California North Coast Offshore Wind Studies

Offshore Wind and Regional Load Compatibility Report

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Disclaimer

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1. INTRODUCTION

Humboldt County is an access point to the enormous offshore wind resource located on the north coast of California, but there is limited regional load and transmission capacity to absorb this electricity or transfer it to other load centers in the state. Offshore wind farms off the coast of Humboldt County would either need to be 1) small scale to fit within the existing load and transmission constraints, 2) a modest scale development using a combination of strategies to minimize grid impacts such as storage, load development, and curtailment, or 3) a large-scale development requiring major transmission infrastructure improvements to connect the wind farm to other locations in the state. The Humboldt Call Area, located 20 - 30 miles offshore Humboldt Bay, which is being considered for a lease auction (BOEM, 2018), could accommodate up to a 1.8 GW-scale wind farm, but smaller wind farms could also be deployed. The analysis presented below evaluates the compatibility between offshore wind farms and the existing generation sources and loads in Humboldt County, assuming the existing transmission infrastructure has a maximum export capacity of 70 MW of power out of the county (Zoellick et al., 2011).

The Humboldt County transmission system is partially isolated from the rest of California's network. There are two transmission corridors that connect the county from the east and one transmission corridor heading south (Figure 1).

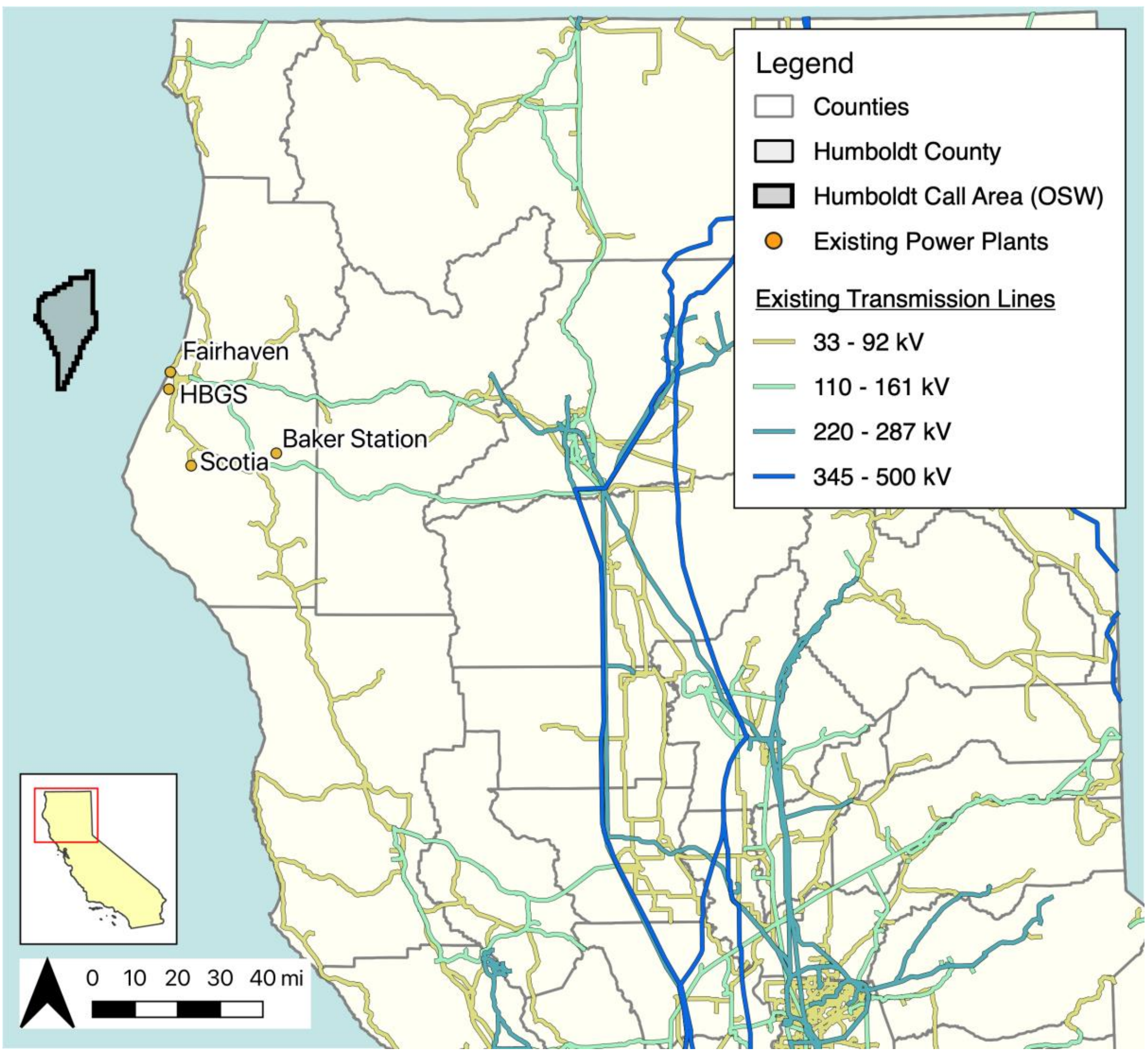


Figure 1. Existing transmission lines in northern California.

Humboldt County's electrical demand is intended to be served primarily by four regional power plants, relying on limited electricity transmission into or out of this region. The 60-kV transmission line heading south into Mendocino County serves small communities along its path, but it is not meant to transfer large amounts of power because of its size and voltage. The two parallel, 115-kV transmission lines heading east are redundant lines used to import power to Humboldt County as needed and serve the communities along the way. Lastly, a 60-kV transmission line connects to the east in the same right of way as the northern 115-kV circuit.

1.1 Purpose

To understand the potential for offshore wind development using existing infrastructure, this report describes the regional electricity load and generation sources and then adds different scales of offshore wind development to see how they impact the electricity grid. The analysis evaluates the compatibility between electricity demand, existing generation sources, and potential offshore wind development in Humboldt County, California. The purpose of the study is to determine what scale of wind farms could fit within the current transmission constraints and to understand the impact of offshore wind generation on the regional grid.

**Note:* This study is not a technical assessment of the capacity of existing transmission infrastructure or the requirements of new transmission to accommodate offshore wind. In order to evaluate the transmission capacity and required upgrades, the electric grid operator, Pacific Gas and Electric Company (PG&E), conducted an informational transmission planning study (Pacific Gas and Electric Company, 2020). The analysis described below is used to understand the interaction between future offshore wind generation and existing generators in Humboldt County. PG&E's analysis shows that transmission upgrades could be required at small scales of development based on energy flows and line capacity, even if the simplified load compatibility analysis below does not identify them. A discussion of the different modeling approaches is provided below.

2. METHODS

Existing and historical data for regional electricity demand and generation sources were compiled and projected to the year 2030 to create a future baseline condition. Offshore wind generators at scales of approximately 50 MW, 150 MW, and 1,800 MW are added to the future conditions to determine how these generators could be used to meet electricity demand with existing infrastructure. These wind farm scales were selected to be representative of a pilot-scale project (50 MW), a small commercial-scale project (150 MW, which matches an unsolicited lease request for this area (RCEA, 2018)), and a full build out of the Humboldt Call Area (1,800 MW). The impact of offshore wind generation is quantified in terms of 1) reduction in the energy output of Humboldt Bay Generating Station (HBGS) that was displaced by offshore wind, 2) reduction in energy imports necessary to meet county demand, 3) increase in energy exports from the county, and 4) curtailment of offshore wind energy output. This analysis uses an export limitation of 70 MW for the Humboldt County transmission system (Zoellick et al., 2011), assuming that no significant upgrades to the transmission system are made to accommodate offshore wind. Instead of upgrading infrastructure, offshore wind power is curtailed in this model so that it does not exceed the transmission capacity.

The analysis was conducted by creating an input/output model of generation plus electricity imports (input) and local load plus electricity exports (output) in the statistical computing language R. The central node in this model is the Humboldt County electrical system (Figure 2). The electricity generators include all four existing local generators plus three potential scales of future offshore wind development. These generation sources are used to meet local load in the region. Energy cannot be stored in the Humboldt node, so the sum of inputs must equal the sum of outputs at each time interval (of one hour). If local load cannot fully meet this demand, electricity is imported into the area; if there is a surplus of generation, electricity is exported outside of this region. The transmission line into and out of the area is limited to a maximum capacity of 70 MW (Zoellick et al., 2011). If generation exceeds the 70 MW export capacity, offshore wind (OSW) energy is curtailed to meet this criterion. Other capacity limitations and energy losses on electricity transmission between each node are not considered in this analysis.

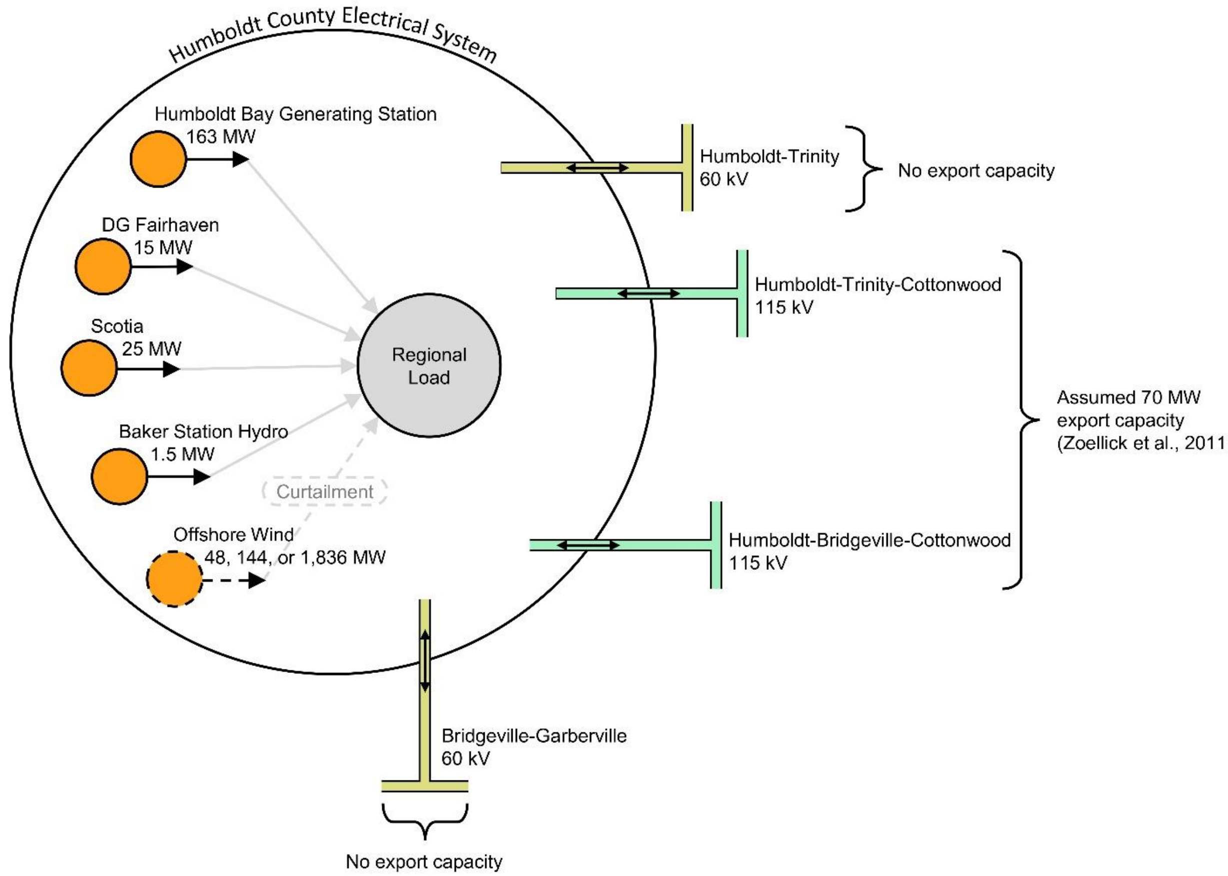


Figure 2. Humboldt County electrical system and model inputs and outputs.

2.1 Data Sources

This analysis required data sources for regional electricity demand, generation profile of existing power plants, and simulated generation profile from offshore wind. The data sources are described in the following sections.

2.1.1 Electricity Load

Future electricity load in 2030 was used for this analysis to better align with the timeframe when offshore wind generators could be in operation. Historic electricity load in Humboldt County has been decreasing according to data provided by PG&E for the period from 2008 to 2018 (PG&E, 2019), but future projections expect electricity demand to be higher (Figure 3). The California Energy Commission (CEC) publishes projected electricity demand through 2030 for PG&E's service territory (CEC, 2020a), but these projections may not be representative of Humboldt County's future load for three reasons. First, Humboldt County is a winter peaking region, meaning that it has the maximum demand in the winter months unlike the majority of PG&E's service territory. Second, Humboldt County's load has been changing at a different rate than PG&E service territory as a whole (Figure 3). While the CEC estimates that electricity demand in PG&E service territory may increase by 6%, 13%, or 21% from 2018 to 2030 based on the low, mid, or high demand scenarios, respectively, the demand in Humboldt County is likely to change at a different rate. Third, Humboldt County comprises less than 1% of PG&E's combined load, and their projections may not be representative of this smaller region.

Instead of using PG&E's 2030 projected load and scaling it down for Humboldt County, a local demand forecast was determined to be more suitable. The future county load for 2030 was obtained from the community choice aggregator in Humboldt County, the Redwood Coast Energy Authority (RCEA). The 2030 County Load in the Business as Usual scenario (RCEA, 2020), which provides an hourly load profile for a typical day for each month, was used in the following analysis. The projected load anticipates the annual average electrical load rising to 102 MW by 2030, an increase of 6% relative to the 96.4 MW figure reported in the most recent year of historical data from November, 2017 to October, 2018 (Figure 3). This load growth aligns with the low demand future scenario for PG&E service territory (CEC, 2020a), but matches the hourly and monthly load profiles that are specific to Humboldt County.

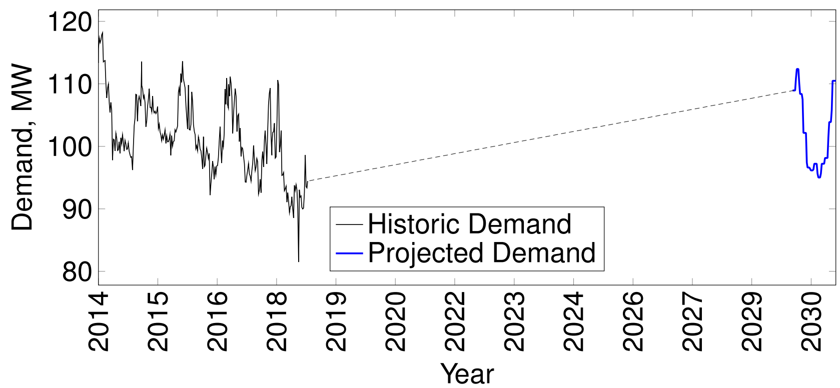


Figure 3. Historical and projected Humboldt County load used in this model.

2.1.2 Existing Power Plants

The operation schedule of existing power plants is considered in this model to evaluate if and when offshore wind can contribute to meeting the regional load. There are four active power plants located within Humboldt County: a small hydroelectric facility, two biomass power plants, and a reciprocating engine natural gas power plant (Table 1). Historical electricity generation data in Humboldt County were obtained from the California Energy Commission's Quarterly Fuel and Energy Report (QFER) (CEC, 2020b), which reports production data from all California power plants larger than 1 MW. Recent production levels were used to project the future output in 2030. Detailed methods for estimating future generation are provided in Appendix A.

Table 1. Humboldt County generation resources.

Plant Name	*Nameplate Capacity*	*Plant Type*	*Annual Energy Production[1]*	*Notes*
Baker Station Hydro	1.5 MW	Small Hydro	4,340 MWh	Annual production reported in QFER. Assumed equal output every hour.
DG Fairhaven Power Plant	15 MW	Biomass[2]	116,000 MWh	Monthly generation reported in QFER. Hourly profile is flat by month.
Scotia	25 MW[3]	Biomass[2]	118,000 MWh	Monthly generation reported in QFER. Hourly profile is flat by month.
Humboldt Bay Generating Station	163 MW[4]	Natural Gas	422,000 MWh	Operated in the model as a load following plant to meet demand. Air permits restrict operating level.[5]

[1] Based upon historic averages. See Appendix A.
[2] Wood/Wood waste solids (CEC, 2020c).
[3] The QFER lists three generators for Scotia: Gen A, Gen B, and #3. Gen A and Gen B are 12.5 MW each, while #3 is 7.5 MW. #3 is not included in this total because it has not produced power since 2014.
[4] The QFER lists HBGS's capacity as 167 MW, but other sources report it as 163 MW (CEC, 2020c).
[5] Minimum output restricted to12 MW (Royall & Holm, 2018).

2.1.3 Offshore Wind Generation

Electricity generation from offshore wind in the Humboldt Call Area is modeled using simulated power output from Severy et al. (2020) that provides energy generation profiles for wind farms at different scales. Three different scales of wind farms were evaluated for compatibility with existing load:

- Pilot scale: 48 MW total using 4x 12 MW turbines.
- Small commercial scale: 144 MW total using 12x 12 MW turbines.
- Large commercial scale: 1,836 MW total using 153x 12 MW turbines, which is a full build out of the Humboldt Call Area identified by the Bureau of Ocean Energy Management (2018).

2.2 Power Plant Dispatch Model

Power plants are dispatched to meet the electricity demand at every hour of each day. The model selects which power plants to dispatch and where to deliver the energy based on the flow diagram shown in Figure 4. In the model, the output from all generators except HBGS is determined based on historical output. The generators' outputs plus offshore wind are added together to meet Humboldt County load. If the production exceeds the demand, offshore wind is exported. If production is below demand, HBGS is ramped up to meet the local load without causing exports. HBGS's air quality permit does not allow the plant to continuously run below 12 MW of output (Royall & Holm, 2018), so in order to maintain ramping capability a lower limit of 12 MW was applied to HBGS.

The transmission interconnection between Humboldt County and the rest of the state was assumed to have a maximum capacity of 70 MW (Zoellick et al., 2011). When there is more than 70 MW of excess offshore wind energy, the offshore wind farm is curtailed to stay below the capacity restriction.

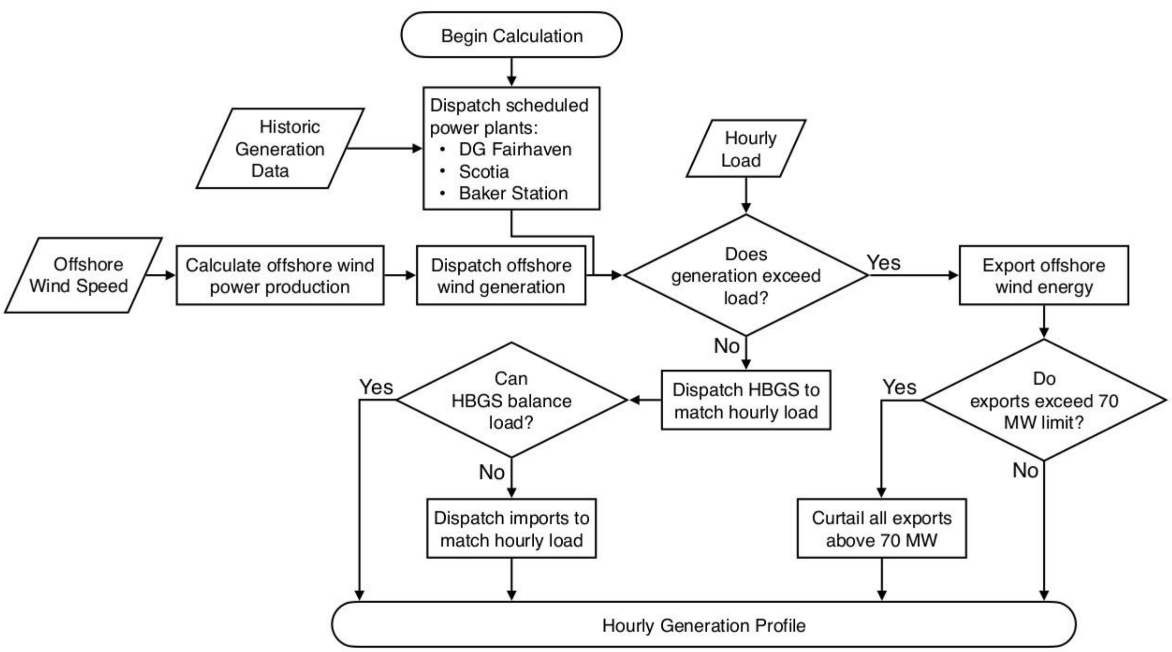


Figure 4. Decision process for calculating hourly load and generation profile.

2.3 Differences between PG&E Transmission Planning Study

Importantly, the methodology used in this analysis differs from how PG&E evaluated what transmission upgrades are required to interconnect an offshore wind farm. While this analysis allows generators to ramp up or down to meet regional load, the interconnection feasibility study (PG&E, 2020) evaluates the electrical conditions during peak load scenarios with all power plants producing their nameplate capacity.

Electrical transmission infrastructure is designed and built to safely withstand peak conditions and needs to evaluate the most extreme scenarios to make sure the system can handle this capacity. Results from the informational interconnection study (PG&E, 2020) yield different results that show transmission infrastructure is needed to accommodate offshore wind developments 48 MW and greater. PG&E's study is answering the question of what infrastructure is needed to support all generation in a peak scenario, while this report studies the compatibility of offshore wind and existing generation in meeting the regional load throughout the entire annual operating cycle.

The results from the analysis presented below do not indicate whether or not transmission upgrades are required. Instead, the results illustrate how offshore wind farms could be integrated into the regional electricity grid given the existing load, generation resources, and assumed transmission capacity.

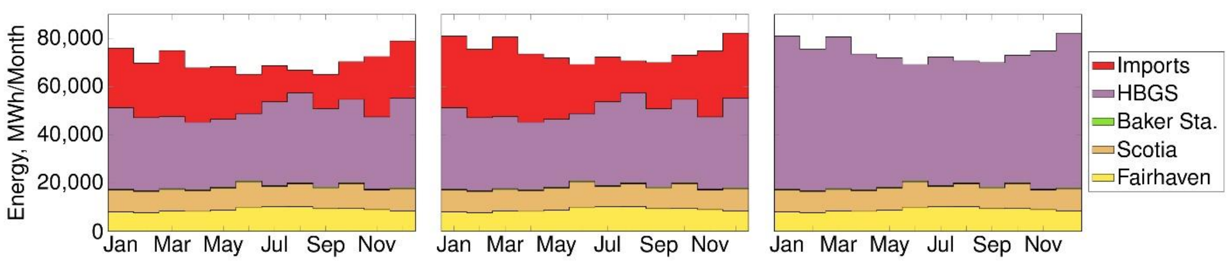
3. RESULTS

Four offshore wind development scenarios were analyzed, consisting of a baseline with no offshore wind development and three sizes of offshore wind development: 48 MW, 144 MW, and 1,836 MW.

3.1 Baseline Generation in Humboldt

The dispatchable natural gas-fired Humboldt Bay Generating Station is the primary electricity generating source for the Humboldt Area. In this model, we assume HBGS is ramped up and down to meet the regional demand. Two biomass-fuel power plants are operated consistently throughout the year as baseload power. Excess electricity demand is met with energy imported on transmission lines that connect elsewhere in the state. Note that Baker Station, a small hydroelectric facility, provides a small amount of energy relative to the other generators.

Figure 5 shows the monthly electricity demand and the generation portfolio that is used to meet that energy demand for current 2018 load (left) and 2030 projected load (center and right). The current profile uses reported generation data and adds imports to meet the demand (Figure 5 (a), left). Using the same historic generation data, imports can be increased to meet the expected load in 2030 (Figure 5 (b), center) without overloading the 70 MW transmission capacity.



(a) 2018 Load and Generation Portfolio (b) 2030 Projected Load met with Current Generation (c) 2030 Projected Load met with HBGS Operation

Figure 5 Historic generation in Humboldt County coupled with imports required to meet 2030 projected load. The height of each monthly bar exactly matches the regional load in 2018 (a) and 2030 (b) and (c).

Instead of relying on imports, the 2030 electricity demand could also be met by increasing the capacity factor of HBGS to match the hourly demand. Figure 5 (c) shows HBGS ramping up to meet the future load. This method of modeling the future generation portfolio provides a preference for power from HBGS over imported electricity. Future generation scenarios that include offshore wind also dispatch HBGS before selecting imports, similar to the algorithm depicted in Figure 5 (c).

3.2 Daily Generation Profile

Adding offshore wind generation to Humboldt County changes the sources of electricity used in the region. Figure 6 shows how the energy generation portfolio changes for different scale wind farms and different daily wind patterns. The chart includes the generation profile for a low, variable, and high wind speed regime with 48 MW, 144 MW, and 1,836 MW of installed offshore wind capacity.

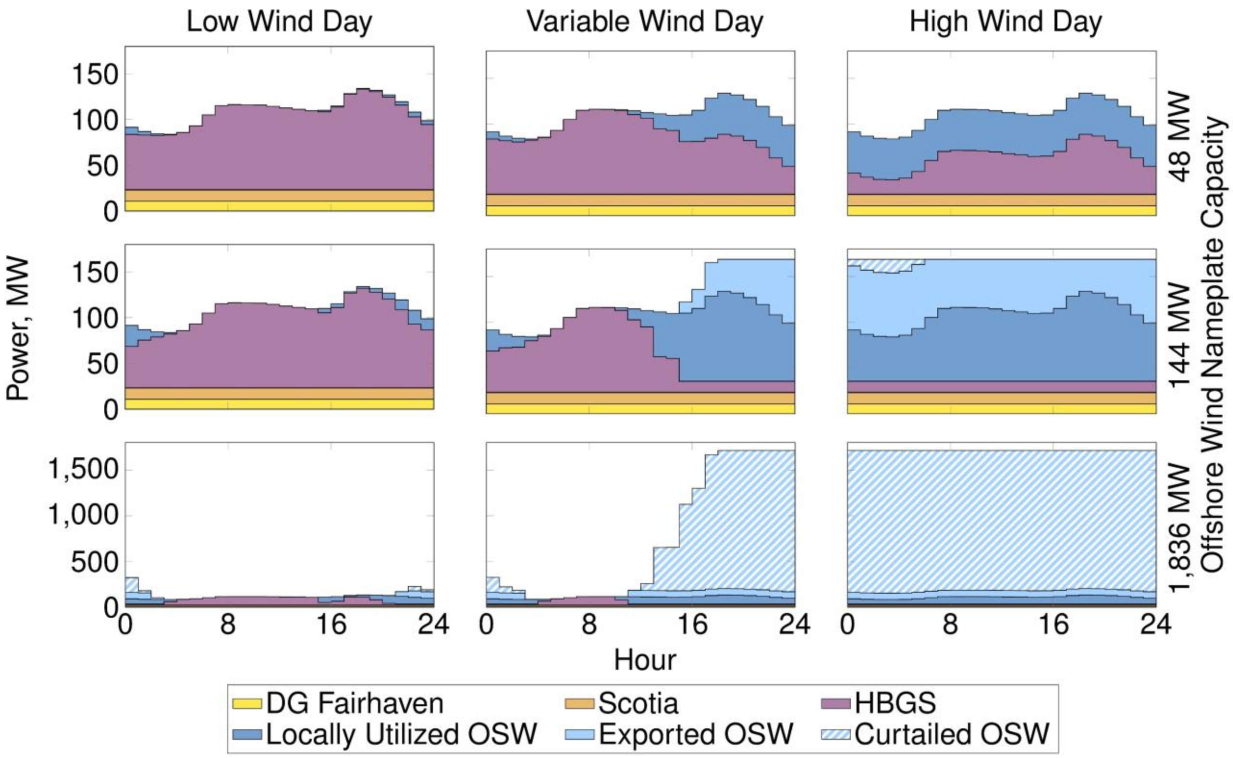


Figure 6. Hourly generation and load during three different wind speed regimes in February (vertical columns). The generation mix is shown for each day when adding 48 MW, 144 MW, and 1,836 MW wind farms (horizontal rows). Note that the y-axis scale for the 1,836-MW cases covers a much wider range of values than the y-axis scales for the 48 and 144-MW cases.

The example days in Figure 6 provide an overview of how different scale generators affect the portfolio of regional generation.

- Pilot Scale - A 48-MW wind farm (top row) operates in tandem with HBGS to meet electricity demand. Even during high wind speed days, offshore wind generation does not exceed regional load, and there is no offshore wind energy exported out of the region.
- Small Commercial Scale - During high wind speeds days, the 144-MW wind farm exceeds local demand. Power output from the wind farm is consistent under high winds (notice the flat upper bound in the high wind speed day) and the electricity is distributed between local load first, then to export, and lastly it is curtailed if the 70 MW export capacity limit is reached. During high wind, HBGS operates at its minimum power output; during low or variable winds, HBGS follows the local load.
- Large Commercial Scale - Production from an 1,836-MW wind farm far exceeds the energy demand in the region. During periods of moderate to high wind speed, offshore wind energy is exported at maximum capacity, but the majority of the production is curtailed due to transmission limitations. Importantly, even with a large offshore wind installed capacity, HBGS still needs to operate on low and variable wind speed days to meet the regional energy demand when the wind farm is not producing.

3.3 Annual Generation Summary

Adding offshore wind generation changes the annual energy generation portfolio in the area. The annual generation portfolio is shown in Figure 7 for historic, baseline, and three different wind farm scales. The historic generation portfolio includes electricity imported to meet current electrical load. The baseline portfolio represents the modeled generation portfolio in 2030 before adding offshore wind. Note that the baseline is slightly higher than historic, indicating the increase in load between 2018 and 2030. The baseline condition does not include any imports because HBGS is dispatched to meet load in this model before relying on imports. In the actual energy market, an economic decision would be made whether to dispatch HBGS or rely on imports based on market prices

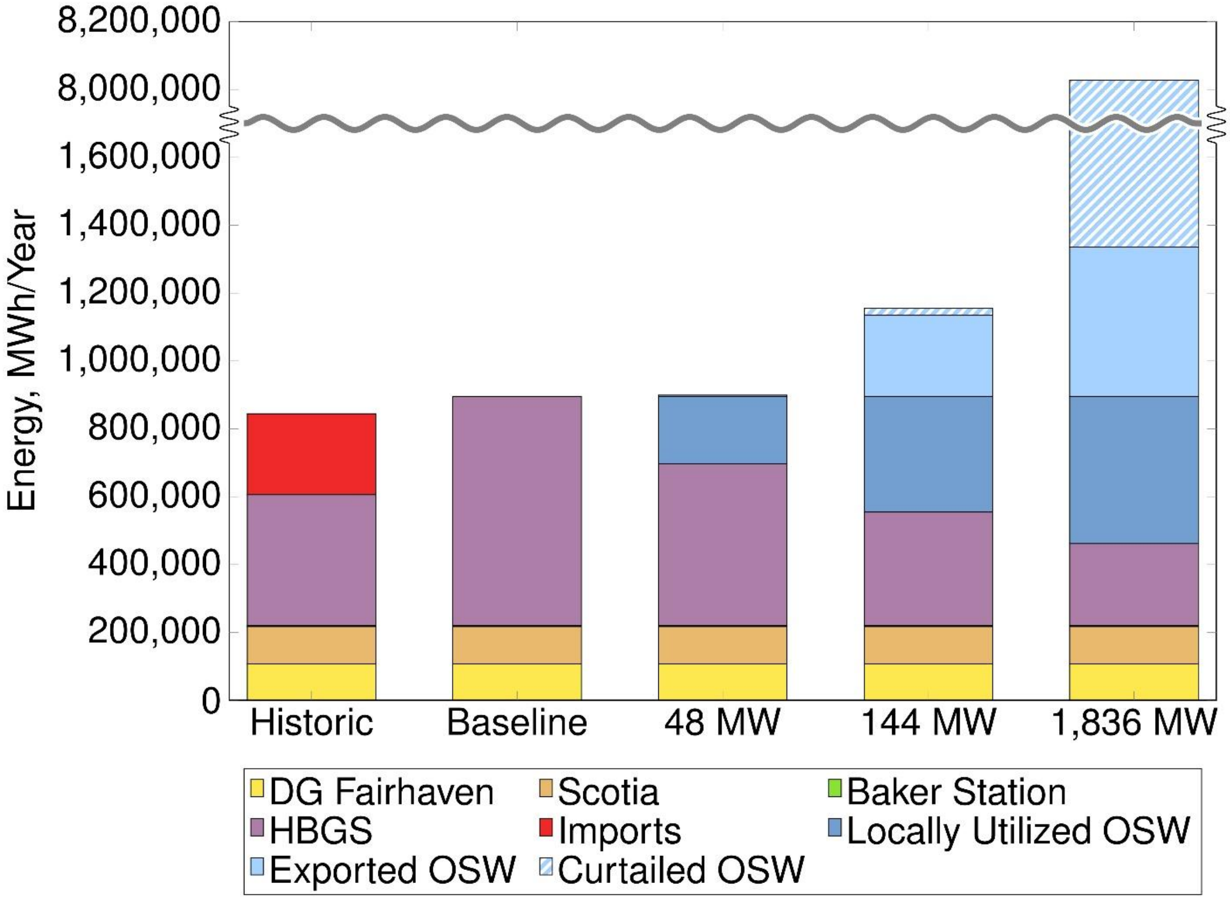


Figure 7. Annual energy generation by source for different levels of offshore wind development. Note the discontinuity in the vertical axis.

Increasingly large wind developments reduce the need for HBGS generation. Furthermore, while curtailment is absent entirely for the 48 MW scenario and is clearly a very small fraction of potential wind output for the 144 MW scenario, for the 1,836 MW scenario nearly all of the output is curtailed, with roughly equal portions utilized locally and exported. Little more usable electricity is extracted from the 1,836-MW scenario compared to the 144-MW scenario given the assumed grid constraints discussed previously.

Offshore wind development reduces HBGS output by 29% at 48 MW, by 51% at 144 MW, and by 64% at 1,836 MW (Table 2). In contrast, exports and curtailment increase steadily with increased nameplate capacity of offshore wind. For a 48-MW development, nearly all output could be consumed locally, with less than 2% exported and none curtailed. In the 144-MW scenario, exports increase to 40% of output with 3% curtailment, and in an 1,836-MW development with no transmission upgrades, exports represent 6% of the total offshore wind output with 88% curtailment.

Table 2. Annual offshore wind electricity generation, end use, and HBGS operating characteristics.

Scenario	*Offshore Wind Capacity Factor*[1]	*Total Offshore Wind, MWh*	*Curtailment, MWh*	*Exports, MWh*	*HBGS Output, MWh*	*HBGS Reduction*
Baseline	no offshore wind	0	0	0	674,000	-
48 MW	48%	203,000	0	4,330	476,000	29%
144 MW	47%	602,00	21,024	241,000	334,000	51%
1,836 MW	47%	7,570,000	7,189,514	440,000	241,000	64%

[1] Capacity factor determined from the Humboldt Call Area in Severy et al. (2020).

3.4 Monthly Generation Summary

The historic and baseline cases have previously been shown at monthly resolution (Figure 5), while the monthly outputs with the addition of offshore wind generation are depicted in Figure 8 to Figure *10*.

In a 48-MW wind development scenario, offshore wind provides 22% of regional load (Figure 8). HBGS remains the dominant electricity source throughout the year. HBGS output rises in the winter months to meet the increased local demand. Generation exceeds total demand in the months of May through October, leading to a small amount of export, but no curtailment.

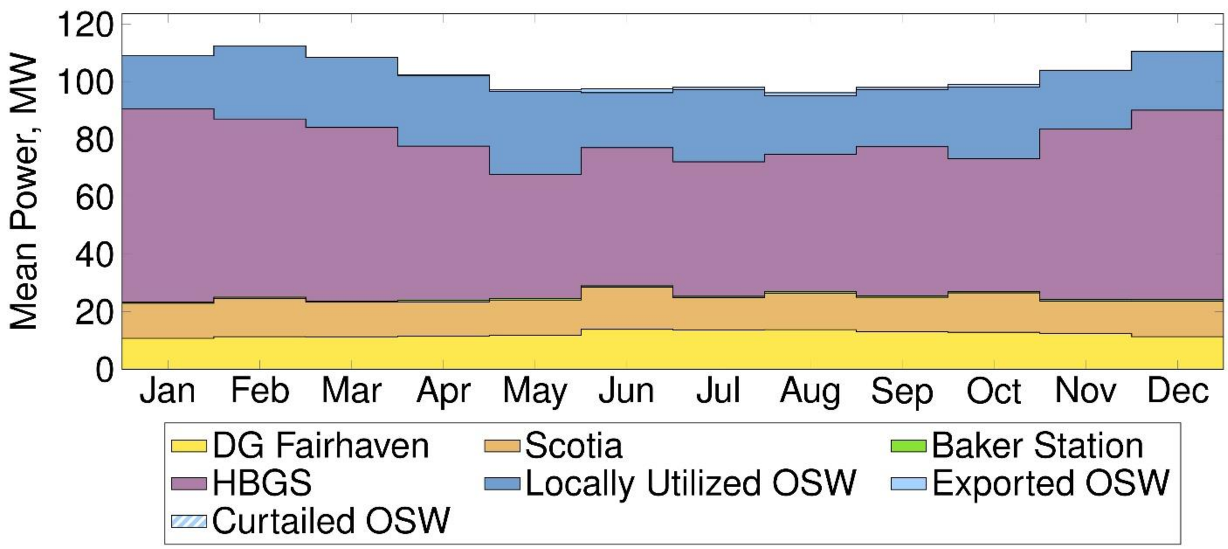


Figure 8. Monthly electricity generation by source to meet Humboldt County's projected 2030 load profile with addition of a 48 MW offshore wind farm.

With a larger, 144-MW offshore wind project, exports increase to significant levels, and small amounts of curtailment - caused by local generation exceeding local demand by more than 70 MW - are required (Figure 9). Some HBGS output is displaced by offshore wind, and offshore wind grows to become the largest source of local electricity.

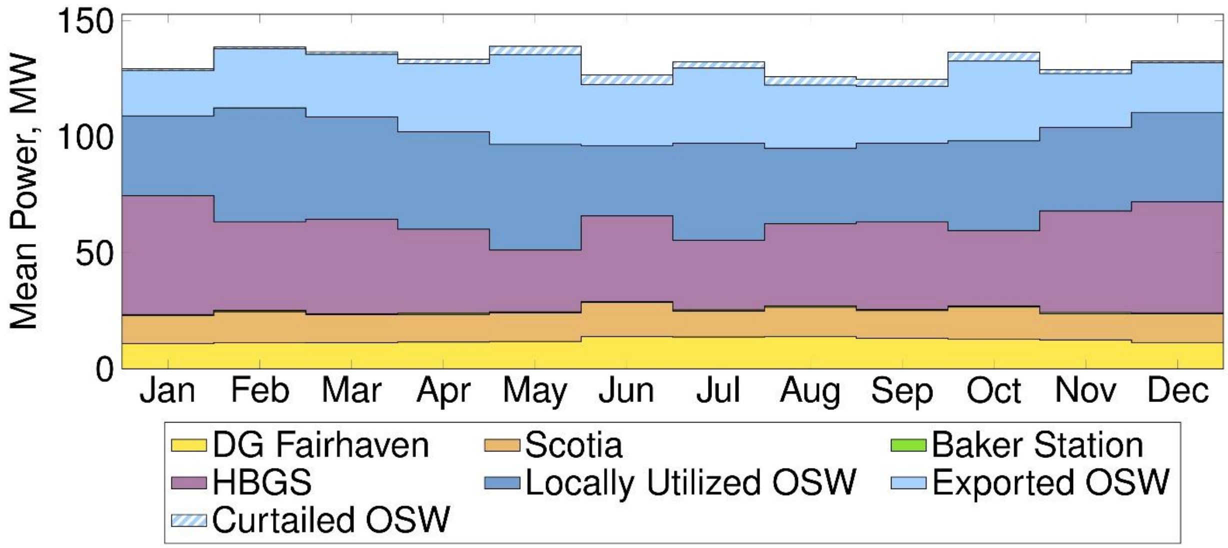


Figure 9. Monthly electricity generation by source to meet Humboldt County's projected 2030 load profile with addition of a 144 MW offshore wind farm.

The result of an 1,836 MW offshore wind development is much more dramatic (*Figure 10*). Electricity from wind energy is greater than all other factors by more than an order of magnitude, leading to generation far exceeding demand in all months, and tremendous exports and – without changes to transmission infrastructure – massive curtailment.

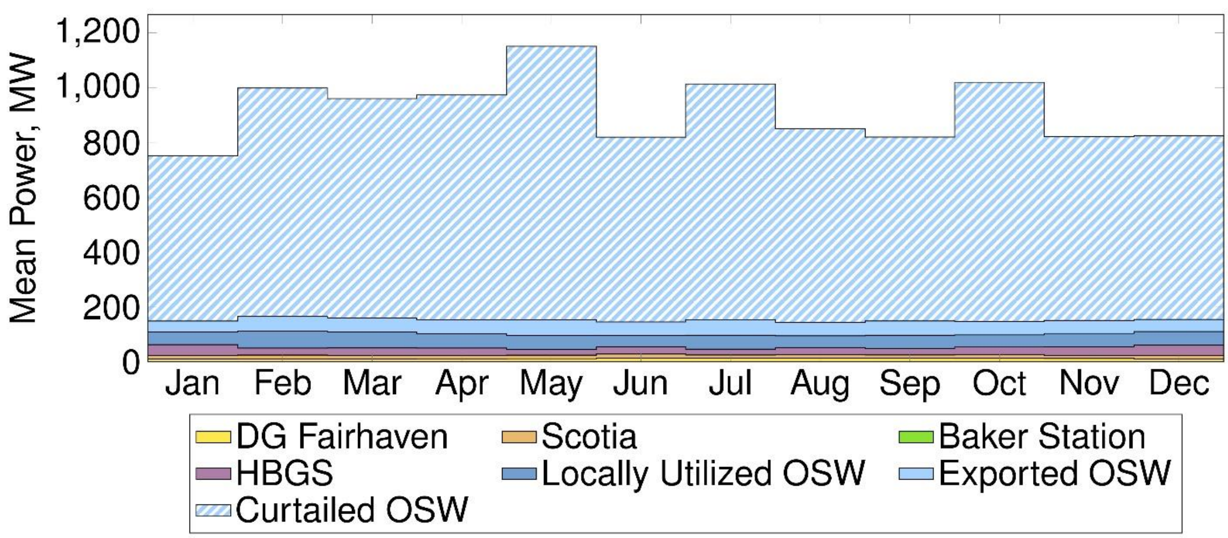


Figure 10. Monthly electricity generation by source to meet Humboldt County's projected 2030 load profile with addition of an 1,836-MW offshore wind farm.

4. DISCUSSION

Humboldt County's historic yearly consumption of 923 GWh has been met by a mix of 72% local generation (including 26% renewable, local generation) and 28% imports. With the projected increase in load and in the absence of offshore wind development, consumption increases to 977 GWh, met by an increasing quantity of imports equaling 32% of demand. Local generation falls to 67%, with only 24% of demand met by local renewables. In the baseline scenario in this report, the local natural gas plant, HBGS, is ramped up to eliminate imports (see Figure 5 (c)). This model allows HBGS to ramp up to meet regional load, while in practice, remaining regional load could be met through either HBGS or imported electricity. The decision whether to dispatch HBGS or imports would be an economic decision that is outside the scope of this analysis.

Under the 48-MW offshore wind development scenario, HBGS's yearly generation can be reduced by 29% compared to the baseline scenario, now serving 54% of local load instead of 76%. Offshore wind meets 22% of local consumption, raising the share of local renewables to 46%. In this scenario, 2% of offshore wind generation is exported and none is curtailed.

Under the assumptions of a 144-MW offshore wind development, local wind can meet 38% of local demand, increasing the share of local renewables to 64% and reducing HBGS's role to 38% of local demand. Under this scenario, 44% of electricity generation from offshore wind is exported, and 3.5% is curtailed. Curtailments would be reduced to zero with an additional 36 MW of export capacity (106 MW total).

With an 1,836-MW development, local renewables meet 73% of local demand, as offshore wind increases to provide 48% of local demand. Note that increasing the size of the wind farm by a factor of 13 only increases the local share from 38% to 48%, a modest increase by comparison. HBGS, in this scenario, delivers only 36% the energy of the original scenario, 27% of local load. In this scenario, 94% of offshore wind generation cannot be used within Humboldt County, and transmission infrastructure upgrades would be required to avoid the tremendous level of curtailment resulting from current transmission limitations. This model shows peak curtailment of 1,580 MW, elimination of which would require expansion of the existing transmission capacity from 70 MW to 1,650 MW.

The assumptions built into this model result in offshore wind displacing some output from the natural gas-fired Humboldt Bay Generating Station, which reducing greenhouse gas emissions from the regional electricity generating sources. Based on HBGS's 2018 production and emissions (CEC, 2020b; CARB, 2019), this plant has an emissions intensity of 0.465 metric tons of CO_2 equivalent per MWh, or 1,030 lb/MWh (see Appendix C). As shown in Table 2, above, the addition of 48, 144, and 1,836 MW of offshore wind would result in HBGS's energy output reducing by 29%, 51%, and 64%, respectively. This leads to a reduction of 92,000, 158,000, and 202,000 metric tons of CO_2 per year, respectively.

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APPENDIX A - CALCULATION OF HOURLY GENERATION

The methods used to calculate hourly generation for each power plant are described below.

A.1 DG Fairhaven Power Plant E0037

Monthly generation records between January 2001 and December 2018 were available through QFER. These records showed significant variability, short periods of shutdown, and a long period of shutdown during 2016/2017. All records in which the power plant operated were averaged by month, and then divided by the number of hours in the month to create a flat generation profile (i.e., a constant power output) for each month.

A.2 Scotia E0063

Monthly generation records between January 2001 and December 2018 were available through QFER. These records showed significant variability, short periods of shutdown, and a long period of shutdown at the end of 2015. Note that there was also a third generator running prior to 2014, which has not since been operated. Since the data before and after 2016 look distinctly different, only data starting from 2016 were used. All records since 2016 were averaged by month, and then divided by the number of hours in the month to create a flat generation profile for each month.

A.3 Baker Station Hydro H0547

Only yearly generation for the years 2017 and 2018 were available for this plant through QFER. The average was taken and assumed to be distributed evenly across the year for every hour.

A.4 Offshore Wind

As mentioned previously, offshore wind generation by hour had previously been projected. It was not altered in any way for this analysis.

A.5 Humboldt Bay Generating Station G0268

Total monthly generation for HBGS between January 2001 and December 2018 were available by engine through QFER. This plant was retrofitted in 2010 with the replacement hardware (i.e., 10x 16.3 MW Diesel cycle engines) brought online during 2011.

Because HBGS is a load following power plant (CEC, 2020d), its output was analytically shaped to match county demand. This method resulted in a monthly output 75% higher than historical (QFER) data would suggest. Nevertheless, because it was carried through all analyses, the assumed behavior allows for a consistent comparison.

According to the air quality permits for HBGS, the facility is not allowed to operate any engine for more than 80 hours per year at less than 12 MW (75% output) (Royall & Holm, 2018). To avoid complicating the implementation, the HBGS output was therefore restrained from going below 12 MW. Therefore, we assumed that HBGS was able to produce anywhere from 12 MW to 163 MW (its nameplate capacity) at any hour such that imports and exports are minimized.

APPENDIX B - HUMBOLDT BAY GENERATING STATION OPERATIONAL CHARACTERISTICS

Formerly Humboldt Bay Power Plant (HBPP), the Humboldt Bay Generating Station (HBGS) was repowered and renamed in 2010. It is located at 1000 King Salmon Avenue, in Eureka, California and owned by Pacific Gas and Electric Company (Kessler, 2007). Previously, HBPP was powered by two fossil fuel steam plants of 53 and 54 MW, installed in the late 1950s, and two 15 MW mobile emergency power plants (MEPPs), which were brought online in 1976 (CEC, 2020b; Herbert & Root, 2012). The repowered HBGS hosts ten Wärtsilä 18V50DF (dual fuel) reciprocating engines. The primary fuel for these engines is natural gas, but they can be operated with diesel during times of natural gas curtailment. Each engine at HBGS has a nameplate capacity of 16.3 MW, for a total power plant nameplate capacity of 163 MW (Kessler, 2007; Wärtsilä, 2020). Since repowering in 2010, annual output from HBGS has ranged between 360,000 MWh/year and 470,000 MWh/year (Table 3) with power output varying by month (Figure 11). Since repowering to HBGS, the capacity factor has ranged from 25 to 32% each year.

Table 3. Annual output from HBPP (2001-2009) and HBGS (2010-2019) reported by the California Energy Commission (2020c).

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Output, MWh/year	673,401	375,715	225,065	372,161	438,432	441,313	482,871	521,879	552,072	452,810
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Output, MWh/year	467,071	429,408	373,054	362,095	392,783	367,748	431,524	384,787	405,143	

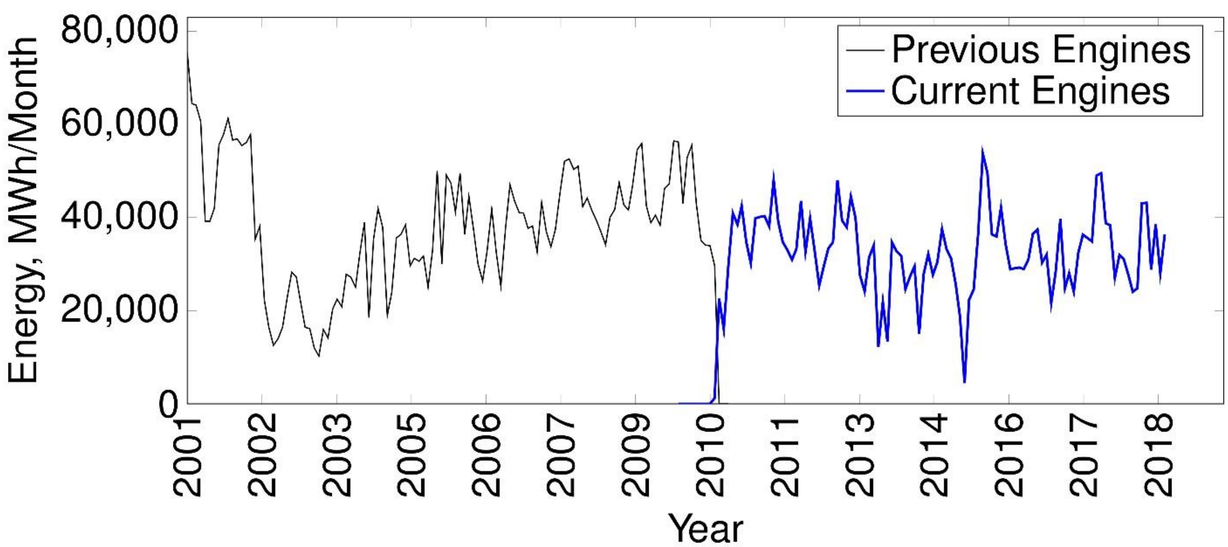

Figure 11. Monthly HBGS energy generation before and after repowering.

B.1 Operating Characteristics

Due to the limited transmission into and out of Humboldt County, power plants within the county must meet a large fraction of local electric demand, supplying both real power and reactive power. As the largest power plant in Humboldt County, HBGS may provide base load power during extended periods of high demand and operate as a load following plant to meet varying energy demand. The power plant is dispatched following signals from the California Independent System Operator (CAISO) based on economic market conditions, demand, and local grid stability. The air district operating permit states, “As a commercial power plant, market circumstances and demand … dictate the exact operation of permitted equipment” (Royall & Holm, 2018).

In its Application for Certification for the Humboldt Bay Repowering Project, the HBGS is described as being designed to operate in two modes: load following, in which the plant operates at output levels between 11.4 MW and 163 MW; and daily cycling, in which the plant can cycle up to its maximum output and be shut down on nights or weekends (CEC, 2008). The HBGS air quality permit, which expires on March 16, 2023, similarly allows for two operational modes, labeled as load following and base load (Royall & Holm, 2018). In addition to meeting local real power demand, synchronous generators, such as HBGS, can supply reactive power by adjusting the generator’s field current to maintain a constant voltage at the generator bus (von Meier, 2006, p. 184-185, 202-203); this is sometimes termed “voltage support”. Additionally, HBGS is capable of filling in gaps due to generation by intermittent renewables. In 2008, air quality certifications were changed "to integrate the operation of the HBGS with intermittent renewable energy resources (e.g. wind and solar)" (Winstead, 2018; Goldthrite, 2018).

The modes of operation for HBGS are summarized below.

- Daily cycling (Base Load per Royall & Holm (2018))
  In a base load mode of operation, “HBGS may be operated at maximum continuous output for as many hours per year as scheduled by load dispatch, and limited by operational constraints of the permit to operate (approximately 75% annual capacity factor)” (Royall & Holm, 2018). The engines may operate for a sum total of up to 80 engine-hours per calendar day at output levels between 50% and 75% (8-12 MW) (Royall & Holm, 2018, p. 33). Engines are not permitted to operate below 50% capacity (Royall & Holm, 2018).

- Load following
  As a load-following plant (CEC, 2008; CEC, 2020d; Royall & Holm, 2018), the engines can be operated at any level from “a single unit operating at 70 percent load to all 10 units operating at full load” to meet variable demand (CEC, 2008).

- During Regional Power Outages
  PG&E has submitted a variance petition to allow HBGS to “operate in an island mode, or as a black start unit, or to serve area load, during times of regional power outages” (Bitner, 2020). This petition waives the requirements that engines not run more than 80 engine-hours per calendar day at loads less than 75%, and that engines not run below 50% load. The variance is intended to be in place while PG&E’s operating permit is amended.

- Integration with renewables
  The ramping capabilities of Wärtsilä internal combustion engines could allow HBGS to integrate operation with intermittent sources of renewable energy resources (see Winstead, 2018; Goldthrite, 2018). This mode of operation has not been employed by HBGS and would require approval and may have implications to engine lifetime or maintenance costs.

The HBGS is dispatched like any other power plant participating in the CAISO market. The Scheduling Coordinator for the plant submits bids into the market. The bids submitted can be crafted to meet the objectives of the operating modes described above. CAISO then awards bids and dispatches plants in an optimal fashion in order to meet system requirements for power quantity, power quality, and reliability, all while minimizing the cost of service. If the output from the plant does not meet its dispatch instructions, the deviation can be resolved through the energy imbalance market and/or uninstructed deviation penalties may be incurred.

As a fossil fuel-fired plant, the HBGS has a marginal operating cost that is greater than that of fuel-free renewable generators, such as an offshore wind plant. Intermittent renewables like wind and solar are typically offered into the CAISO market as “price takers.” This means that they offer their power at a price of zero dollars per MWh. This essentially ensures that they will be awarded their bid. They are then compensated at the market clearing price.

If a large wind farm were interconnected within the Humboldt Area and it were offered into the CAISO market as a price taker, then it would typically be dispatched ahead of the HBGS plant. The HBGS plant would then be dispatched to meet the remaining net load for the area in a fashion that met power requirements and minimized cost. Available power that could be imported via the transmission lines serving the Humboldt Area would also be considered when optimizing the dispatched power mix.

B.2 Application in Load Compatibility Model

In the load compatibility model described in the main body of this report, Humboldt County power plants were dispatched on an hourly basis starting with the production from existing biomass and hydroelectric resources, then adding the modeled offshore wind power, and finally HBGS's minimum output in load following mode: 12 MW (CEC, 2008, rounded up to the nearest MW). Then, if total generation was less than demand, HBGS output was increased to meet county demand, up to its maximum output of 163 MW. If additional power was needed, it was met with imports. Surplus local generation up to 70 MW was exported, and surplus generation above 70 MW was curtailed.

This method resulted in a monthly HBGS output 75% higher than historical production data reported by the California Energy Commission (2020c). The increased HBGS output in this model is a result of the model prioritizing HBGS over imported electricity, while in actual operation imports are used more frequently in the area based on price. Nevertheless, because it was carried through all analyses, the assumed behavior allows for a consistent comparison. Otherwise, economic assumptions would have to be included in the model to make a dispatch decision between imports and HBGS to balance regional load.

APPENDIX C - HUMBOLDT BAY GENERATING STATION EMISSIONS INTENSITY CALCULATION

The EPA's Emissions & Generation Resource Integrated Database lists Humboldt Bay Generating Station (HBGS) 2018 emissions as 179,007 metric tons of CO_2 equivalent, and annual net generation as 383,862 MWh (EPA, 2020). This leads to an emissions factor of 0.466 metric tons CO_2 equivalent per MWh, or 1030 lb per MWh.

QFER annual data record for 2018 lists HBGS production as 384,787 MWh, matching the QFER monthly data exactly, and quite close to the EPA's data (CEC, 2020b). The California Air Resources Board lists HBGS 2018 emissions as 179,025 metric tons of CO_2 equivalent (CARB, 2019). These data lead to a slightly lower emissions factor of 0.465 metric tons CO_2 equivalent per MWh, or 1025 lb per MWh.

These factors are within 0.3% of each other, and the emissions factor of 0.465 metric tons CO_2 equivalent is used because it is more conservative for the purposes of calculating CO_2 reduction.