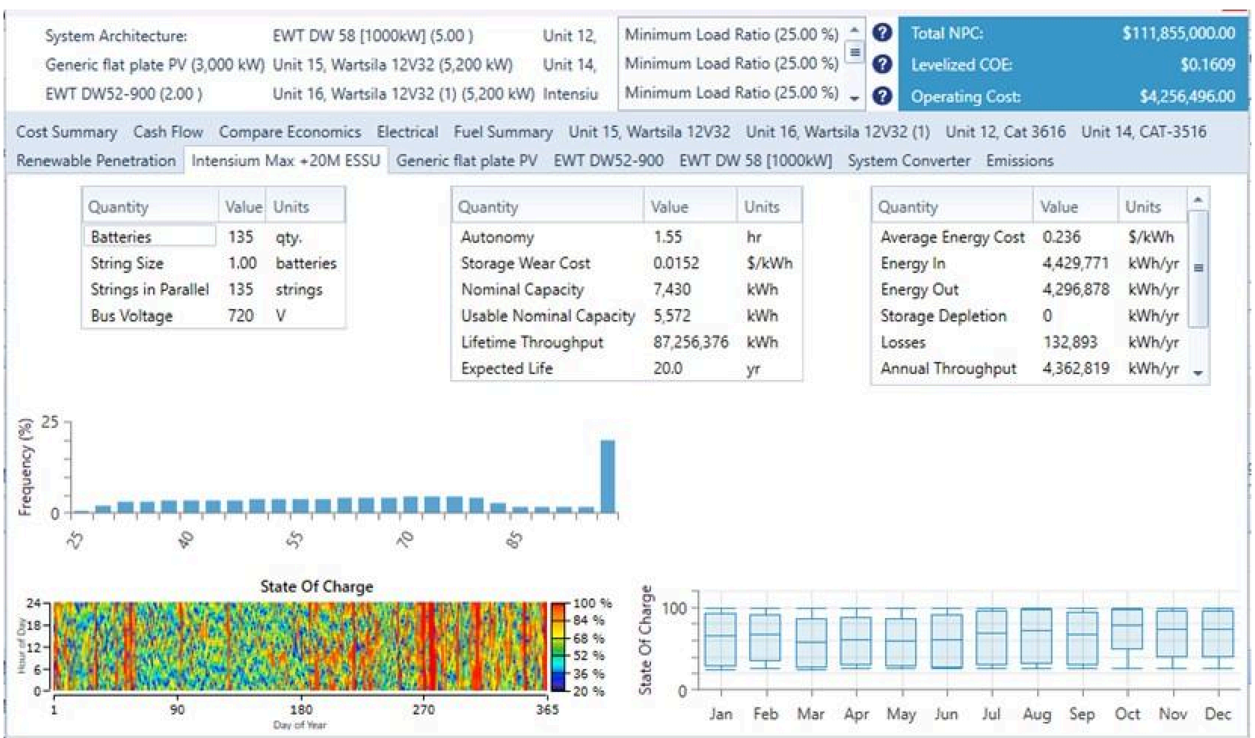
Solar PV energy generation, Homer software



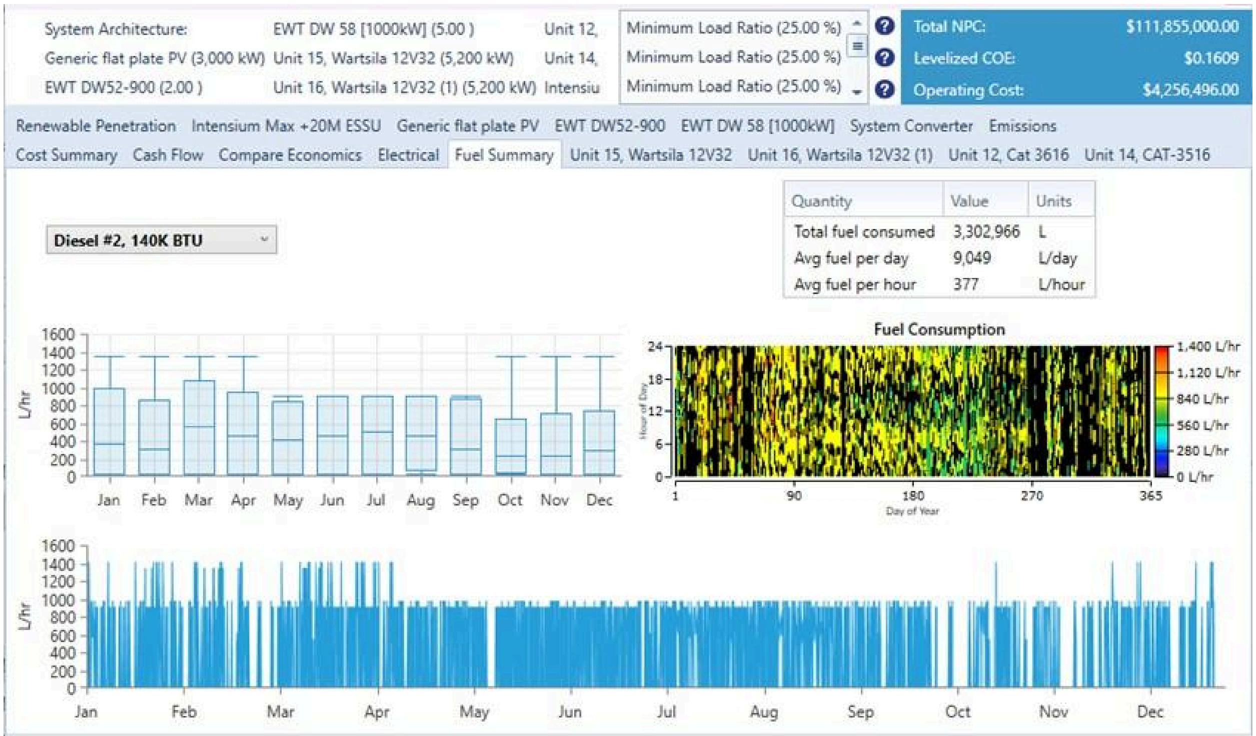
EWT DW58-1000 wind turbine energy generation, Homer software



BESS model, Homer software



Fuel usage with 3 MW solar, 5 MW new wind, 7.75 MWh BESS, Homer software



GHG Calculator

Besides static energy balance and economic optimization, Homer software calculates carbon dioxide emissions for the baseline (comparison) configuration (diesel generation plus the two existing EWT DW52-900 wind turbines), versus the renewable energy alternatives one chooses to analyze, in this case 3 MW solar capacity, 5 additional MW wind capacity (for 7 MW total), and 7.75 MWh BESS capacity with a 7.5 MW converter. These are presented below and compared to CO2-e calculations using EPA's GHG calculator tool. Note that Homer software and EPA's GHG calculator tool return nearly identical results for CO2-e, hence confirming each method.

GHG summary table

Item	Units	Baseline (year 0)	With 3 MW solar, 5 MW new wind, 7.75 MWh BESS (year 3+)	Reduction Magnitude	Reduction Percentage	Notes
Fuel use	gal	1,879,942	872,551	1,007,391	53.6%	Homer software
CO2-e	MT	18,941	8,831	10,110	53.4%	Homer software
CO2-e	MT	19,258	8,938	10,320	53.6%	EPA's Calculator tool

The following table illustrates **GHG emission reductions** for each year of the project with summaries for the first five years of the project and the following twenty years. Modeling indicates that cumulative GHG reduction for project years 1-to-5 is 35.2 kMT and cumulative reduction in project years 6-to-25 is 201.4 kMT. Total project GHG reduction for all 25 years of the project is estimated at 236.6 kMT.

Project timeline of GHG reduction

Project Year	Year	Nome Load, GWh	Existing Wind (2 MW), GWh	Solar (3 MW), GWh	Banner Wind (1 MW), GWh	Cape Wind (4 MW), GWh	Renewable Energy Supplied, GWh	Fossil Fuel Gener., GWh	Fossil fuel usage, M Gal	Total GHG CO2-e, kMT	GHG Reduc. CO2-e, kMT	GHG Reduct. %	Project Period	GHG Reduct. CO2-e, kMT
0	2024	31.5	4.6				4.6	26.9	1.88	18.9			Baseline	
1	2025	31.5	4.6	2.5			7.1	24.5	1.72	17.4	1.5	8.0%		
2	2026	31.5	4.6	2.5	2.8		9.9	21.8	1.53	15.5	3.5	18.3%		
3	2027	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%	Year 0-to-5	35.2
4	2028	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
5	2029	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
6	2030	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
7	2031	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
8	2032	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
9	2033	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
10	2034	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
11	2035	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
12	2036	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
13	2037	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
14	2038	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
15	2039	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%	Year 6-to-25	201.4
16	2040	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
17	2041	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
18	2042	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
19	2043	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
20	2044	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
21	2045	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
22	2046	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
23	2047	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
24	2048	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
25	2049	31.5	4.6	2.5	2.8	11.1	21.0	12.7	0.87	8.8	10.1	53.3%		
Total							503.5				236.6			236.6

Environmental Pollutants

Besides carbon dioxide, Homer software accounts for other environmental pollutant emissions associated with burning fossil fuel for electrical energy generation. These are listed below.

Environmental pollutant summary table

	Baseline (2 MW wind)		7 MW wind, 3 MW solar, 7.5 MWh		Reduction	Reduction Quantity	
Pollutant	Value	Units	Value	Units	%	Value	Units
Carbon dioxide	18.9	kMT/y	8.8	kMT/y	53.3	10.1	kMT/y
Carbon monoxide	58.9	MT/y	6.2	MT/y	89.4	52.7	MT/y
Unburned HC	4.4	MT/y	1.6	MT/y	64.8	2.9	MT/y
Particulate matter	0.8	MT/y	0.4	MT/y	53.8	0.4	MT/y
Sulfur dioxide	38.4	MT/y	18.0	MT/y	53.1	20.4	MT/y
Nitrogen oxides	54.8	MT/y	47.4	MT/y	13.5	7.4	MT/y

References - Available upon request.