Technical Appendix - City of Unalaska

Wind Resource Measurement

The modeling for this grant proposal is a continuation of work that COU initiated six years ago with the installation of four meteorological (met) test towers for wind measurement, including an NRG Systems (NRG Systems - Wind + Solar Measurement Tools) 60 meter met tower at the primary wind site on Obernoi Point. The four year wind study was concluded with a comprehensive wind resource assessment report (*City of Unalaska Wind Power Development and Integration Assessment Project, Wind Resource Assessment Report*, Feb. 2022, V3 Energy LLC) that characterizes the wind resource options for City of Unalaska from several perspectives, including International Electrotechnical Commission (IEC) 61400-1, 3rd ed. design standards to enable selection of an appropriate wind turbine model. We accomplished this latter objective via extensive discussions in late 2022 with Emergya Wind Technologies, B.V., Amersfoot, The Netherlands (Home - EWT - Creating distributed energy champions (ewtdirectwind.com)) that led to our selection of their DirectWind DW58-1000 (1 MW rated capacity) model, coupled with a 59 meter tower. COU choose EWT as a wind turbine provider as their turbine is permanent magnet, direct drive, particularly well suited to isolated grid applications, and EWT as a company is highly responsive and has an extensive support network in the State of Alaska.

Lower Pyramid 60-meter met tower data summary

Data dates	10/16/2018 to 8/12/2021 (34 months)
Datalogger information	NRG Symphonie PRO, 26 channel, site no. 3550
Site coordinates	53.8496 North, 166.5625 West (WGS 84 datum)
Site elevation	103 meters (334 ft.)
Wind speed, mean annual, 60 m level	6.84 m/s corrected to Dutch Harbor Airport long-term weather station data; 6.39 m/s as measured
Wind power density, mean annual, 60 m	548 W/m2 when corrected to Dutch Harbor Airport long-term weather station data; 446 W/m2 as measured
Wind power class	5 (excellent), when corrected to Dutch Harbor Airport long-term weather station data) of 7 defined classifications; 4 (good) as measured
Maximum 10-min. avg wind speed	37.5 m/s (83.9 mph)
Maximum 3-sec. gust wind speed	51.4 m/s (115.0 mph)
Wind shear power law exponent	0.100 (low; 0.140 considered nominal)
Calm wind frequency (winds < 4 m/s)	Approx. 33%

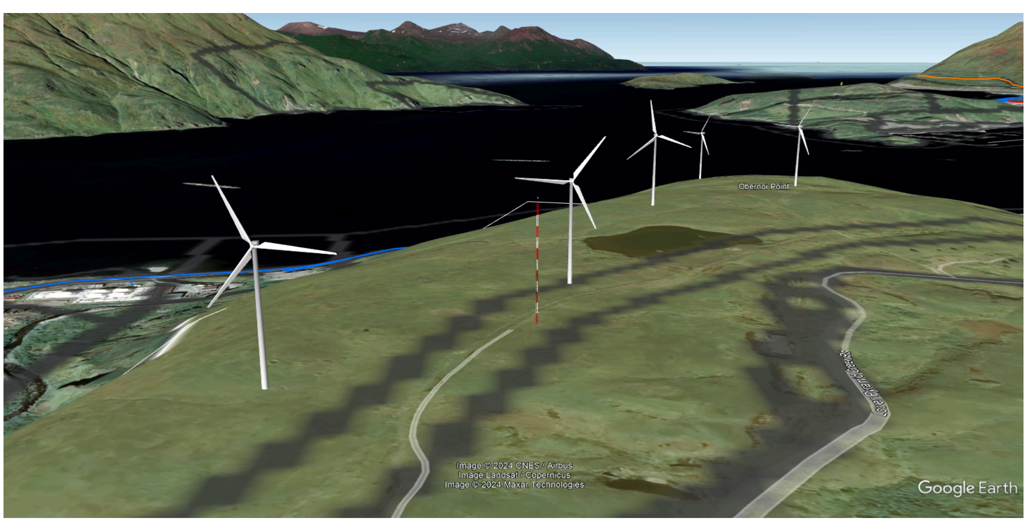
Extreme wind probability (50-year period)	41.3
Turbulence intensity, 60 m level	0.120
IEC 61400-1 3rd ed. classification	Class IIB

Turbine Array Modeling

Following completion of the wind resource study in 2022, a wind flow model of Obernoi Point and lower Pyramid Valley was developed using industry-standard WAsP software (WAsP) to model and predict energy production for several wind turbine array (wind farm) power capacity and array design options that we have considered. This was accomplished by creation of a digital elevation map using XYZ data obtained from the USGS (TNM Download v2 (nationalmap.gov)). With the digital topology map, a wind reference - the met tower data - was inserted into the model with our chosen DW58-1000 wind turbine to assess the maximum number of turbines possible on Obernoi Point that meet industry standards of separation spacing and interference effects. WAsP calculates wind speed and annual energy production for each turbine location in reference to the met tower, and interaction between the turbines throughout the year as wind direction and wind speed changes. This is expressed as wake loss, or the loss of energy generation potential due to shadowing. The accepted wind industry standard of 5 to 8% net wake loss reflects a generalized economic optimization of energy production versus project development costs (e.g., land lease, road access, electrical connection, environmental impact, etc.).

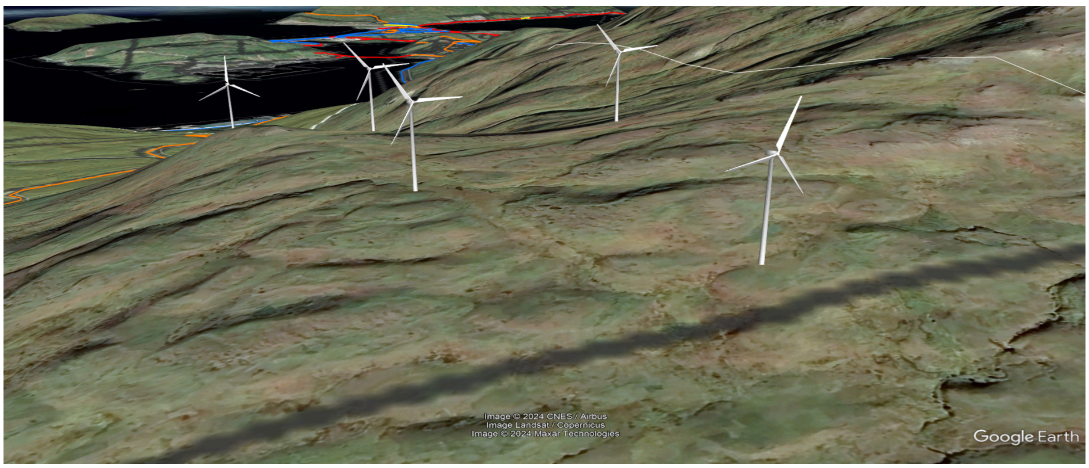
As noted, the primary wind power site area, or that slated for Phase 1 wind power development in project year 2, is Obernoi Point in lower Pyramid valley, where a 60-meter met tower had been located. This location is easily accessed via the well-developed Pyramid Creek Road and fortuitously, a buried high-capacity electrical distribution line that serves the COU water treatment plant routes nearby, to which the turbines can be connected. Obernoi Point is mostly Ounalashka Corp. land with a smaller area of COU ownership. Turbine array design optimization completed by COU's wind energy consultant, using wake loss guidance referenced above, indicates that five (5) EWT DW58-1000 wind turbines will suitably fit on the Point.

Phase 1, five turbine array on Obernoi Point, project year 2, view north

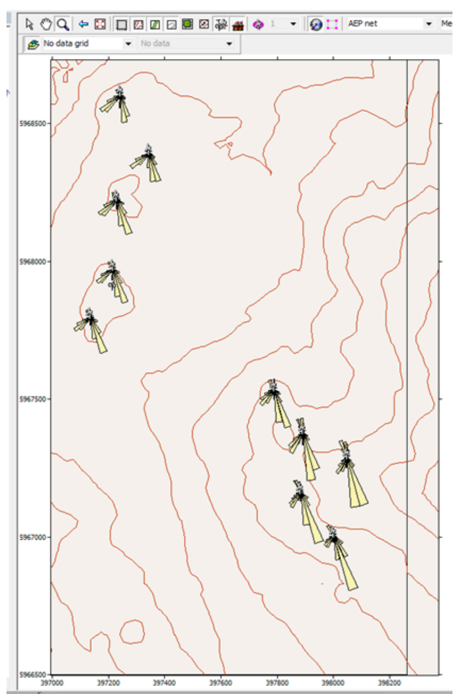


The second wind turbine project site does not yet have a formal name but is referenced here as Pyramid East, a high exposed flank of nearby Pyramid Peak which lies on the east side of Pyramid Valley and immediately up valley from Obernoi Point. The site does require construction of a one-half mile long road from Pyramid Creek Overlook on Pyramid Creek Rd. between the water treatment plant and Icy Creek Reservoir for access. Wind flow modeling predicts higher wind speeds and enhanced potential for wind energy generation at Pyramid East compared to Obernoi Point, but Pyramid East requires more development effort and another wind study, which is why wind turbine construction is split into two phases with Obernoi Point as Phase 1 in Year 2 and Pyramid East to follow as Phase 2 in year 3.

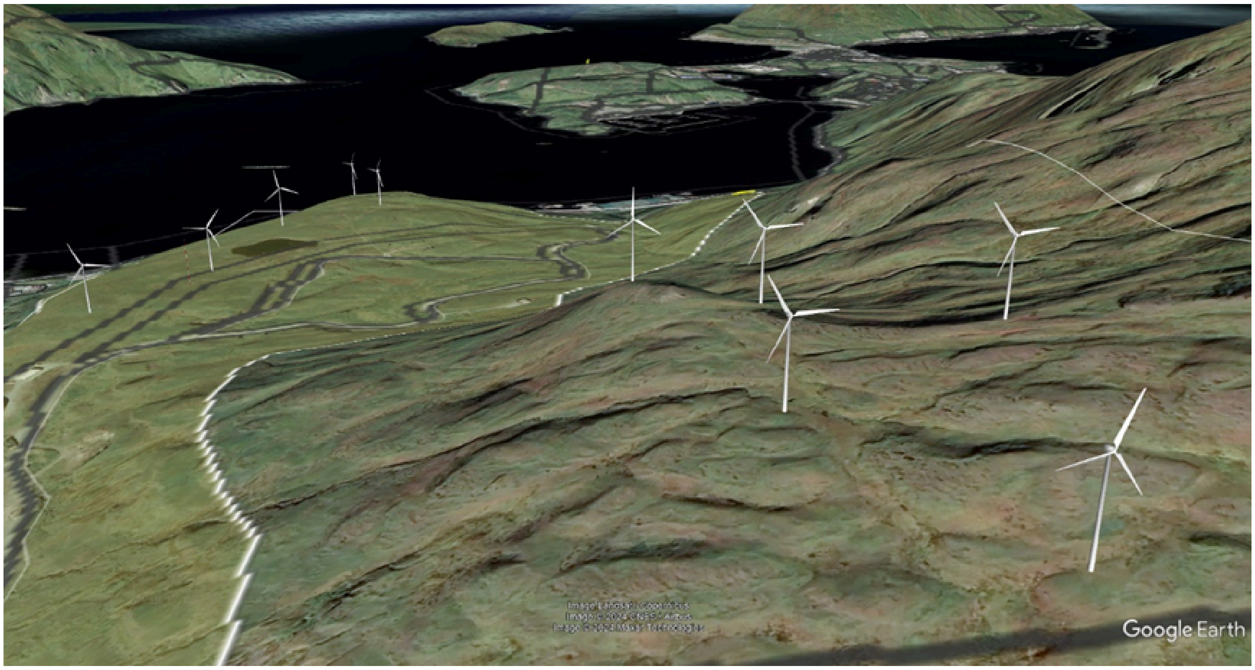
Phase 2, five turbine array on Pyramid East, project year 3, view north



Phase 1 (Obernoi Point) and Phase 2 (Pyramid East) wind turbine locations on digital elevation map of Lower Pyramid Valley in WAsP software



Combined 10-turbine Pyramid Valley wind turbine array, view north



The wind flow modeling used to predict wind turbine annual energy production for the GHG reduction estimates in this application is documented in a short report from our wind consultant: *Pyramid Valley 10 WTG's Array Report, 3/20/2024, V3 Energy LLC.* Excerpts of the report are presented in the table below.

WAsP modeling summary results

Parameter	Total	Average	Minimum	Maximum
Net AEP [GWh]	31.211	3.121	2.826	3.403
Gross AEP [GWh]	32.765	3.277	2.984	3.619
Wake loss [%]	4.74	-	-	-

WAsP modeling site results

Site	Location [m]	Turbine	Elevation [m a.s.l.]	Height [m a.g.l.]	Net AEP [GWh]	Wake Loss [%]
WTG1	(397136, 5967796)	EWT58-1000	100	59	2.928	2.29
WTG2	(397216, 5967971)	EWT58-1000	100	59	2.914	5.04

WTG3	(397230, 5968223)	EWT58-1000	100	59	3.101	4.04
WTG4	(397344, 5968390)	EWT58-1000	84.00264	59	2.843	6.82
WTG5	(397242, 5968602)	EWT58-1000	55.76484	59	2.826	5.31
WTG6	(397790, 5967534)	EWT58-1000	211.0441	59	3.301	5.42
WTG7	(397892, 5967378)	EWT58-1000	237.2161	59	3.403	5.95
WTG8	(398050, 5967287)	EWT58-1000	259.7275	59	3.384	3.8
WTG9	(397885, 5967161)	EWT58-1000	238.9915	59	3.318	5.11
WTG10	(398003, 5967002)	EWT58-1000	238.1178	59	3.193	3.52

Solar Resource

Unalaska’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 Unalaska. For this, several years of electric load data collected by the Secondary Control and Data Acquisition System (SCADA) were combined to create a representative year in one hour time steps.

To this are added the two Wartsila diesel generators in the new Power House that burn #2 diesel fuel and the three organic rankine cycle generators that generate electrical energy from diesel generator jacket water heat (co-generation). They are:

- Unit 10: Wartsila 12V32 – 5.2 MW
- Unit 11: Wartsila 12V32 – 5.2 MW
- Unit 12: Caterpillar C280-16 – 4.4 MW

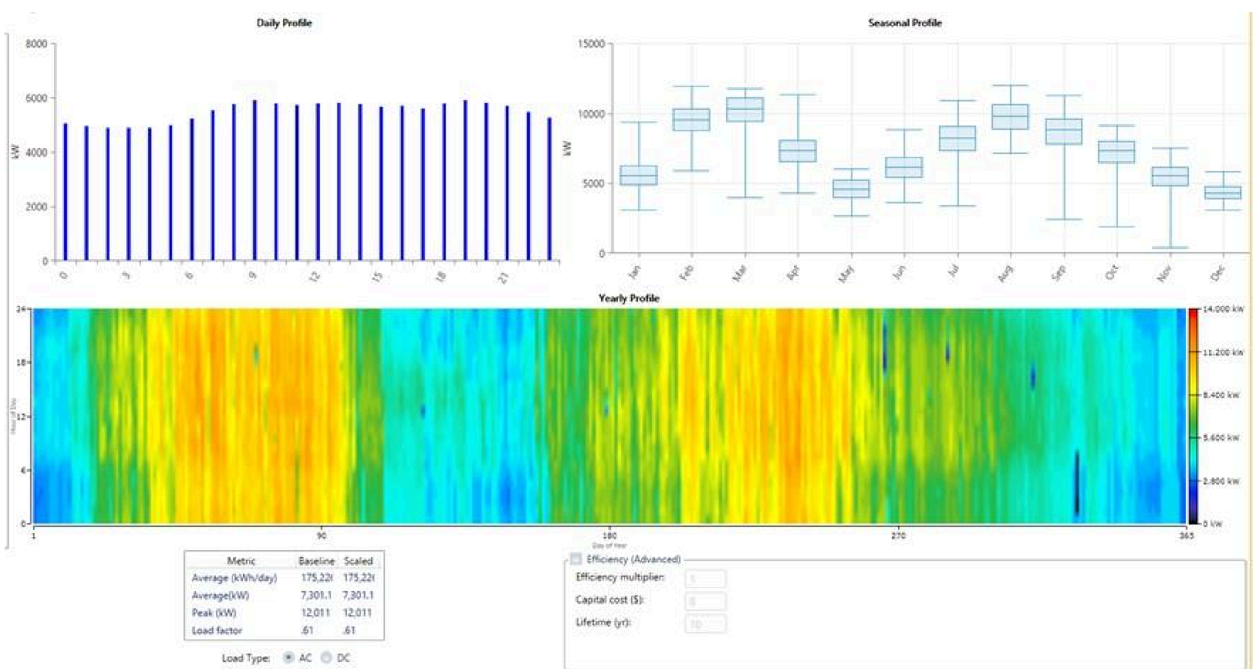
- Unit 13: Caterpillar C280-16 – 4.4 MW
- Organic Rankine Cycle (ORC) generators – 3 units – 50 kW each

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 the 60 meter-level Pyramid met tower data as noted above. For the solar resource, Homer software was programmed to access a NASA database that combines solar irradiance at Unalaska's latitude with satellite-measured temporal clearness data.

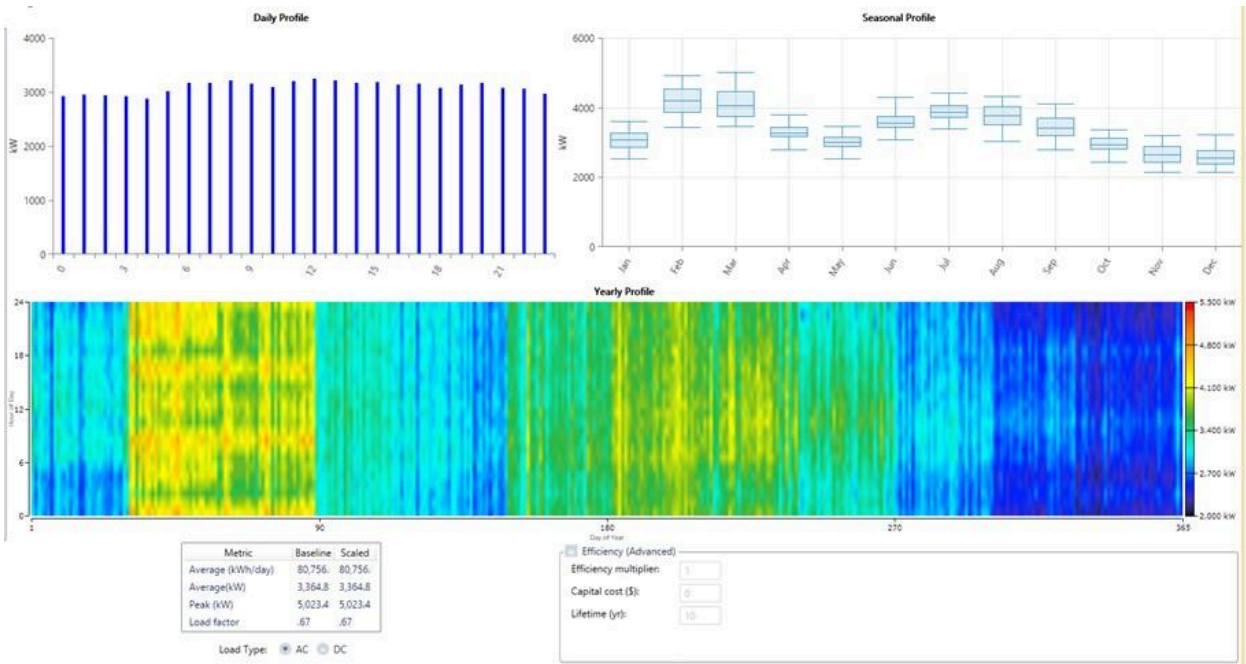
Homer software also enables one to model a battery energy storage system to demonstrate the benefit of diesel-off operation, which was accomplished in the modeling effort for this grant application. Twenty MWh capacity of Saft Intensium Max +20 and a 10 MW converter were modeled to ensure no battery limitations were encountered in the modeling, but note that battery modeling is a highly complex task and possibly the energy storage and/or converter capacities will be modified during project design.

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 2 MW solar power capacity in year 1, construction of 5 MW wind power capacity in year 2, and construction of an additional 5 MW wind power capacity in year 3. Homer modeling results are shown below:

City of Unalaska + Westward Seafoods and Alyeska Seafoods electric loads, Homer software



Unisea electric load, Homer software



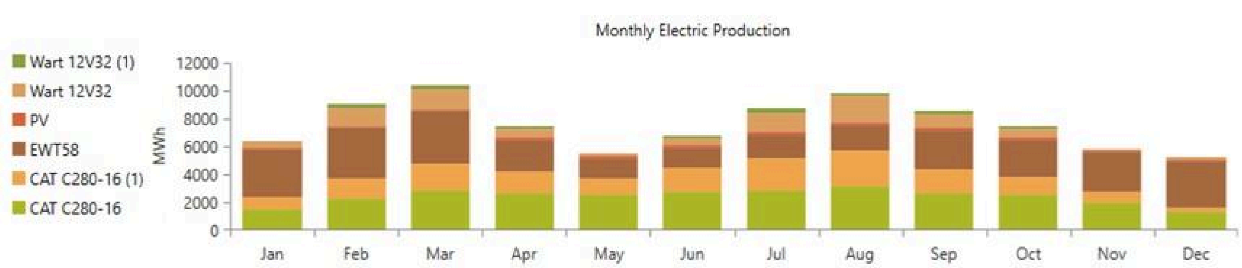
Electrical generation by production source, Homer software

Production	kWh/yr	%
Generic flat plate PV	1,771,112	1.94
Wartsila 12V32	9,610,155	10.5
Wartsila 12V32 (1)	1,805,700	1.98
Caterpillar C280-16	29,260,911	32.1
Caterpillar C280-16 (1)	17,557,467	19.3
EWT DW 58 [1000kW]	31,115,283	34.1
Total	91,120,627	100

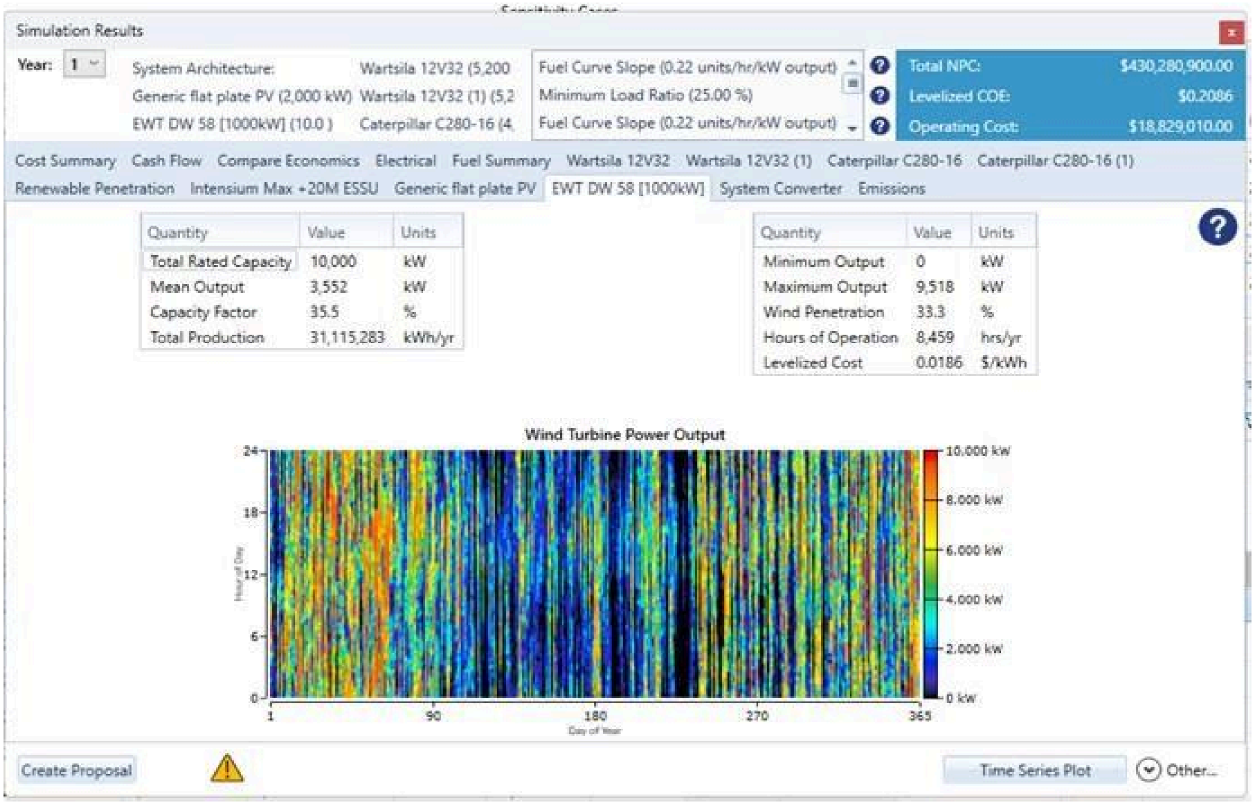
Consumption	kWh/yr	%
AC Primary Load	89,745,111	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	89,745,111	100

Quantity	kWh/yr	%

Quantity	Value	Units
Renewable Fraction	35.1	%
Max. Renew. Penetration	311	%

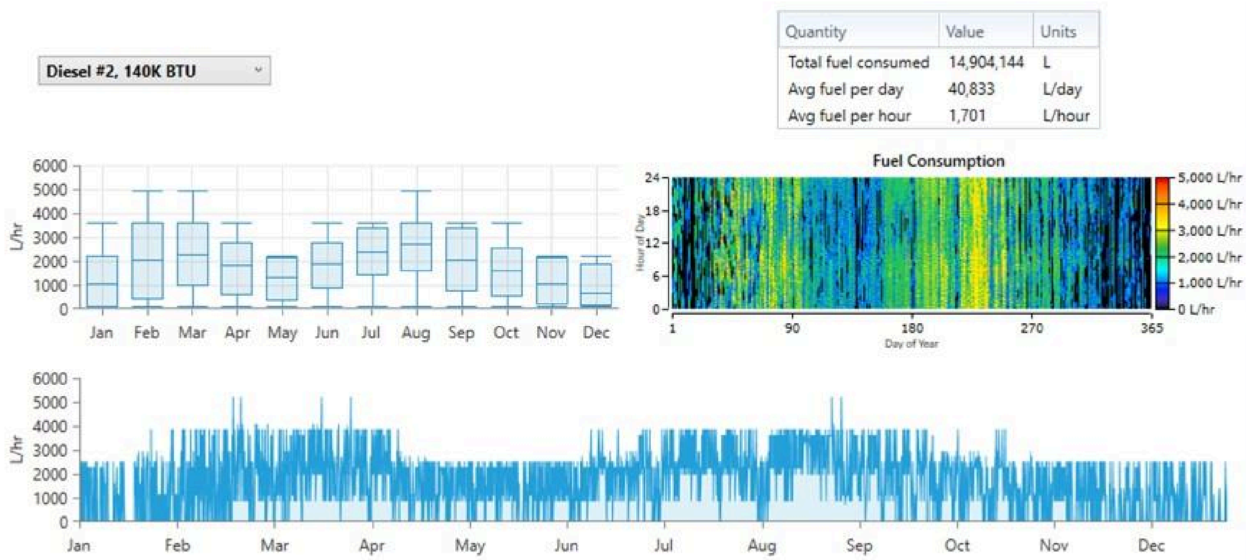


Wind turbine energy generation, Homer software



BESS model, Homer software

Fuel usage with 10 MW wind, 2 MW solar, 20 MWh BESS, Homer software



GHG Calculator

Besides static energy balance and economic optimization, Homer software calculates carbon dioxide emissions for the baseline (comparison) configuration, versus the renewable energy alternatives one chooses to analyze, in this case 2 MW solar, 10 MW wind, and 20 MWh BESS capacities. 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 2 MW solar, 10 MW wind, 20 MWh BESS (year 3+)	Reduction Magnitude	Reduction Percentage	Notes
Fuel use	gal	6,159,724	3,937,258	2,222,465	36.1%	Homer software
CO2-e	MT	62,213	39,799	22,414	36.0%	Homer software
CO2-e	MT	62,949	40,334	22,615	35.9%	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. Note that Westward, Alyeska, and Unisea electrical loads shown in red in project year 0 (baseline) and year 1 to represent non-COU, or self-generating, loads, but would be connected to the COU grid by year 2 to share the benefit of Phase 1 wind turbine development. Modeling indicates that cumulative GHG reduction for project years 1-to-5 is 79.9 kMT and cumulative reduction in project years 6-to-25 is 448.0 kMT. Total project GHG reduction for all 25 years of the project is 527.9 kMT. Note that calculation excludes emissions reductions under Measure 4.

Project timeline of GHG reduction

Project Year	Year	Electric Load Demand, Annual, GWh COU	Westward	Alyeska	Unisea	Combined	Solar (2 MW), GWh	Wind Phase 1 (5 MW), GWh	Wind Phase 2 (5 MW), GWh	Renewable Energy Supplied, GWh	Fossil Fuel Gener., GWh	Fossil fuel usage, M Gal	GHG CO2-e, kMT	GHG Reduct. CO2-e, kMT	GHG Reduct. %	Project Period	GHG Reduct. CO2-e, kMT
0	2024	42.7	16.1	1.5	29.4	89.7				0.0	89.7	6.16	62.2			Baseline	
1	2025	42.7	16.1	1.5	29.4	89.7	1.8			1.8	87.9	6.05	61.0	1.2	1.9%	Year 0-to-5	79.9
2	2026	42.7	16.1	1.5	29.4	89.7	1.8	14.6		16.4	73.3	4.95	50.7	11.5	18.5%		
3	2027	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
4	2028	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
5	2029	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
6	2030	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%	Year 6-to-25	448.0
7	2031	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
8	2032	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
9	2033	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
10	2034	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
11	2035	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
12	2036	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
13	2037	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
14	2038	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
15	2039	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
16	2040	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
17	2041	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
18	2042	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
19	2043	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
20	2044	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
21	2045	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
22	2046	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
23	2047	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
24	2048	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
25	2049	42.7	16.1	1.5	29.4	89.7	1.8	14.6	16.5	32.9	56.8	3.94	39.8	22.4	36.0%		
Total										774.9				527.9			527.9

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		10 MW wind, 2 MW solar, 20 MWh BESS		Reduction	Reduction Quantity	
Pollutant	Value	Units	Value	Units	%	Value	Units
Carbon dioxide	62.2	kMT/y	39.8	kMT/y	36.0	22.4	kMT/y
Carbon monoxide	121.9	MT/y	57.5	MT/y	52.8	64.4	MT/y
Unburned HC	12.9	MT/y	7.9	MT/y	38.8	5.0	MT/y
Particulate matter	2.6	MT/y	1.7	MT/y	34.6	0.9	MT/y
Sulfur dioxide	126.8	MT/y	81.2	MT/y	36.0	45.6	MT/y
Nitrogen oxides	248.5	MT/y	178.5	MT/y	28.2	70.0	MT/y

References

All references are available on request.