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Northern California and Southern Oregon Offshore Wind Transmission Study

Volume 2 – Appendices (Revised)

This report was prepared by staff from the Schatz Energy Research Center, Quanta Technology, the National Renewable Energy Laboratory of the U.S. Department of Energy (NREL), H. T. Harvey & Associates, Mott MacDonald, Inc., and Conaway Geomatics. It was first published by the Schatz Energy Research Center in October 2023, and a revised report was published in January 2024 (revision notes are provided on page ii). The contract was administered by the Cal Poly Humboldt Sponsored Programs Foundation.

Prepared for the California Energy Commission under Agreement No. 700-22-002; the Oregon Department of Energy, and the Office of Local Defense Community Cooperation of the U.S. Department of Defense
Commission Agreement Manager: Jim Bartridge

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Report Availability

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The report is also available on the Schatz Energy Research Center website at: schatzcenter.org/publications

About the Schatz Energy Research Center

The Schatz Energy Research Center at Cal Poly Humboldt advances clean and renewable energy. Our projects aim to reduce climate change and pollution while increasing energy access and resilience.

Our work is collaborative and multidisciplinary, and we are grateful to the many partners who together make our efforts possible.

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b - Quanta Technology, Inc.
c - National Renewable Energy Laboratory
d - H. T. Harvey & Associates
e - Mott MacDonald

Revision Notes

This report was first published in October 2023. Subsequently, minor errors were detected and this revised report was published in January 2024 with corrections. All corrections are consistent with the analysis the was conducted. The changes in this revised report include the following:

1. Figure E-3 -- Corrected the arrows on the export cables from the Del Norte and Humboldt wind farms; they are now unidirectional.
2. Figure E-6 -- Corrected the arrows on the export cables from the Del Norte and Humboldt wind farms; they are now unidirectional.
3. Figure E-9 -- Corrected the arrows on the export cables from the Del Norte and Humboldt wind farms; they are now unidirectional.
4. Figure E-10 -- Corrected the export cables from the Brookings wind farm to go to both the Rogue and Del Norte substations. Added undersea HVDC cables from the onshore Del Norte substation to the onshore Humboldt substation and from the onshore Humboldt substation to the onshore Martin substation; added overland HVDC cable from the Humboldt substation to the Collinsville substation.
5. Figure E-12 -- Corrected the arrows on the export cables from the Del Norte and Humboldt wind farms; they are now unidirectional. Corrected the arrows on the export cables from the Brookings wind farm; they are now bidirectional since they go to two different onshore substation locations and therefore could be used to transmit power from one onshore location to another.
6. Figure E-30 -- Corrected the arrows on the export cables from the Coos Bay wind farm; they are now unidirectional.

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Appendix A: List of existing studies reviewed

(prepared by Schatz Energy Research Center)

BPA (2022). Transmission Service Request Study and Expansion Progress - 2022 Cluster Study Report. Transmission Study, FE-1200: TSEP Cluster Study.

Douville, T., Bhatnagar, D., O'Neil, R., & Mongird, K. (2020). Exploring the Grid Value Potential of Offshore Wind Energy in Oregon. *Pacific Northwest National Laboratory*, *PNNL-29935* (OCS Study BOEM 2020-026). https://www.boem.gov/sites/default/files/documents/regions/pacific-ocs-region/environmental-science/BOEM-2020-026.pdf.

Douville, T., Severy, M., Eisdorfer, J., He, L., & Pamintuan, B. (2023). West Coast Offshore Wind Transmission Literature Review and Gaps Analysis. *US Department of Energy - Energy Efficiency and Renewable Wind Energy Technologies Office*, *Contract No. DESC0014664*. https://www.pnnl.gov/sites/default/files/media/file/West_Coast_OSW_Tx_Literature_Review__PNNL_WETO_021623_0.pdf.

Department of Energy (2021). Atlantic Offshore Wind Transmission Literature Review and Gaps Analysis. *US Department of Energy - Energy Efficiency and Renewable Wind Energy Technologies Office*, *Contract No. DESC0014664*. https://www.energy.gov/sites/default/files/2021-10/atlantic-offshore-wind-transmission-literature-review-gaps-analysis.pdf.

PacifiCorp (2022). Local Transmission System Plan (LTSP). *(2022-203 Biennial Cycle)*.

Gill, L., Gutierrez, A., & Weeks, T. (2021). 2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment. *CEC Energy Assessments*, (CEC-200-2021-001). https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

Pacific Gas and Electric Company (2020). Interconnection Feasibility Study Report. In M. Severy, Z. Alva, G. Chapman, M. Cheli, T. Garcia, C. Ortega, N. Salas, A. Younes, J. Zoellick, & A. Jacobson (Eds.) California North Coast Offshore Wind Studies. Humboldt, CA: Schatz Energy Research Center. http://schatzcenter.org/pubs/2020-OSW-R4.pdf.

Daneshpooy, A. and R. Anilkumar. (2022). Transmission Alternatives for California North Coast Offshore Wind, Volume 3: Transmission Analysis. Cal Poly Humboldt, Arcata, CA: Schatz Energy Research Center. http://schatzcenter.org/pubs/2022-OSW-R3.pdf.

Porter, A., and Phillips, S. (2020). Subsea Transmission Cable Conceptual Assessment. In M. Severy, Z. Alva, G. Chapman, M. Cheli, T. Garcia, C. Ortega, N. Salas, A. Younes, J. Zoellick, & A. Jacobson (Eds.) California North Coast Offshore Wind Studies. Humboldt, CA: Schatz Energy Research Center. http://schatzcenter.org/pubs/2020-OSW-R5.pdf.

California ISO (2022). 20-Year Transmission Outlook. *California ISO/TP&ID*. http://www.caiso.com/InitiativeDocuments/20-YearTransmissionOutlook-May2022.pdf.

California ISO (2022). 2021-2022 Transmission Plan. *California ISO/I&OP*. http://www.caiso.com/InitiativeDocuments/20-YearTransmissionOutlook-May2022.pdf.

Evolved Energy Research, Renewable Northwest, GridLab, & Clean Energy Transition Institute (2021). Oregon Clean Energy Pathways Analysis. https://www.cleanenergytransition.org/projects/deep-decarbonization-pathways/oregon-clean-energy-pathways-analysis.

Wu, G.C.; Leslie, E.; Allen, D.; Sawyerr, O.; Cameron, D.; Brand, E.; Cohen, B.; Ochoa, M.; Olson, A. Power of Place: Land Conservation and Clean Energy Pathways for California, (2019). https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/power-of-place/.

NorthernGrid (2023). Economic Study Request Offshore Wind in Oregon (Draft). https://www.northerngrid.net/private-media/documents/DraftforPostingNGESROSW.pdf.

Sierman, J., Cornett, T., Henry, D., Reichers, J., Schulz, A., Smith, R., & Woods, M. (2023). FLOATING OFFSHORE WIND: Benefits & Challenges for Oregon. *Oregon Department of Energy* https://www.oregon.gov/energy/Data-and-Reports/Documents/2022-Floating-Offshore-Wind-Report.pdf.

Novacheck, Josh, Marty Schwarz. (2021). Evaluating the Grid Impact of Oregon Offshore Wind. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A40-81244. https://www.nrel.gov/docs/fy22osti/81244.pdf.

The Research Group, LLC (2021). Oregon Commercial and Recreational Fishing Industry Economic Activity Coastwide and in Proximity to Marine Reserve Sites for Years 2018 and 2019, Executive Summary. Prepared for Oregon Department of Fish and Wildlife, Marine Reserve Program and Marine Resource Program. June 2021.https://www.dfw.state.or.us/agency/docs/TRG%20ec%20summary%20Oregon%20Coast%20fishing%20industry%202018-2019%20TR.pdf.

Appendix B: List of GIS data layers

(prepared by Schatz Energy Research Center)

Dataset	**Source**
Wind Energy Areas & Planned BOEM Lease Areas	Bureau of Ocean Energy Management
Electric Transmission Lines	Homeland Infrastructure Foundation-Level Data - HIFLD.
Electric Substations (CA)	Homeland Infrastructure Foundation-Level Data - HIFLD.
Electric Substations (OR)	Homeland Infrastructure Foundation-Level Data - HIFLD.
Energy Generation Facility Information (Type/fuel & Capacity)	Homeland Infrastructure Foundation-Level Data - HIFLD.
DOD Operational Areas (Flight Corridor)	Department of Defense
DOD Operational ARea (Special Use Airspace)	Department of Defense
Geomorphology of Oceans "Canyons" Layer	Harris et al, 2014
Submarine Cable shore landing locations	North American Submarine Cables Association (NASCA)
Marine Protected Areas Inventory (2017)	Noaa Marine Protected Areas Center
PacPars Fairway Designations	United States Coast Guard
100-m Interval Bathymetry	United States Geological Survey (USGS)

Appendix C: Wind generation profile memo

Prepared by: Eli Wallach, Charles Chamberlin, and Jim Zoellick (Schatz Energy Research Center)

Generation Profiles Approach

The purpose of the document is to present the methods used in the estimation of generation profiles for the wind farm scenarios to be investigated in this transmission study. These generation profiles will be for a typical meteorological year at a 1-hour resolution. These generation profiles will be used to develop a power flow analysis and eventually inform cost modeling for transmission scenarios. For this study three development scenarios have been envisioned, including Low (7.2 GW cumulative nameplate capacity), Mid (12.4 GW cumulative nameplate capacity) and High (25.8 GW cumulative nameplate capacity) development scenarios. Each of these development scenarios consists of four or five wind farms spanning from Cape Mendocino to Coos Bay. This memo describes the steps and assumptions taken to get from a defined wind study area and desired nameplate capacity to a generation profile. Upstream assumptions and decisions that lead to either the wind area determination or the nameplate capacity buildout levels are not addressed here. These decisions are described in the *Task 4 - Technical memo documenting scaled scenarios, clean energy goals and other relevant information*.

Table 1 below reports the 14 wind farm scenarios to be modeled, which include all of the wind farms needed for the three development scenarios described above. The turbine counts reported here assume a 15 MW turbine.

Table 1: Wind Farm Scenarios to be modeled

Wind Study Area Name	Nameplate Capacity (GW)	Required 15 MW Turbines (Count)	Prevailing Wind Direction (Degrees from North)
Brookings Call Area	1.8	120	0
Brookings Call Area	5.9	393	0
Cape Mendocino Notional Area (North)	2.1	140	355
Cape Mendocino Notional Area (North)	6.3	420	355
Cape Mendocino Notional Area (South)	2.1	140	340
Coos Bay Call Area	1.3	260	5
Coos Bay Call Area	3.9	140	5
Del Norte Notional Area	2.1	140	350
Del Norte Notional Area	4.6	307	350
Del Norte Notional Area	6.7	447	350
Del Norte Notional Area	7.0	467	350
Humboldt Wind Energy Area	2.0	133	350
Humboldt Wind Energy Area	2.6	173	350
Humboldt Wind Energy Area	2.7	180	350

Methods

To create these generation profiles, a conceptual turbine layout for the wind farm was first determined. Based on wind data derived from the WIND toolkit, NREL's FLORIS utility was used to estimate the annual hourly series of power generation at each turbine considering upstream turbine wakes and other losses. Wake loses are a function of the turbine layouts, windspeed, and turbine characteristics. Finally, these unadjusted generation estimates were further downrated based on technical losses including potential turbine and transmission downtime.

Layouts and wake modeling assume a 15 MW IEA model turbine (Gaertner 2020). This turbine was selected as it is a well-documented and accepted model turbine which is in the size range expected to be installed in these wind energy study areas.

During these simulations each of the six wind areas were treated separately. The following graphic shows each wind energy area considered. For some of the larger buildout scenarios, treating each of the call areas as independent may have neglected some inter-project wake losses, for example between Brookings and Del Norte.

In the sections below, the methods used for turbine layouts, wind speed data handling, wake modeling, and other loss estimation are further described.

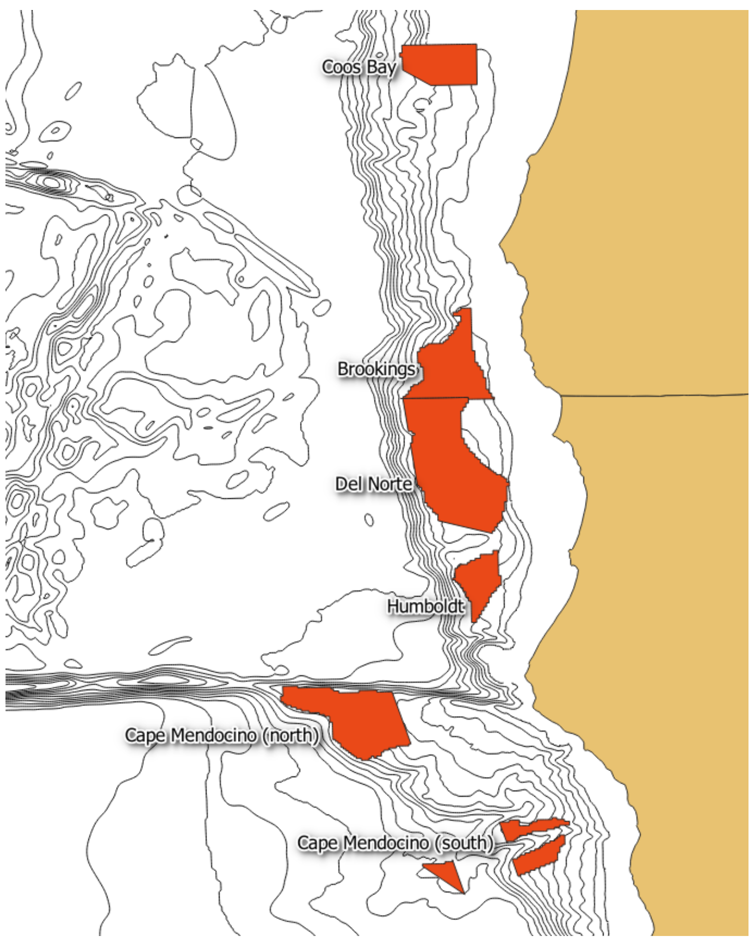


Figure 1: Wind Energy Areas Considered

Turbine layouts

Turbine layouts were assumed to be a hexagonal close packed structure of offset rows. Rows of turbines were assumed to be spaced at ten rotor diameters while columns were spaced at four rotor diameters. The rows of turbines were set perpendicular to the prevailing wind direction. These assumptions follow NREL's site assessment (Cooperman et al., 2022). This 4D x 10D turbine packing is more than sufficient to fit the turbine counts listed in Table 1 within the corresponding WEAs. The placement algorithm limited the number of rows and kept the turbines clustered near the centroid of the call area. If partial rows were needed, the algorithm placed turbines nearest the centroid. These placements were meant to reduce wake losses without limiting future buildout of the wind area.

For this analysis the placement of mooring anchors or lines was not considered. The only limitation of turbine placements was that the turbine itself (represented as a point) fall within the call area. In reality some setback from the edge of the call area is likely needed to ensure that subsea structures and components all fall within the call area. However, since these conceptual layouts are only used to estimate wake losses this is not expected to be a significant factor.

Figures 2 depicts the conceptual layout for a 2.6 GW farm in the Humboldt Wind Energy Area. This figure showing the elliptical turbine standoffs for each of the turbines in the arrays and the wind area shape.

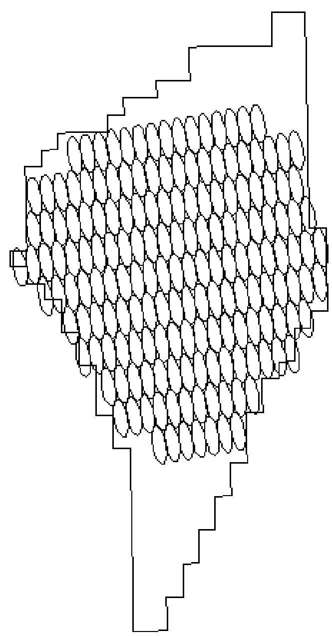


Figure 2: Conceptual layout for a 2.6GW farm at Humboldt

Wind data

The input wind data for this effort was derived from the WIND toolkit (Draxl et al., 2015b). This dataset contains modeled one hour windspeed and direction data for Central and North America including some extent offshore, spanning from 2007-2014. Since the goal of this project is to evaluate power flow from wind farms using an annual hourly load profile, a typical meteorological year (TMY) of hourly wind speed data was assembled from this 8-year data set. In this process, one month of data was selected from the eight years of data available for the TMY dataset such that the month selected most closely matched the average single turbine power generation in that month given the full data set. Each wind area had its TMY data set assembled independent of all other call areas to give the best possible fit for the TMY data.

Note that this WIND toolkit is not the newest available NREL modeled wind speed data. The CA20 and North West Pacific windspeed data was generated as an update to this WIND toolkit. This more recently updated data set was not chosen as it has been shown to have a worse fit (than the WIND toolkit) when compared with real lidar data at the Humboldt and Morro Bay WEAs (Bodini et al., 2022). NREL is currently working to run the Weather Research and Forecasting Model (WRF) with a new configuration based on their validation efforts, however this next iteration of modeled offshore windspeeds is not yet available for use.

Wake loss model

The wake model used is a Gaussian plume wake model as implemented by the FLORIS utility. Bastankhah and Porté-Agel (2014) describe this wake model. It was selected for its ties to measurable physical phenomena such as shear, veer and turbulence intensity via the free shear flow theory (Annoni et al., 2018). This Gaussian wake loss model has also been shown to have good agreement with existing farms (Doekemeijer et al., 2022; Annoni et al., 2018).

In the wake model selection process, multiple wake models were explored using smaller wind farms layouts at each of the call areas. Of the wake models explored, the Gaussian model yielded intermediate wake losses in comparison to the Jensen wake model, which predicted less wake loss, and the Turbo-park model, which predicted more. The Turbo-Park model used in NREL's site assessment was also carefully considered (Nygaard et al., 2020). Although the Turbo-Park model is thought to do a better job of estimating the longer lasting effects of turbine wakes (far downstream) than the Gaussian wake models (Cooperman et al., 2022), the Gaussian model was selected as a more conservative option since higher power generation estimates will lead to more conservative transmission equipment sizing.

One limitation of this wake modeling approach is that wake steering was not considered. It has been shown that wake steering can be used to mitigate wake losses and improve farm productivity. However, modeling wake steering is beyond the scope of this project.

Additional loss factors

Since the power estimates generated from FLORIS only reflect wake losses, they are further downrated based on several additional loss factors that can be divided into three broad categories: proportional losses, shutdown losses affecting single turbines, and shutdown losses affecting the entire farm.

Proportional Losses

Some of the loss factors considered affect all generation and represent a small percentage loss of the power generated. The losses presented in Table 2 below are included in the model as a downrating for power generation at all time steps and throughout all portions of the power curve. These loss factors are based on the experiences of terrestrial wind farms and are additional to wake losses (AWS Truepower 2014).

Table 2: Proportional losses considered (AWS Truepower, 2014).

Loss Origin	Specific Loss	Loss Factor (%)
Electrical	Electrical Efficiency	2.0
Electrical	Power Consumption of Weather Package	0.1
Turbine Performance	Sub-optimal operation	1.0
Turbine Performance	Power Curve Adjustment	2.4
Turbine Performance	Inclined Flow	0.0
Environmental	Blade Degradation	1.0
Total		6.5

Single turbine-associated shut-down losses

Turbines shut down for a variety of reasons ranging from environmental conditions to routine maintenance and mechanical failure. To account for these factors a binomial distribution is used to randomly select turbines and time stamps during which turbines are "shut-down" (generation set to zero) according to the probability that we expect shut-downs to occur. These turbine losses are in addition to the proportional and wake losses and represent a total downtime of approximately 8%.

In previous wind generation profile work conducted by the Schatz Center the portion of the time that single turbines were shut down was based on data from onshore farms. As part of the current project a literature review of turbine availability in fixed bottom offshore farms was completed and found that turbine availability ranges from as low as 80% to as high as 93% for fixed bottom offshore wind farms (Pfaffel et al., 2017). This availability is tightly related to distance offshore, as this is related to response time required for repairing shut-down turbines. Typical sea state is another factor that is related to turbine availability, as this also relates to response time (ability for boats to travel offshore) for repairing turbines (Carroll et al., 2016).

While historic data from fixed-bottom offshore wind farms is useful to get an estimate of the impact turbine shutdowns may have on generation, it does not capture the reality of the situation for floating wind farms. The depths at which floating turbines are to be installed are in excess of what a jack-up vessel can operate in. Given that jack-up vessels are extensively used for repair of fixed bottom offshore wind turbines, a tow-to-shore scheme is envisioned as the alternative for major repairs of floating offshore wind turbines (Saeed et al., 2022).

To address these considerations, an in-depth analysis was conducted of the downtimes resulting from different typical failures for wind turbines. By combining the probability of failure data, information about which vessel(s) would be needed to repair each failure type, the repair time required, and the waiting period for suitable weather based on historic, site-specific weather data, an estimate of availability losses was made. This analysis showed that the three areas considered (Brookings, Humboldt and Cape Mendocino Call areas) have similar expected availabilities of around 92% (or an 8% loss).

Transmissions-associated shut-down losses

In some cases, a shut-down loss does not only impact a single turbine but instead prevents an entire wind farm from providing power to the grid. These transmission-associated shut-down losses were modeled using a binomial distribution to select time steps when the entire farm could not generate electricity. The probability of these failures was informed by data from terrestrial wind farms (AWS Truepower 2014). Table 3 summarizes these loss probabilities.

Table 3: Transmission-associated shut-down loss factors (AWS Truepower 2014).

Loss Origin	Loss Factor, Typical (%)	Loss Factor, Low (%)	Loss Factor, High (%)
Availability of Collection & Substation	0.2	0.2	0.4
Availability of Utility Grid	0.3	0.3	0.6
Plant Re-start after Grid outages	0.2	0.2	0.4

Results

This section reports the power generation estimates for each of the wind farms considered. Figures 3 and 4 show the overall estimate of Capacity Factor and losses considered, respectively. losses are framed as a percentage of the farm generation assuming no wake losses. Table 4 reports the values shown in Figure 4.

Once windspeeds exceed around 12 m/s wake losses are no longer an important factor. The turbine model used reports nameplate generation is achieved at windspeeds above 11m/s. Thus, in high winds a slight loss in wind velocity from upstream turbines does not represent any wake losses.

Larger nameplate farms tend to have higher wake losses but the wind resource also plays and important role (as noted above), this can be seen in the wake estimates for the Coos Bay area. This area had the highest wake loss estimates as modeled wind speeds estimate a more variable wind pattern and a higher frequency of intermediate wind speeds compared to other areas.

Appendix A contains detailed load duration curves for each farm alternative. Small “steps” in the load duration curves are caused by modeling single turbine failures as statistically independent.

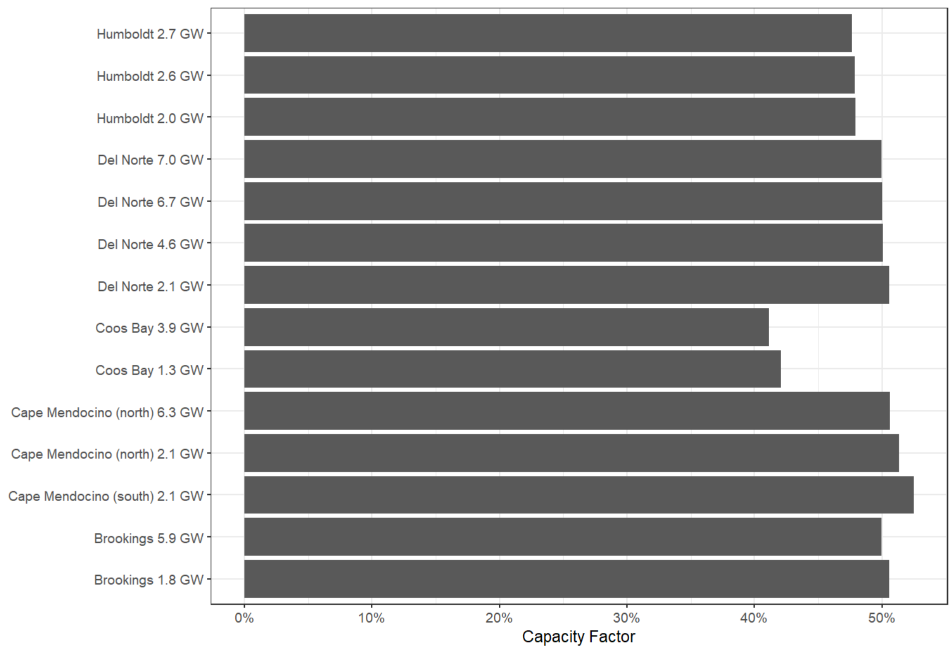


Figure 3: Estimated capacity factor.

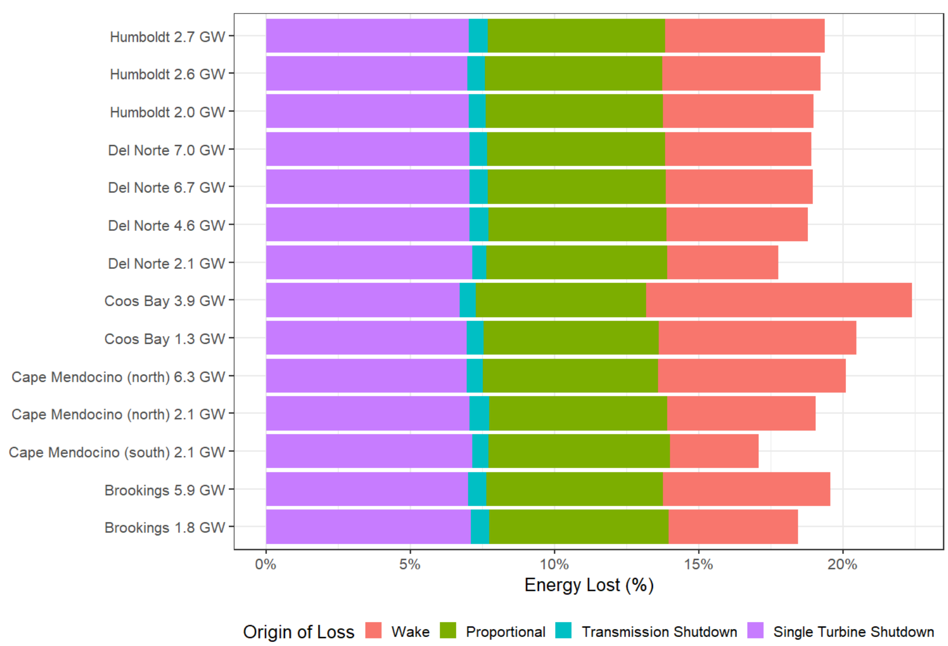


Figure 4: Loss factors considered (Presented as a percentage of un-waked generation).

Figure 3 shows capacity factors ranging from 42% to 52%. Figure 4 shows total loses ranging from 17% to 22%. Figure 4 displays the comparative size of the 4 types of losses, with single turbine shutdown losses being the largest contribution, transmission shutdown losses being almost negligible, and proportional and wake losses being roughly comparable and intermediate in magnitude. It should be noted that in the methods losses are presented as a portion of the generation at the phase the loss factor is applied, here loss factors are presented as a portion of the un-waked farm generation leading to a slight reduction in these percentages as compared to the methods

Table 3: Losses considered as a percentage of un-waked generation

Wind Study Area Name	Nameplate Capacity (GW)	Wake Losses	Proportional Losses	Transmission Shutdown Losses	Single Turbine Shutdown Losses
Brookings Call Area	1.8	4.50%	6.21%	0.64%	7.10%
Brookings Call Area	5.9	5.80%	6.12%	0.65%	7.00%
Cape Mendocino Notional Area (North)	2.1	5.16%	6.16%	0.69%	7.04%
Cape Mendocino Notional Area (North)	6.3	6.51%	6.08%	0.56%	6.95%
Cape Mendocino Notional Area (South)	2.1	3.07%	6.30%	0.54%	7.16%
Coos Bay Call Area	1.3	6.87%	6.05%	0.60%	6.95%
Coos Bay Call Area	3.9	9.22%	5.90%	0.56%	6.71%
Del Norte Notional Area	2.1	3.87%	6.25%	0.50%	7.15%
Del Norte Notional Area	4.6	4.89%	6.18%	0.64%	7.06%
Del Norte Notional Area	6.7	5.10%	6.17%	0.64%	7.06%
Del Norte Notional Area	7.0	5.07%	6.17%	0.61%	7.06%
Humboldt Wind Energy Area	2.0	5.22%	6.16%	0.58%	7.02%
Humboldt Wind Energy Area	2.6	5.50%	6.14%	0.62%	6.97%
Humboldt Wind Energy Area	2.7	5.53%	6.14%	0.67%	7.02%

Due to an error in the data-handoff process, the power flow model used a generation time series which did not include the effects of the single turbine shutdown losses. As presented above, the intention was for shutdown losses to be incorporated as 8% of total turbine-hours being estimated at zero generation. These shut down losses of 8% (time based) resulted in an average energetic loss of ~7% across all scenarios. To account for the downstream impacts to the production cost and power flow models, final estimates of energy generation and revenue from energy sold were reduced by 7%. While this single reduction factor does not account for the nuances of the power flow modeling, such as transmission congestion and its effect on local market prices or curtailments, it does shift these final estimates nearer to the intended analysis.

References

AWS Truepower, 2014, Loss and Uncertainty Methods. https://aws-dewi.ul.com/assets/AWS-Truepower-Loss-and-Uncertainty-Memorandum-5-Jun-2014.pdf

Annoni, J., P. Fleming, A. Scholbrock, J. Roadman, S. Dana, C. Adcock, F. Porte-Agel, S. Raach, F. Haizmann, and D. Schli S.., . 2018. Analysis of control-oriented wake modeling tools using lidar field results. Wind Energy Science, 3(2):819–831, 2018. URL: https://www.wind-energ-sci.net/3/819/2018/, doi:10.5194/wes-3-819-2018.

Bastankhah, M. and Porté-Agel, F., 2014, “A new analytical model for wind-turbine wakes”. Renewable Energy 70:116–123, 2014.

Bodini, N., Rybchuk, A., Optis, M., Musial, W., Lundquist, J.K., Redfern, S., Draxl, C., Krishnamurthy, R., and Gaudet, B., 2022, Update on NREL’s 2020 Offshore Wind Resource Assessment for the California Pacific Outer Continental Shelf. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-83756. https://www.nrel.gov/docs/fy23osti/83756.pdf.

Carroll, J., McDonald, A., Dinwoodie, I., McMillan, D., Revie, M., and Lazakis, I., 2016, “Availability, operation and maintenance costs of offshore wind turbines with different drive train configurations.” Wind Energy, 20(2), 361–378.

Cooperman, Aubryn, Patrick Duffy, Matt Hall, Ericka Lozon, Matt Shields, and Walter Musial. 2022. Assessment of Offshore Wind Energy Leasing Areas for Humboldt and Morro Bay Wind Energy Areas, California. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-82341. https://www.nrel.gov/docs/fy22osti/82341.pdf.

Doekemeijer, B.M.; Simley, E.; Fleming, P. Comparison of the Gaussian Wind Farm Model with

Historical Data of Three Offshore Wind Farms. Energies 2022, 15, 1964. https://doi.org/10.3390/en15061964

Draxl, C., B.M. Hodge, A. Clifton, and J. McCaa. 2015a. Overview and Meteorological Validation of the Wind Integration National Dataset Toolkit (Technical Report, NREL/TP-5000-61740). Golden, CO: National Renewable Energy Laboratory.

Draxl, C., B.M. Hodge, A. Clifton, and J. McCaa. 2015b. "The Wind Integration National Dataset (WIND) Toolkit." Applied Energy 151: 355366.

FLORIS. Version 2.4 (2021). Available at https://github.com/NREL/floris

Gaertner, Evan, Jennifer Rinker, Latha Sethuraman, Frederik Zahle, Benjamin Anderson, Garrett Barter, Nikhar Abbas, Fanzhong Meng, Pietro Bortolotti, Witold Skrzypinski, George Scott, Roland Feil, Henrik Bredmose, Katherine Dykes, Matt Shields, Christopher Allen, and Anthony Viselli. 2020. Definition of the IEA 15-Megawatt Offshore Reference Wind. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-75698. https://www.nrel.gov/docs/fy20osti/75698.pdf

King, J., A. Clifton, and B.M. Hodge. 2014. Validation of Power Output for the WIND Toolkit (Technical Report, NREL/TP-5D00-61714). Golden, CO: National Renewable Energy Laboratory.

Nygaard, N.G., Søren, T.S. , Poulsen, L., and Pedersen, J.G. 2020. "Modelling cluster wakes and wind farm blockage." In Journal of Physics: Conference Series, volume 1618, 062072. IOP Publishing, 2020.

Pfaffel, S., Faulstich, S., and Rohrig, K.. 2017. Performance and Reliability of Wind Turbines: A Review. Energies 2017, 10, 1904

Saeed, K., McMorland, J., Collu, M., Coraddu, A., Carroll, J., and McMillan, D. (2022). "Adaptations of offshore wind operation and maintenance models for floating wind." Journal of Physics: Conference Series, 2362(1), 012036.

Generation Profile Memo - Appendix 1

This appendix contains load duration curves for each of the 14 wind farm scenarios considered.

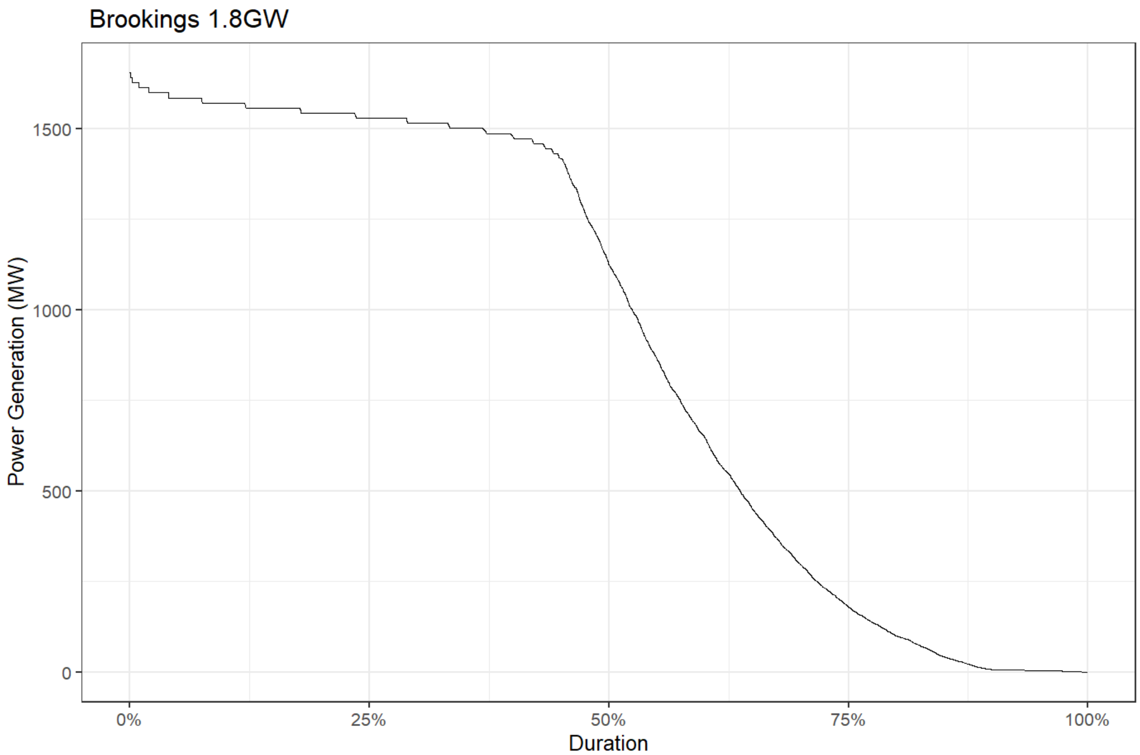


Figure A 1: Load duration curve for a 1 GW farm in the Brookings wind area

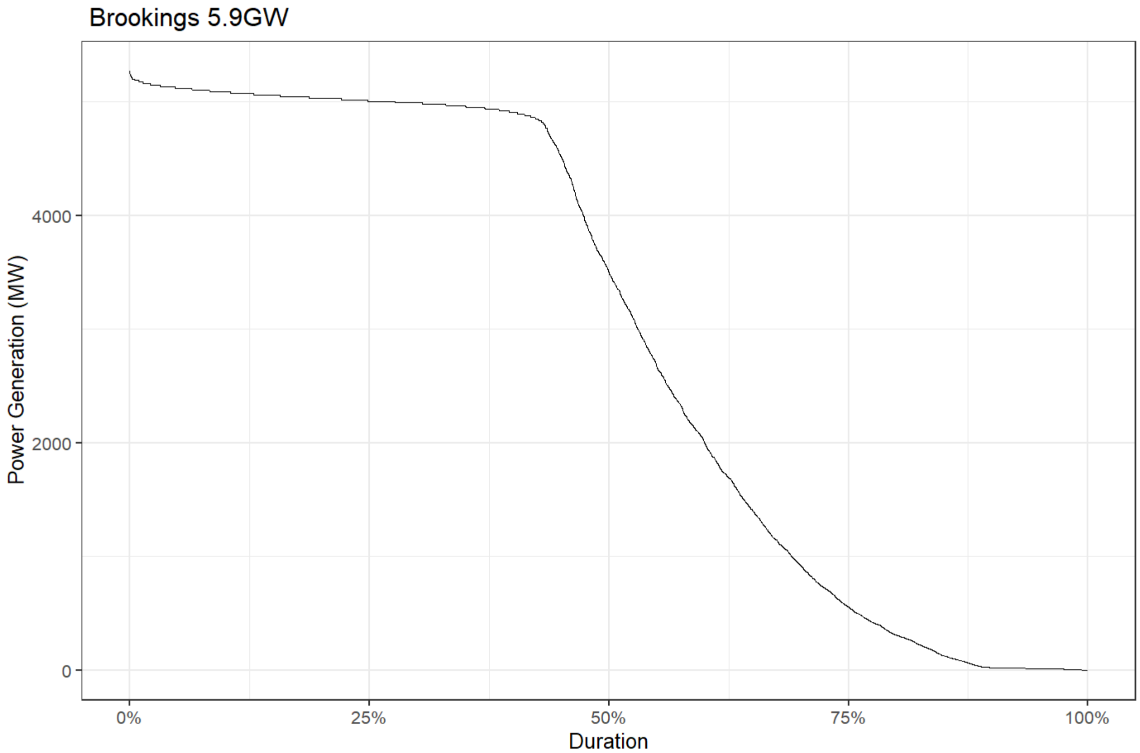


Figure A 2: Load duration curve for a 5.9GW farm in the Brookings wind area.

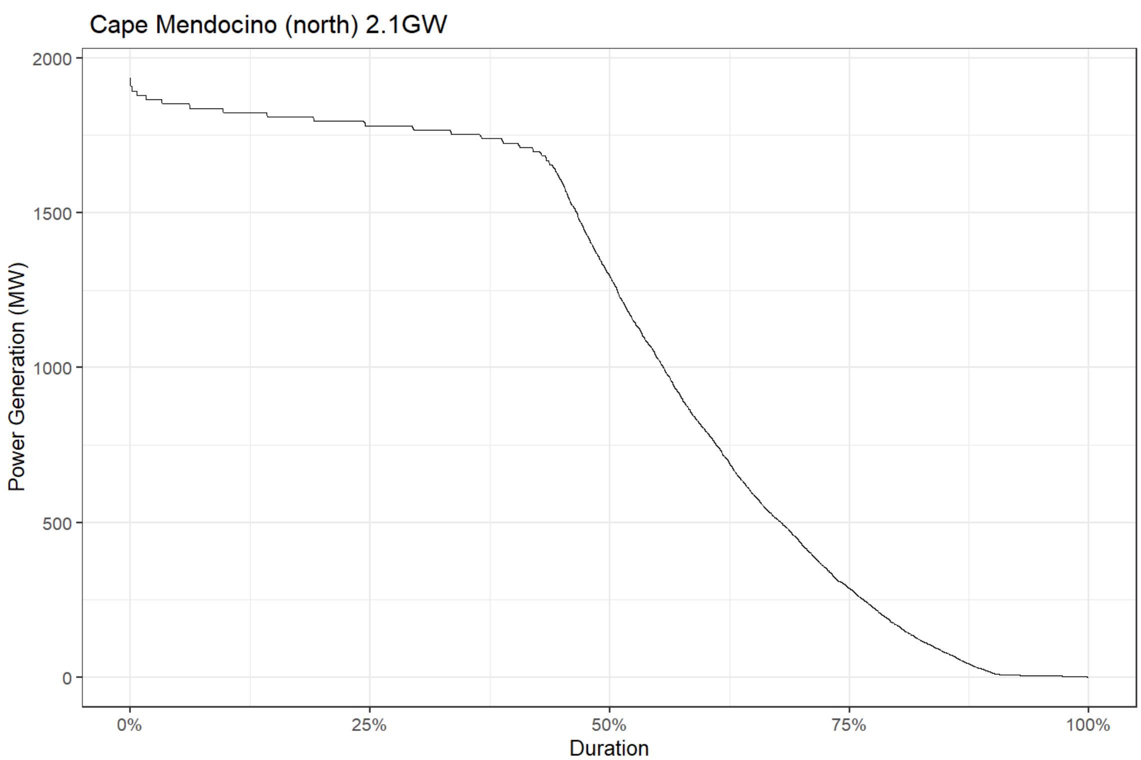


Figure A 3: Load duration curve for a 2.1GW farm in the Northern Cape Mendocino wind area.

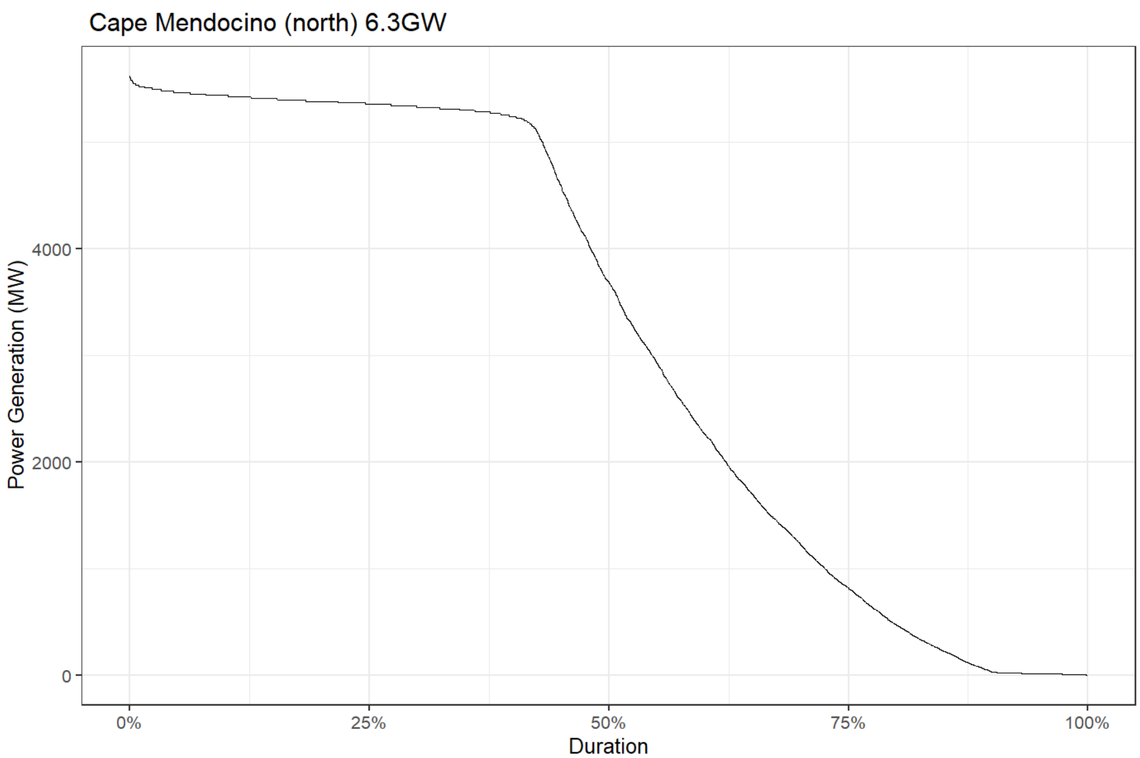


Figure A 4: Load duration curve for a 6.3 GW farm in the Northern Cape Mendocino wind area.

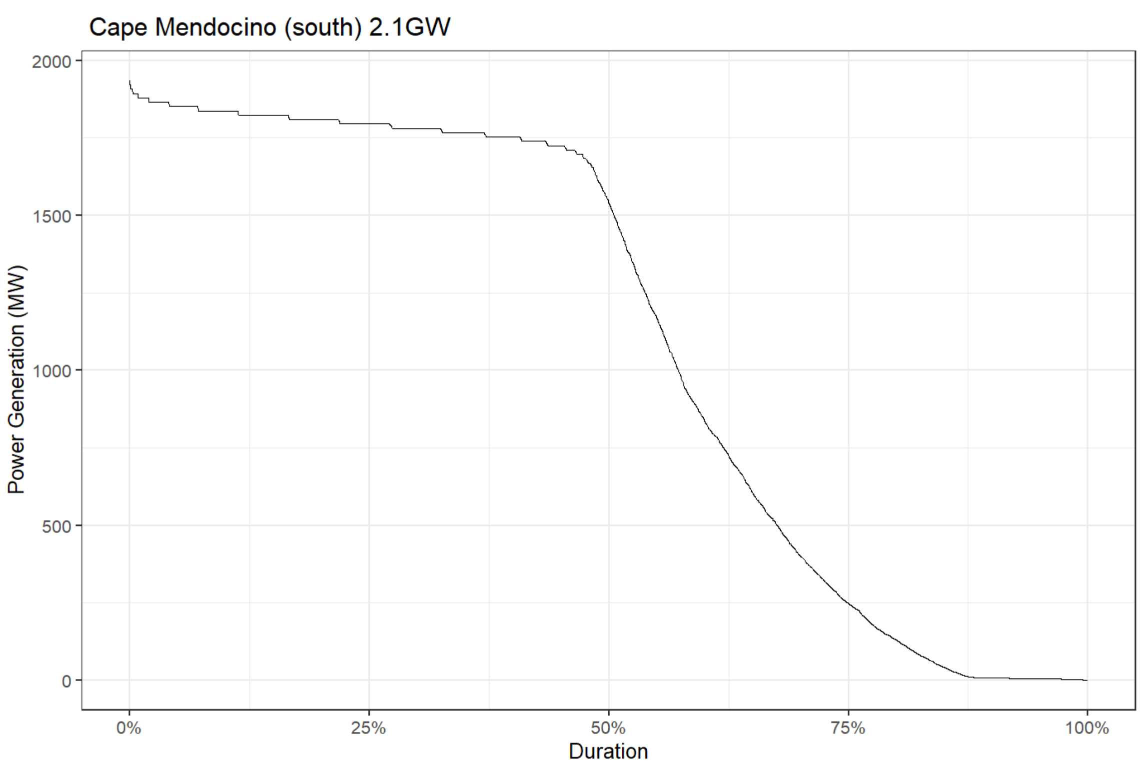


Figure A 5: Load duration curve for a 2.1 GW farm in the Southern Cape Mendocino wind area.

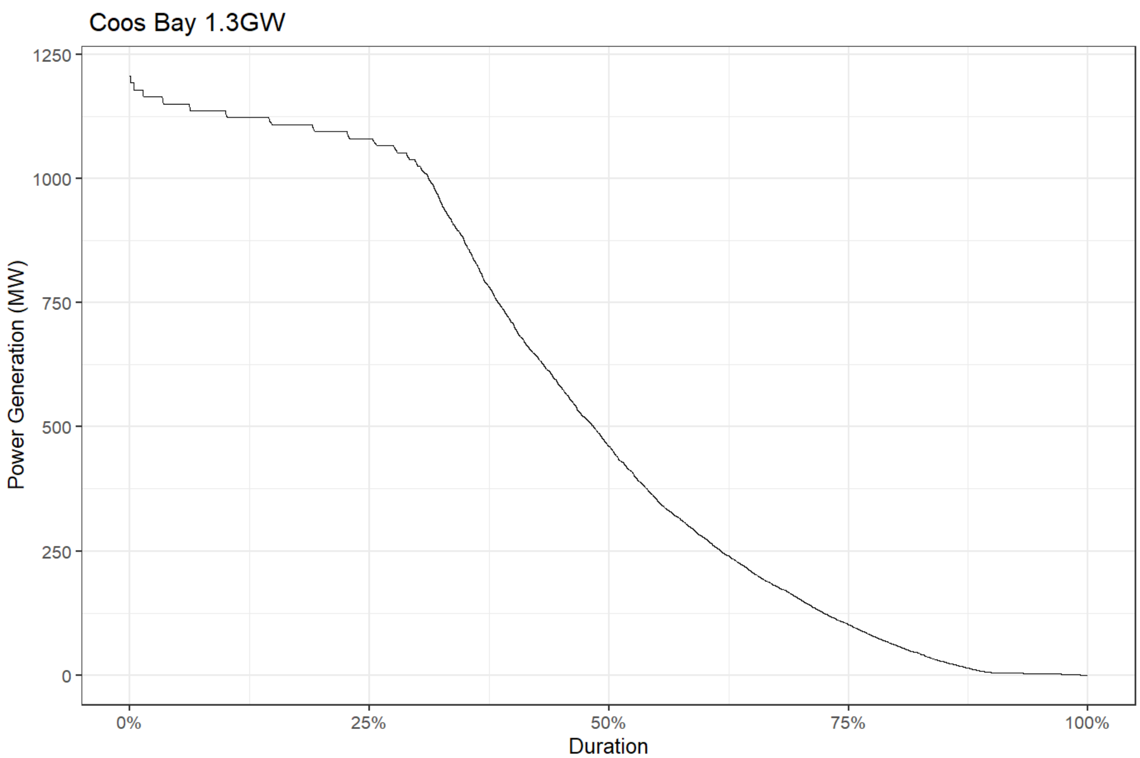


Figure A 6: Load duration curve for a 1.3GW farm in the Coos Bay wind area.

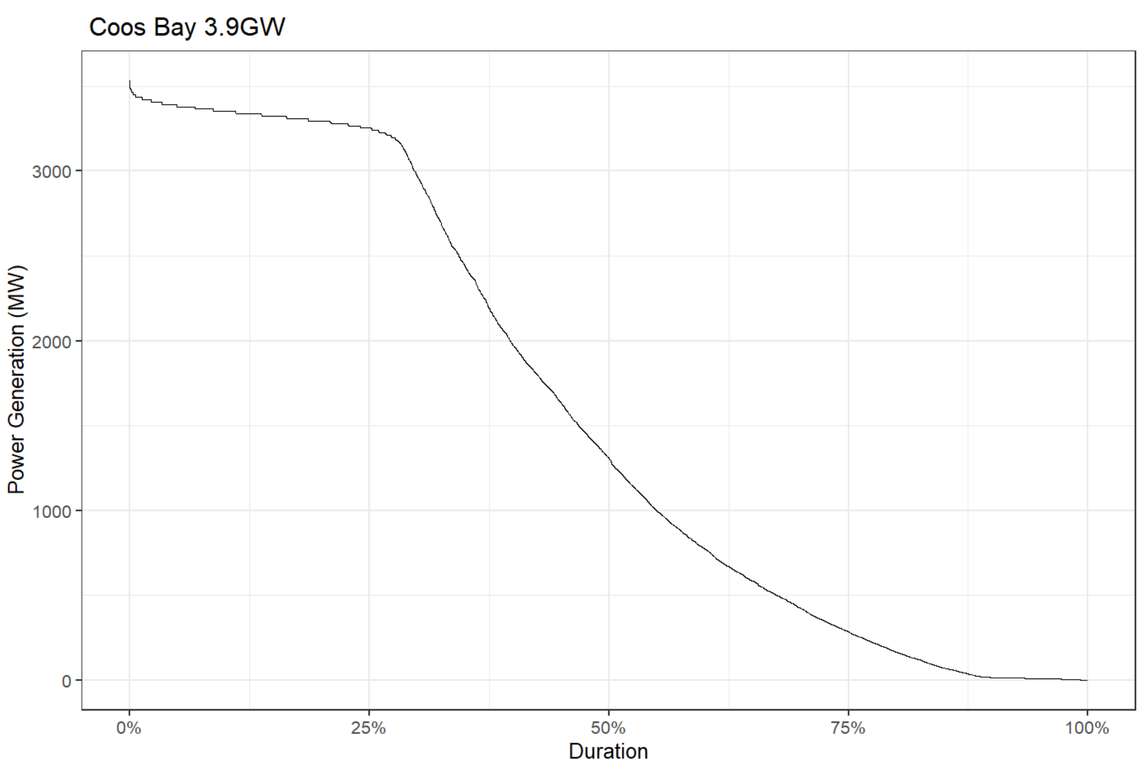


Figure A 7: Load duration curve for a 3.9 GW farm in the Coos Bay wind area.

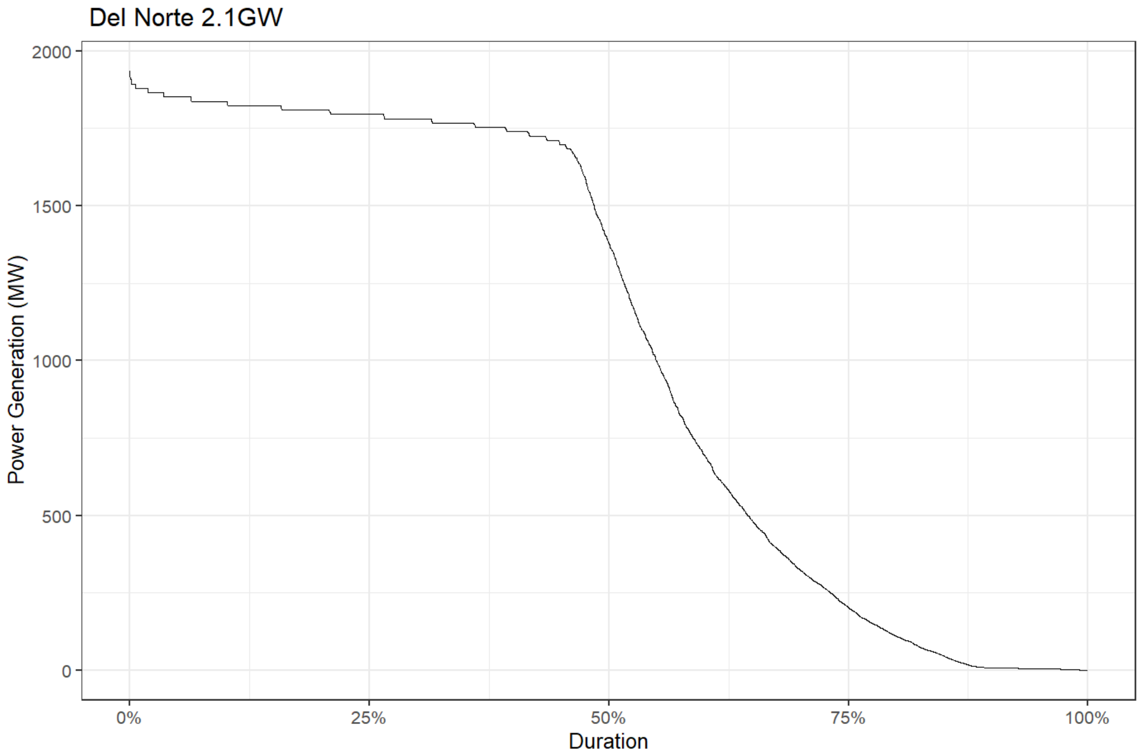


Figure A 8: Load duration curve for a 2.1 GW farm in the Del Norte wind area.

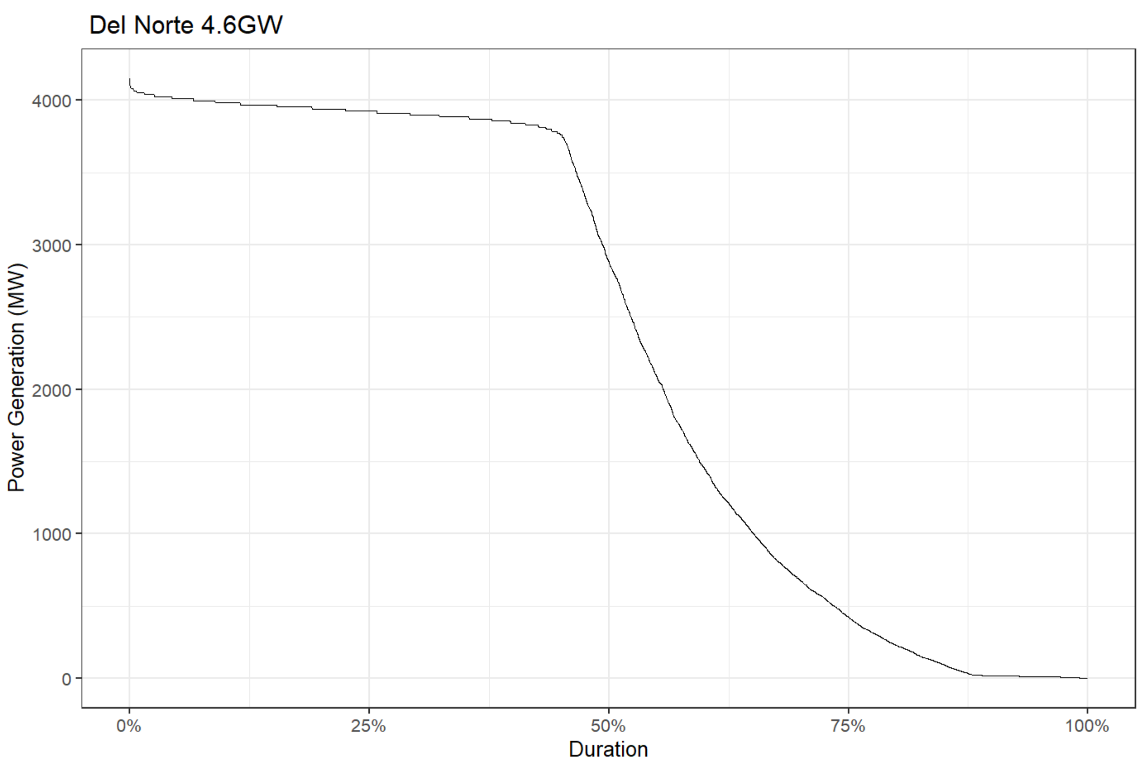


Figure A 9: Load duration curve for a 4.6 GW farm in the Del Norte wind area.

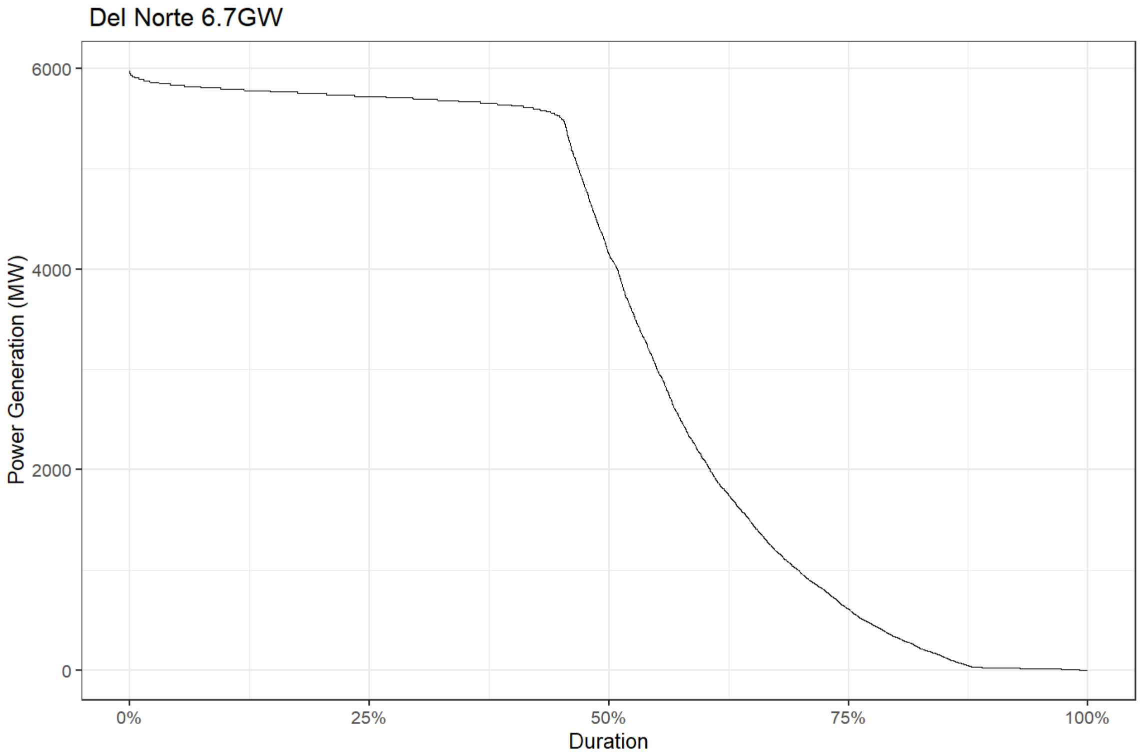


Figure A 10: Load duration curve for a 6.7GW farm in the Del Norte wind area.

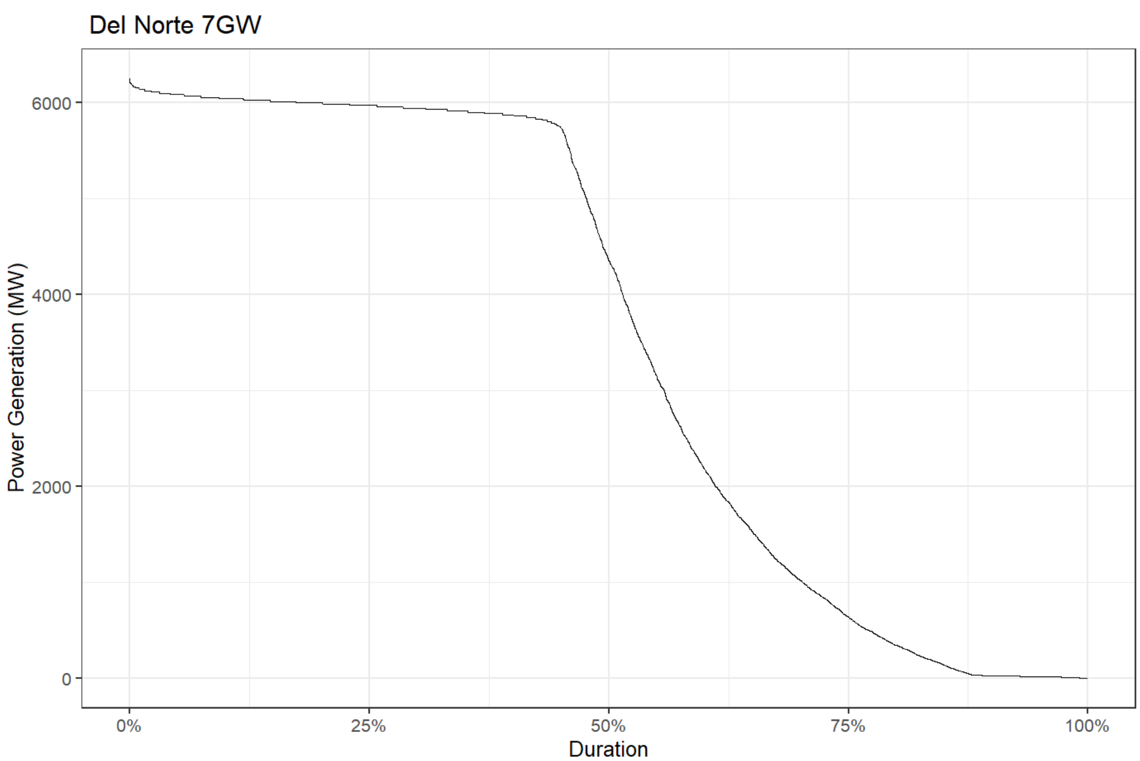


Figure A 11: Load duration curve for a 7GW farm in the Del Norte wind area.

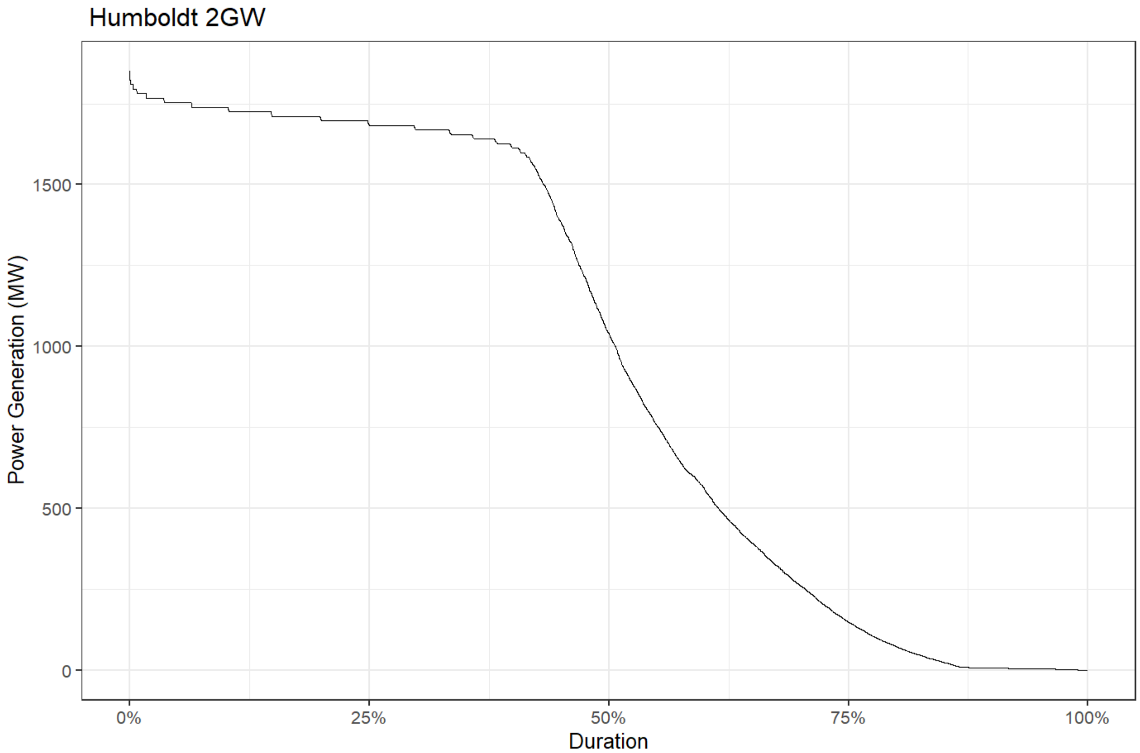


Figure A 12: Load duration curve for a 2 GW farm in the Humboldt wind area.

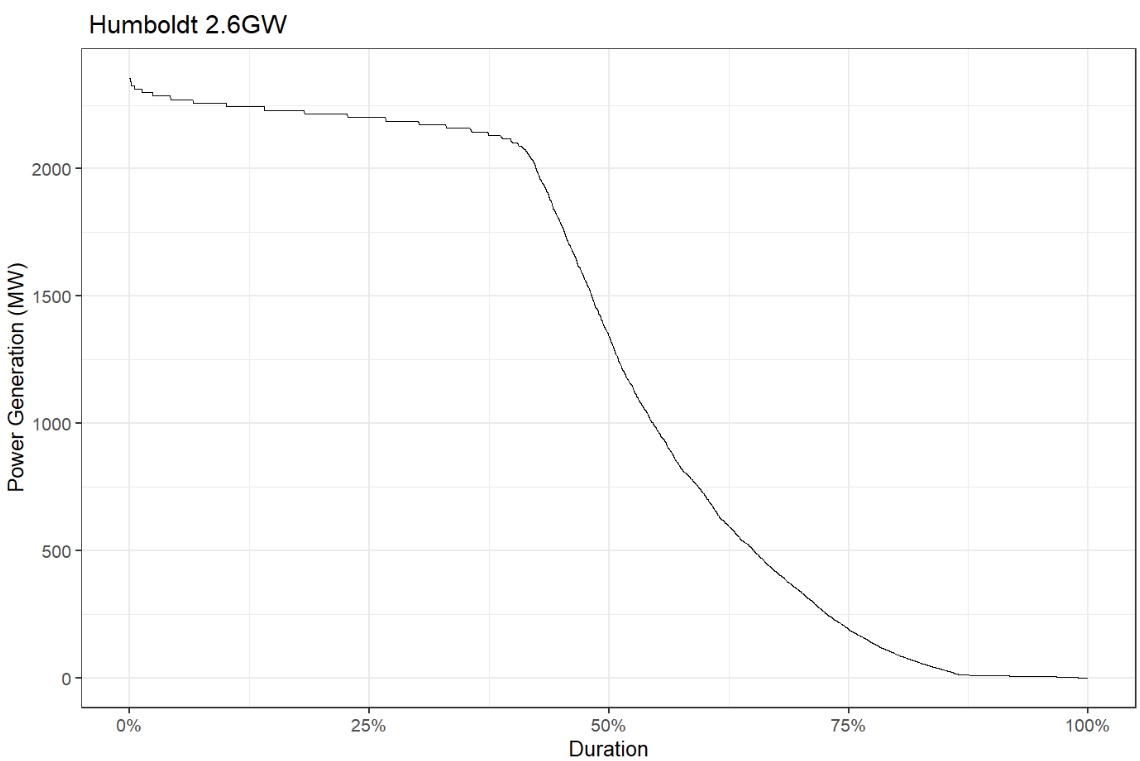


Figure A 13: Load duration curve for a 2.6 GW farm in the Humboldt wind area.

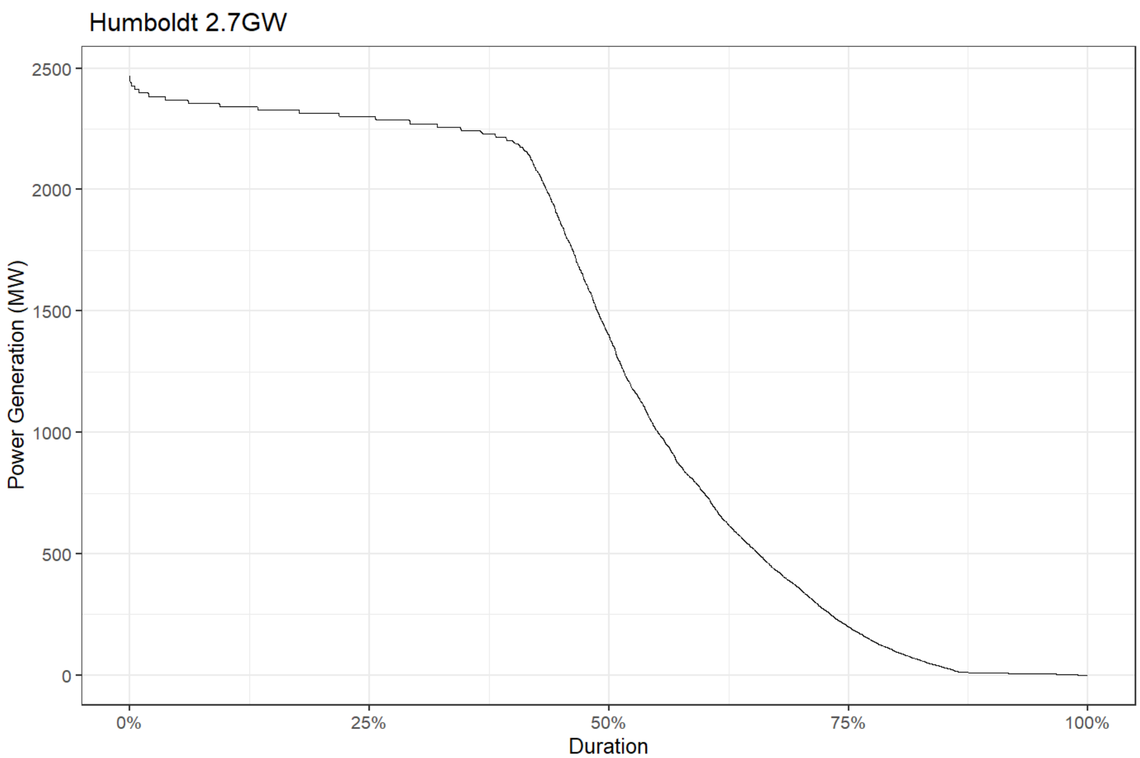


Figure A 14: Load duration curve for a 2.7 GW farm in the Humboldt wind area.

Appendix D: Subsea Cable and Landfall Considerations

(prepared by Mott Macdonald)

MOTT MACDONALD

Northern CA and Southern OR Offshore Wind Transmission Study

Schatz Energy Research Center

Prepared by:	MC, SC	**Date:**	06/23/23
Approved by:	AP	**Checked by:**	AP
Subject:	Subsea Cable and Landfall Considerations		

Introduction

The purpose of this memorandum is to assist the Schatz Center OSW Transmission Study, in support of development and assessment of the transmission scenarios as part of the Northern California and Southern Oregon Transmission Study. This is the first of two documents:

1. Subsea Routing and Landfall Considerations
2. Subsea Cable Network Architecture Technology Review and Considerations

The intent of this memo (Subsea Routing and Landfall Considerations) is to provide a narrative on the constraints, opportunities, and relative challenges of subsea routing and landfall for consideration of scenario development.

Geographic extents, and project-specific areas of study are defined in Figure 1.

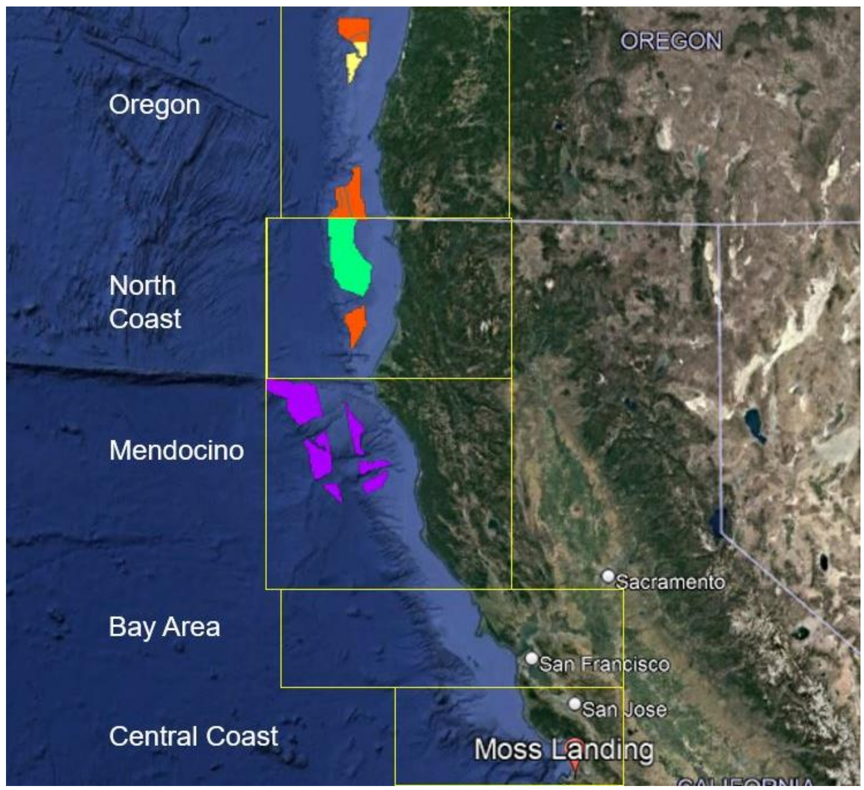


Figure 1.1 - Geographic Area of Study. Cape Mendocino (purple) and Del Norte (green) Notional Areas, Brookings, Coos Bay Call Areas and Humboldt Wind Energy Area are displayed.

This memorandum provides high-level overviews of subsea routing and landfall considerations. This document is not intended to be comprehensive, or representative of final deliverables as part of this contract. Work in this phase is intended to be limited in nature to support the electrical transmission study work.

2 Subsea Cable Routing

This section provides an overview of the general and region-specific considerations for conducting subsea cable routing and landfall operations.

2.1 General

Existing offshore conditions for the five regions (Oregon, California Northern Coast, Mendocino Area, Bay Area and Central Coast) were evaluated based on GIS data layers compiled from public sources. These data layers were reviewed to identify potential hazards and constraints which will likely affect concept-level cable routing in the study area. The following subsections denote the key hazards and constraints seen in each region. Appendix A lists the potential hazards and constraints, their associated risk to undersea cable and potential mitigation options.

There are many challenges to laying out undersea cables off the Pacific Coast. The Schatz Energy Research Center (Porter and Phillips, 2020a) identified the following key considerations for undersea cable installation which would apply to all subsequent sections of this memo.

Key Considerations:

- Hazards in all areas include canyons, fault lines (with varying levels of seismic activity and displacement), steep slopes (particularly within the canyons).
- Water Depths: At present, the approximate limiting water depth for cables is 6500 ft (2,000m) . The technology necessary for cable laying at 9,800ft (3,000m) or deeper is currently under development. In general, the technology risk increases with depth. However, other physical hazards may be more benign in deeper waters.
- Existing Cables:
  - When laying parallel to existing cable, a new cable typically needs to be placed about 2-3x the water depth from existing cables to allow enough space for repairs to be conducted such that the repaired cable will not overlay an adjacent cable. Cables installed in water depths offshore of the continental shelf would therefore potentially be spaced of approximately 3-5 miles (4.8-8.0 km) apart to allow for standard repair methodology. This is not assumed to be a hard constraint, as repairs may potentially be conducted in a shorter width, though at a higher cost.
  - When crossing cables in extreme water depths of 6,500 ft (>2000m), standard cable protections such as mattresses are not likely to be used. A protective coating/sleeve would be likely to be used instead.
- Laying cable in the North-South direction could result in the cable lay vessel operating in beam seas depending on location and season. This would not be preferred for vessel cable laying and could result in potentially slower installations and increased downtime.
- Landfall: Cable lay vessels typically require ~30ft (~10m)of water depth, and therefore the distance to the 30ft contour was assessed along the shoreline to check the distance to this water depth from the shoreline relative to the typical limit of cable pull-in 3280-4920ft (1,000-1,500m).
- Pacific Coast Port Access Route Study (PAC-PARS) results are not shown within this document. However, changes to navigation channels are unlikely to result in increased risk because in very deep water the vessels are not likely to drop anchors.

2.1.1 Oregon

Constraints:

- Nearshore has areas of hard substrate and rocky outcroppings as well as tow lanes.
- Canyons: Exist but appear avoidable.
- Faults: Exist but are not avoidable. Further work needed to prioritize avoidance.
- Access to deep water off the shelf will require cable installation over steep slopes, which may not be preferred.
- North-South Vessel traffic appears to be likely to be shifted further offshore of the proposed lease areas, with a nearshore fairway zone between the lease area. Cable Burial Risk assessments will be needed to determine the need and depth of burial, but these are not likely to preclude cable burial (pending further analysis/engagement).

Opportunities:

Most of the hazards appear to be avoidable through routing a North/South cable nearshore of the lease areas with the tightest constraints offshore of Cape Blanco (13 miles between canyon and shoreline). A nearshore route would avoid sensitive habitat areas, canyons, deep water, and steep slopes. Four subsea cables make landfall together south of Cape Arago, OR. If necessary to make landfall near Coos Bay, crossing of these cables would be required. An offshore route may be needed depending on the number of cables, fewer constraints appear offshore if the technology for installation in water depths of 9,800ft (3,000m) is developed.

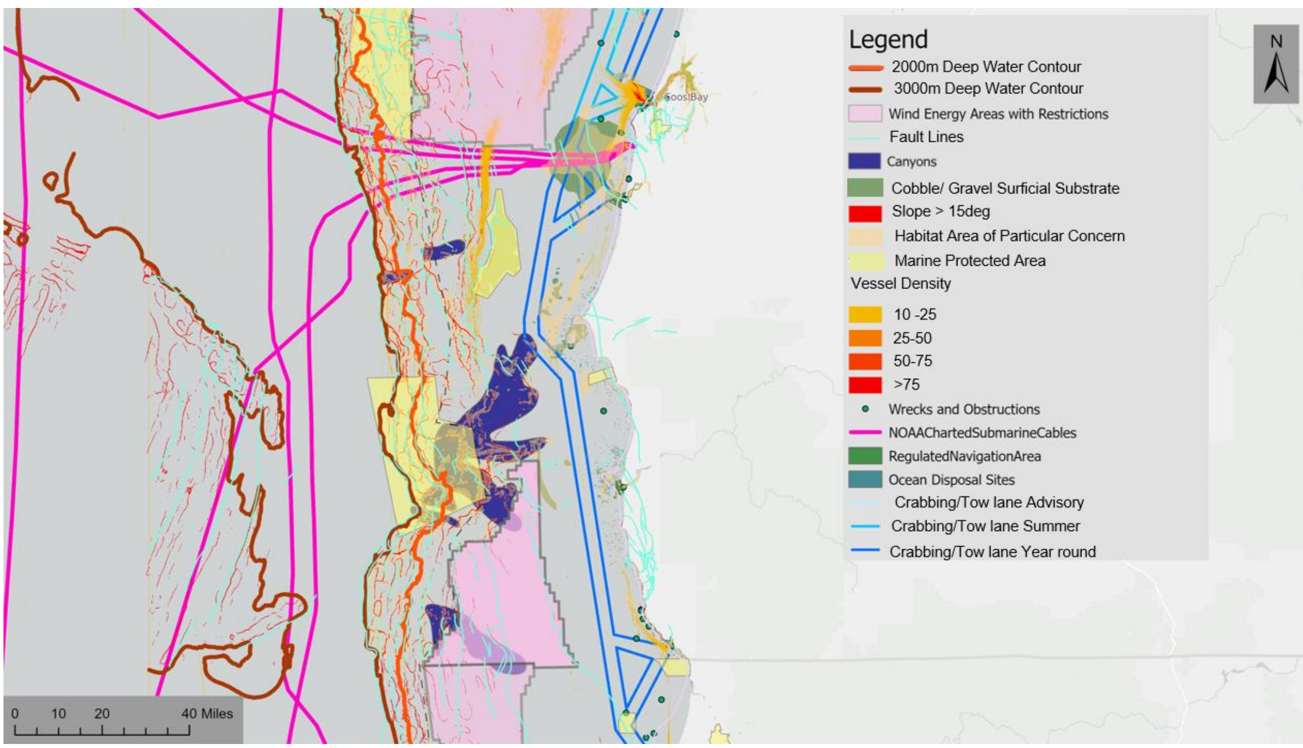


Figure 2.1 Mapped GIS hazards and constraints offshore of southern Oregon.

2.1.2 North Coast

Constraints:

- Canyon in the south extends from 1 mile (1.6km) offshore to 50 miles (80km) offshore, requiring to route through very deep water of more than 6,500 ft (>2000m) to avoid the canyon.
- Depths offshore the canyon and lease areas are upwards of 8200-13,100 ft (2,500-4,000m). Spacing between cables at that depth would have to be between 3.5-5 miles (5.6-8.0 km).
- The Mendocino Fault line appears unavoidable.
- Methane Hydrate gas deposits exist in this area which were denoted in Schatz Energy Research Center, Porter and Phillips (2020b) report.

Opportunities:

There are a limited number of constraints north of the canyon as seen in Figure 2.2, besides the lease areas themselves. Routing a North-South cable in the nearshore appears favorable north of the canyon and Mendocino Ridge, however it becomes very challenging at the southern border. Routing a North/South cable in the offshore deep water would limit the number of encounters with hazards such as sensitive habitats, steep slopes, and potential hard substrate. However, the feasibility of this route depends on cable technology capable of installations in 9,800 ft (3,000 m) or more.

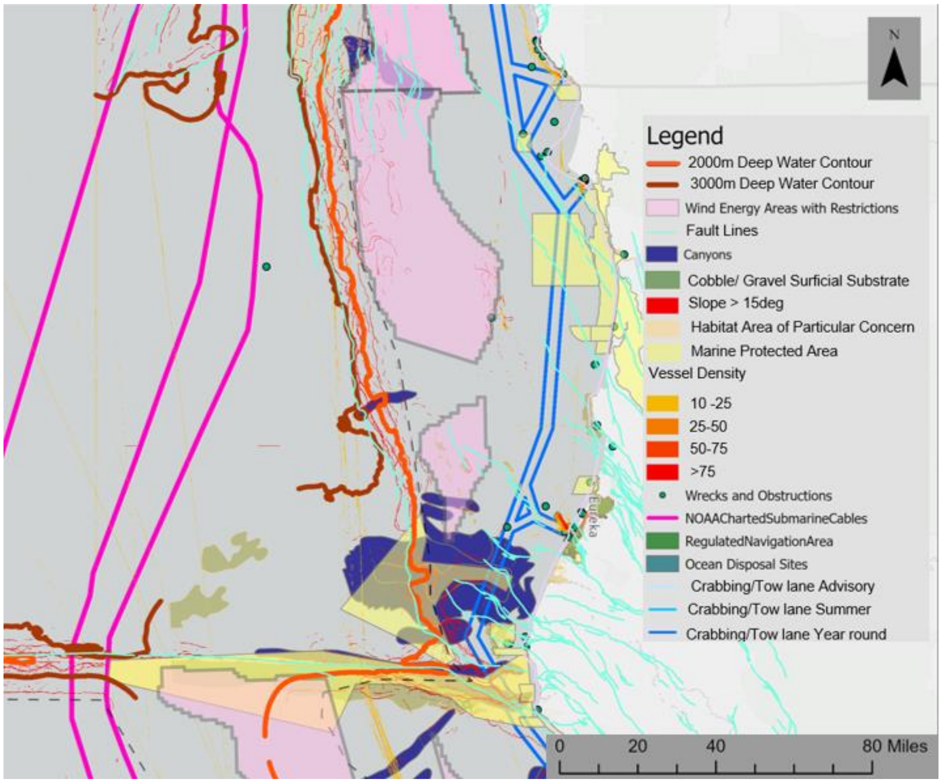


Figure 2.2 Mapped GIS hazards and constraints offshore northern California.

2.1.3 Mendocino

Constraints:

- Several canyons exist north to south in this area and extend 2-100 miles (3.2-160km) from the shore. Routing around submarine canyons would require laying cables at extreme depths, including some at >9,800ft (3000m) depth in order to avoid the longest canyon.
- Several subsea cables make landfall around Point Arena. These cables would likely need to be crossed in extreme depths due to nearshore constraints (canyons).
- The San Andres Fault line appears unavoidable and is a fault with much movement which could cause damage to cables.

Opportunities:

The southern half of the Northern California coast is similar to the northern half, but with even more canyons that are close to shore. Several telecom cables come ashore between canyon fingers at Point Arena. As the North-South nearshore routing looks extremely limiting, these cables will most likely need to be crossed in deep water. Most of the potential development areas will likely require routing to deep water first. This is due to the combination of limited landfall opportunities between Shelter Cove and the mouth of Eel River and the presence of these subsea canyons. This would result in a minimum cable route distance of 90 miles (145km) to shore, which likely necessitates the use of dynamic HVDC cables. The southern resource areas are approximately 60 miles (97km) from Fort Bragg which may allow for HVAC cables.

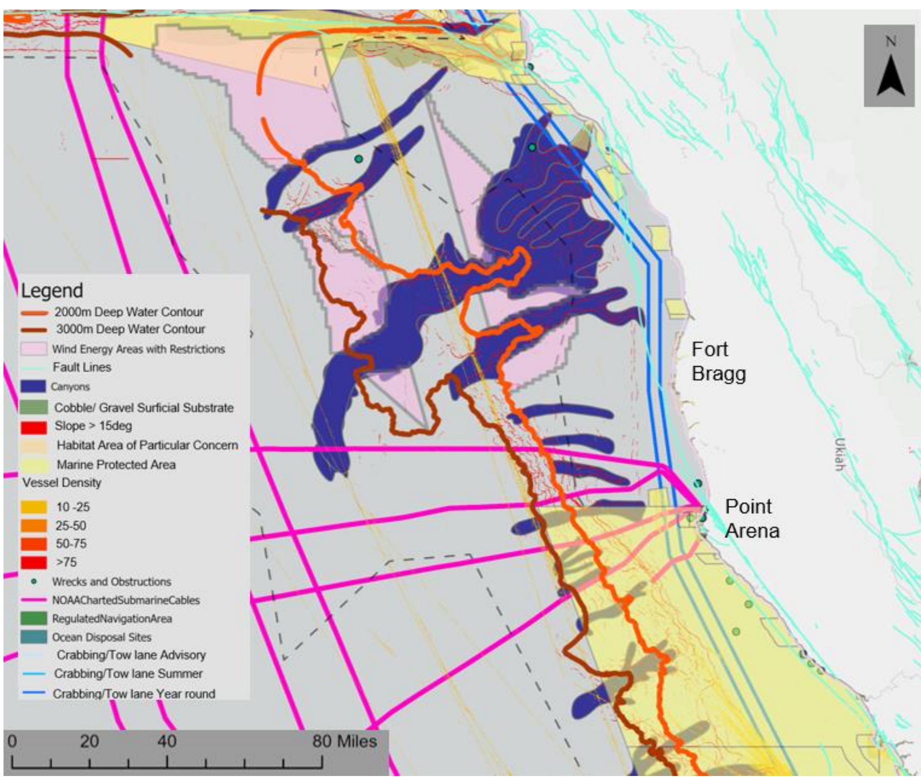


Figure 2.3 Mapped GIS hazard and constraints for the area offshore of Mendocino Area.

2.1.4 Bay Area

Constraints:

- Several canyons exist in this area and extend from 30-100+ miles (48-160+ km) off the shore. Routing around canyons would go through very deep water (6,500ft [2000m]), however there are possible nearshore approaches, less than 30 miles (48km) from shore, that would avoid them.
- Vessel traffic and regulated shipping lanes exist within the nearshore region. By avoiding offshore depths and canyons, the cables would encounter an increase in vessel traffic, necessitating additional planning.
- Two cables make landfall near El Granada, routing nearshore to a location farther south would involve crossing these cables.

Opportunities:

There are no call areas within the San Francisco Bay Area (see Figure 2.4) so this area is being assessed for subsea routing only. A cable routed North-South could start offshore and route nearshore for a landfall or continue south towards Moss Landing. There appear to be opportunities for the cable to route between canyon fingers, with spacing between canyons ranging from 2-6 miles. An offshore North-South routing would take the cable into extreme depths (> 9,800ft [3000m]) to avoid the largest canyon – therefore feasibility for an offshore route option is highly dependent on cable technology.

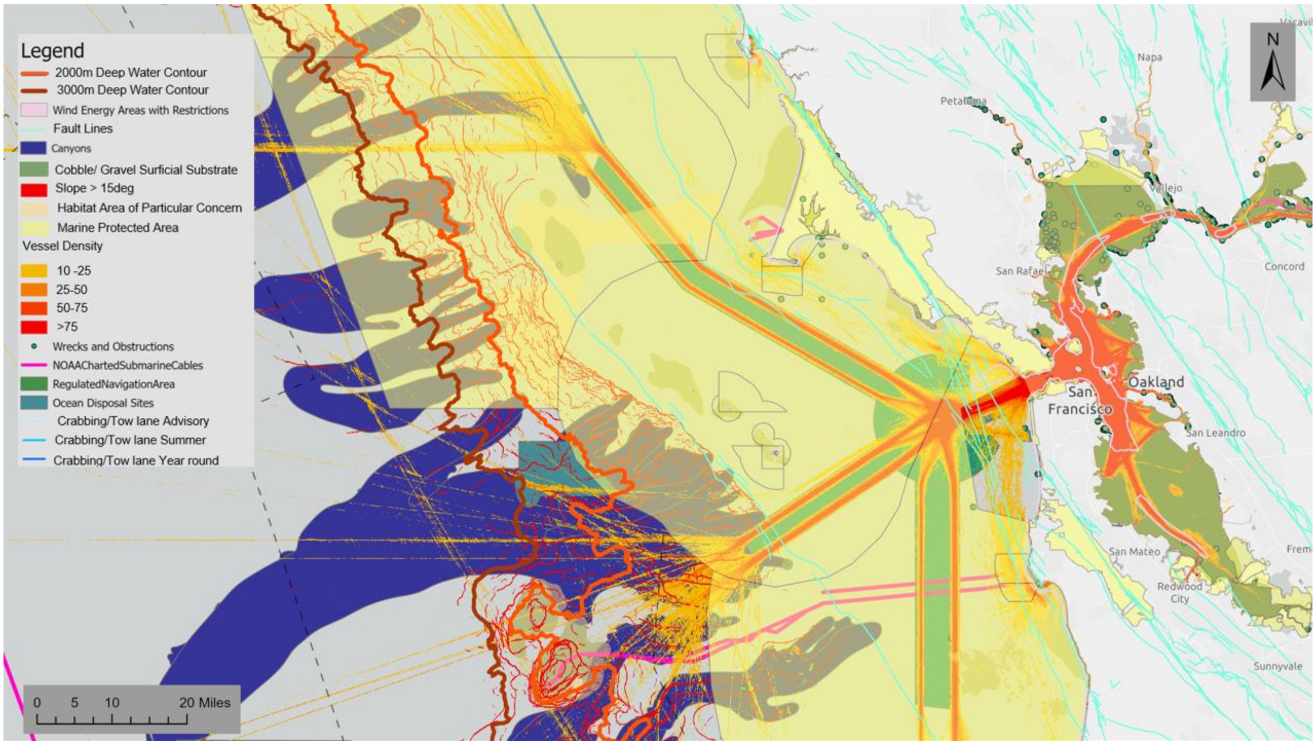


Figure 2.4 Mapped GIS hazard and constraint layers for areas offshore of the San Francisco Bay Area.

2.1.5 Central Coast

Constraints:

- Several canyons are present within the area, including the Monterey Bay Canyon which is a highly dynamic subsea canyon with subsea landslides. Installation in this area will likely require routing between canyon fingers which appears potentially possible.
- Vessel traffic extends south from the San Francisco Bay shipping lanes. In addition, there is a high density of vessels departing from Moss Landing. Routing nearshore may be affected by vessel anchor drop risk, but would need to be balanced with other factors.
- Nearshore is encompassed by Marine Protected Areas including the Monterey Bay National Marine Sanctuary.

Opportunities:

Approaching Moss Landing from the nearshore appears to be more accessible than from offshore. Monterey Canyon does not hug the coastline to the north (by Santa Cruz) and allows for a buffer of around 10 miles (16km) from the edge of Monterey Canyon to a landfall at Moss Landing. There is hard substrate along the near shore but appears to be avoidable. Marine Protected Areas are unavoidable in the nearshore region. If routing from offshore, traversing between the other smaller canyons could be possible. Currently, the Monterey Bay Aquarium Research Institute has a cable that routes from the north into Monterey Canyon which lends to the feasibility of potentially routing between canyons.

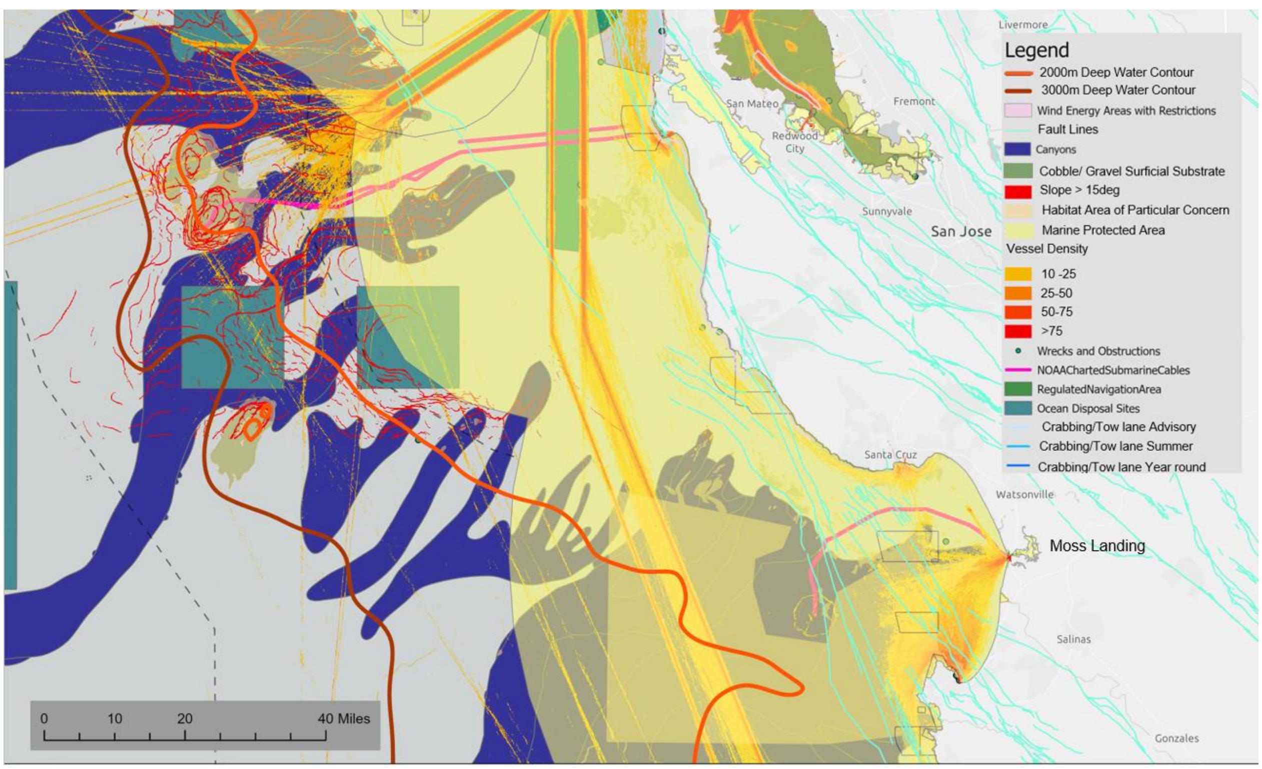


Figure 2.5 Mapped GIS hazard and constraints layers for offshore are of central California coast.

2.2 Landfall

2.2.1 Oregon

Overview:

- The segment of shoreline extending South from Coos Bay to the Oregon-California border has a diverse landscape. Nearly half of the shoreline is composed of steep bluffs with rocky outcroppings, while the remaining half are mostly dynamic beaches with a gentle slope.
- Deep water (-30 ft MLLW) is relatively accessible in this region, as the water level drops to -30 ft (10m) MLLW about 2,300-4,300 ft (700-1,300m) from shore.
- Road access in the region is provided by US Highway 101, which is typically <0.6 mi (1 km) away from the coast and provides a convenient means of transporting equipment to the selected landfall location.

Takeaways:

- There are a number of options for landfall along the Oregon Coast, and though challenging, there appear to be options for feasible landfall. These more favorable locations may get congested with multiple projects and include but are not limited to beaches near Bandon and Brookings.

2.2.2 North Coast

Overview:

- The North Coast of California shares a similar landscape with the Oregon coast and is characterized by a mix of cliffs and bluffs that are located within state parks, and dynamic beaches/dune systems that are found close to coastal towns.
- The distance to deep water is estimated to be around 2,600-4,000ft (800-1,200m) based on existing bathymetry datasets and may impose some challenges to HDD, especially when a large setback distance is needed to accommodate for the large elevation difference between the uplands and sea level.
- Upland infrastructure along the North Coast is adequate for performing landfall operations since both Highway 101 and the electric grid pass through coastal towns where landfall may take place.

Takeaways:

- There are a number of options for landfall in the Humboldt and Crescent City Area which appear likely feasible, including but not limited to Crescent Beach and the North and South Spits of Humboldt Bay.
- In a report published by the Schatz Energy Research Center, Porter and Phillips (2020a) took a closer look at the bathymetric and upland conditions near the bay and determined the location appears feasible to support landfall operations. Two HDD crossings may be required – one at the Pacific Ocean shoreline (Ocean Landfall), and one from the North of South Spit to the east side of Humboldt Bay (Backbay Crossing).

2.2.3 Mendocino

Overview:

- The segment of shoreline in the Mendocino region is hilly with steep bluffs that are often 50+ ft (15 m) above sea level. Making landfall at these locations therefore require a large setback distance for the HDD to have sufficient soil cover upon drilling.
- Deep water is relatively close to the shoreline in this region – the average distance to the -30 ft (10 m) MLLW contour is generally less than 0.6 mi (1,000m).

- The coastline South of Point Arena lies within the Greater Farallones National Marine Sanctuary (NMS) and may complicate the environmental permitting process for making landfall.

Takeaways:

- There are few potential landfall locations within the King Range National Conservation Area and the Sinkyone Wilderness State Park, due to the limited onshore routing options.
- Landfall appears to be more favorable at coastal towns such as Mendocino, Fort Bragg, or Salmon Creek with more upland infrastructure support.

2.2.4 Bay Area

Overview:

- Most parts of the shoreline in the Bay Area (south of Doran Beach to Pescadero) can reach deep water in less than 1,000m.
- The Greater Farallones & Monterey Bay NMS covers the entirety of the shoreline except San Francisco, Daly City, and Pacifica.
- With the exception of the Point Reyes National Seashore, road access is good and generally within 0.6 mi (1km) of the shoreline.

Takeaways:

- Landfall at Point Reyes National Seashore is likely challenging due to limited onshore infrastructure support and potential secondary bay crossings.
- Performing landfall operations at a location within the San Francisco Bay Area is complex due to a variety of reasons including but not limited to the challenge of routing subsea cables into the Bay, considering the presence of large sandwaves, high volume of vessel traffic and multiple submarine cable crossings (Porter and Phillips, 2020b). As such, the authors concluded that it may be costly to mitigate these issues and the option of having landfall within the Bay Area appears unfavorable at the present level of assessment.
- There are several potential options for making landfall on the ocean-facing side of the San Francisco Peninsula. However, the landfall location must be carefully selected to minimize disturbance to the neighboring residential and recreational areas.

2.2.5 Central Coast

Overview:

- The central coast, defined as the strip of shoreline between Pescadero and Moss Landing, can be split into two distinct segments based on shoreline characteristics: Pescadero – Santa Cruz where the shoreline are mostly steep slopes, and Santa Cruz – Moss Landing where the shoreline tends to be beaches with mild slopes.
- Nearly all parts of the shoreline considered can reach deep water in less than 3,200 ft (1,000m).
- Connection to existing roads is good overall, with Highway 101 running along the coastline and minor roads connecting the Highway to the shore at Santa Cruz and Moss Landing.
- Though not the focus of this study, the Monterey Bay NMS covers the entire shoreline and it may be challenging to obtain environmental permits to carry out drilling operations.

Takeaways:

- Making landfall in the vicinity Santa Cruz and Moss Landing is likely more favorable relative to other locations along the central coast.

- Secondary water crossings may be needed at Moss Landing after Ocean Landfall.

Summary

An initial assessment of subsea cable routing from the offshore call areas in Oregon and California was performed using publicly available data of vessel traffic, bathymetry, substrate conditions, protected areas, and existing infrastructure. The main findings of this study are summarized below.

- Defining the limiting water depth for cable installation is a critical element of the planning process. It may be highly preferred to go offshore in some areas considering the nearshore hazards and constraints. If routing in water depths of greater than 8200- 9800ft (2,500-3,000m) is a hard limitation, transmission of power generated in the study area, south towards the Bay Area will be much more challenging.
- Limiting landfall options, combined with the canyons around the Cape Mendocino area may require cables to be routed further offshore first before coming landward. The length of these export cables may require DC, which is likely to be developed later than dynamic HVAC (see memo 2).
- Considering these factors, a conceptual map of example corridors was developed. Note that feasibility of these options is not confirmed, and is based on early review of constraints and hazards. Potential transmission corridors are not intended to be to scale or to represent specific transmission cable locations (indicative of concept only).

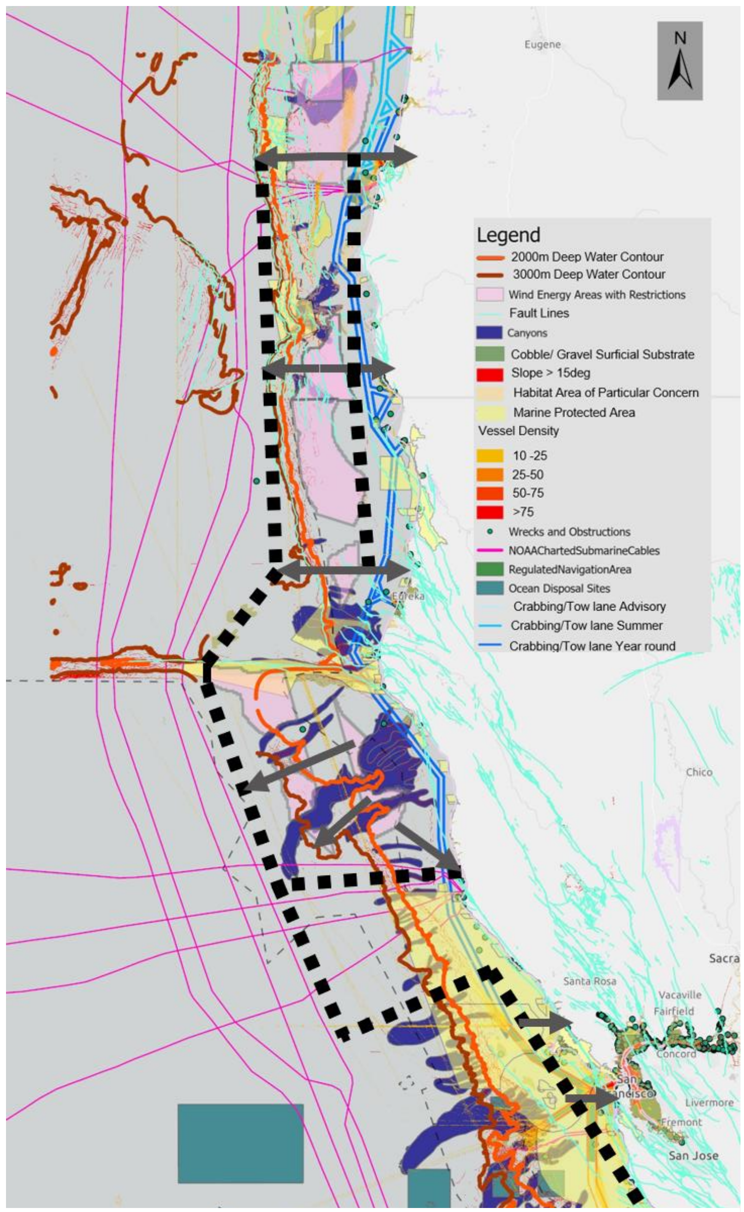


Figure 3.1 Summary of Subsea Constraints and Example Conceptual Large Scale Transmission (Dotted Line) and Landfall Regions (Solid Gray)

Next Steps

There is significant work required to finalize an offshore transmission system at the scale considered as part of this study. Iteration of preferred alternatives is common when planning export cable routing and landfall for a single windfarm, and is likely to also be the case, if not at a greater scale, for the transmission scenarios assessed as part of this study. The following represent next steps to better qualify opportunities, quantify risks, and refine preferred scenarios for further development.

- Subsea route development for the required number of cables for the various generation and transmission scenarios.
- Develop full transmission pathways considering different technology development scenarios, subsea cable routes, landfall options, and onshore routing corridors.
- Investigation of routing constraints on and around the offshore HVDC converter stations.
- Supplier and installation contractor engagement on cable depth limitations and telecommunication cable crossing methods.
- Develop cost estimates of potential pathways.
- Refine preferred landfall methodology (such as HDD, DirectPipe, or other) in areas of interest to confirm staging area requirements relative to potentially available areas.
- Environmental and permitting considerations should be developed and refined in coordination with subsea, landfall, and onshore routing options.
- The cable transmission technology (e.g. AC or DC) will affect the number of cables making landfall in specific areas, and therefore will affect the feasibility/favorability of certain portions of the shoreline to accommodate landfall. AC will require more export cables, and therefore typically a larger staging area onshore.

References

Porter, A., and Phillips, S. (2020a). Export Cable Landfall. In M. Severy, Z. Alva, G. Chapman, M. Cheli, T. Garcia, C. Ortega, N. Salas, A. Younes, J. Zoellick, & A. Jacobson (Eds.) California North Coast Offshore Wind Studies. Humboldt, CA: Schatz Energy Research Center.

Porter, A., and Phillips, S. (2020b). Subsea Transmission Cable Conceptual Assessment. In M. Severy, Z. Alva, G. Chapman, M. Cheli, T. Garcia, C. Ortega, N. Salas, A. Younes, J. Zoellick, & A. Jacobson (Eds.) California North Coast Offshore Wind Studies. Humboldt, CA: Schatz Energy Research Center. schatzcenter.org/pubs/2020-OSW-R5.pdf

A. GIS Hazard List (Adapted from Porter and Phillips (2020))

Table A.1 Major Mitigation

Potential Hazard/Constraint	Potential Risk to Cable Installation	Potential Mitigation Options
Subsea Canyon	Displacement and burial of cables during subsea landslide events Steep slopes of canyon walls give rise to significant installation challenges that may cause spanning/vibration issues	Complex remedial levelling work to mitigate cable spanning over canyons. Alternatively investigate floating the cables over canyons similar to inter-array cables. No known mitigation for subsea landslides and turbidity currents
Extreme Depths	Installation of HVDC transmission cables in depths exceeding 2,000m is not yet proven feasible. Expensive cable repairment in deep-water	Technology advancement is required to enable cable installations in such depths
Subsea Cable Crossings (>2000m)	Installation of cable protection at vertical crossing may be challenging, such protection more common in shallow water	Mitigative measures for installation of cable protection at deep-water are rare or do not exist
Seismic Faults and Rupture Zones	Displacement, dislocation and burial of cables during seismic events	Align cables along fault lines and provide sufficient protection/flexibility to improve cable resistance to seismic events
Sensitive Habitat Areas	Designated sensitive habitat areas have different regulations regarding seabed disturbance, permits may be required. Sensitive habitat areas potentially encountered: State Marine Protected Area, National Wildlife Refuge, National Estuarine Research Reserve, State Research Reserve, Essential Fish Habitat Conservation Area	Coordination, avoidance or other mitigation techniques/requirements TBD.
Hard Substrate	High difficulty in installation and burial of cables, or reaching sufficient depth to provide cable protection	Alternative cable protection measures such as rock cutting, concrete mattresses have to be utilized to protect the cable in such regions
Ocean Disposal Sites	Site permits may be difficult to obtain	Avoid locations as possible, coordinate with USACE

Table A-2. Minor Mitigation

Potential Hazard/Constraint	Potential Risk to Cable Installation	Potential Mitigation Options
Subsea Cable Crossings (<2000m)	Agreements likely need to be obtained. In many cases, protection must be installed at vertical crossing of existing submarine telecommunication cables.	Cable protection measures may need to be installed, such as concrete mattresses. Typical crossing between 65-90 degrees.
Steep Slopes >15deg	Risk of runaway of plough or ROV that cause consequential damage to cable	Avoid location if possible. Prove technical specification for appropriate cable installation and burial equipment.
Vessel Traffic	Anchors dropped from shipping vessels (anchor strike) penetrate and are dragged along seabed, potentially damaging cable. Crabber/Tow lane	A cable burial risk assessment (CBRA) utilizing automatic information system (AIS) vessel tracking data should be conducted to aid in acceptable burial depth recommendations.
Fishing Activities	If not buried to sufficient depth, fishing gear (bottom trawling) can damage cable	A cable burial risk assessment (CBRA) utilizing automatic information system (AIS) vessel tracking data should be conducted to aid in acceptable burial depth recommendations.

Northern CA and Southern OR Offshore Wind Transmission Study
Schatz Energy Research Center

Prepared by:	AH	**Date:**	7/14/2023
Approved by:	AP	**Checked by:**	MC
Subject:	Subsea Cable Network Architecture Technology Review and Considerations		

Introduction

The purpose of this memorandum is to assist the Schatz Center OSW Transmission Study, in support of development and assessment of the transmission scenarios as part of the Northern California and Southern Oregon Transmission Study. This is the second of two documents:

1. Subsea Routing and Landfall Considerations
2. Subsea Cable Network Architecture Technology Review and Considerations

The intent of this memo is to provide a narrative on the general constraints, opportunities, and relative challenges of offshore export transmission for consideration of scenario development. This memo does not include considerations for inter-array transmission between the wind turbine generators (WTGs) and focuses on the high-voltage (HV) commercial scale offshore wind power transmission from offshore substations (OSSs) to Points of Interconnection (POIs).

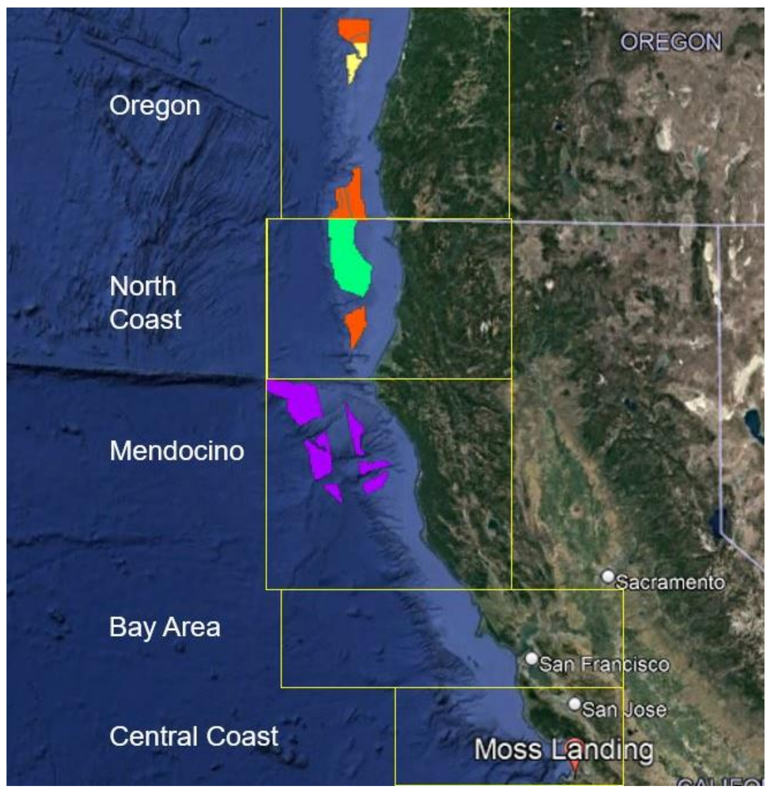


Figure 1.1 – Pacific Coast Offshore Wind Areas

The project-specific offshore wind areas are outlined in Figure 1.1.

This memo provides a high-level overview of electrical offshore transmission technology for consideration. This document is not intended to be comprehensive. Work in this phase is intended to be limited in nature to support the electrical transmission study work.

2 Technology Considerations

This section provides an overview of the general and region-specific considerations for offshore electrical transmission.

2.1 Overview

As briefly noted in the Subsea Routing and Landfall Considerations memo offshore electrical transmission topology typically utilizes either an alternating current (AC) system or direct current (DC) system[1]. Both AC and DC systems present respective benefits and challenges, however AC systems are currently more developed and more widely utilized than DC systems in offshore wind energy transmission. We note however, that due to the electrical nature of how AC and DC submarine cables operate, DC systems may be more economical for longer distances of transmission depending on a few factors. Further information regarding AC vs DC transmission has been provided in Appendix A.

With respect to the offshore wind lease areas identified on the US Pacific Coast, we have summarized some general considerations for offshore wind power transmission as follows.

AC Considerations:

- AC export cable power transmission efficiency is dependent on operating voltage and distance (See Figure 1 in Appendix A).
  - Distance limitations can be mitigated with the use of reactive compensation equipment however this may be cost prohibitive depending on project/site specific conditions.
  - As noted in the Landfall and Subsea Routing Memo, there are a number of obstacles between the current wind lease areas and suitable landfall or POIs which may impact the transmission route and distance.
- Capacity (amount of power to transmit) and site conditions (such as water depth, distance, and subsea/landfall conditions) will heavily influence the type of topology and equipment suitable for transmission.
  - For shallow water, fixed bottom offshore windfarms have used static AC export cables. Low/Medium voltage dynamic AC cables have been deployed in leading floating offshore windfarm demonstrator projects.
  - For deep water floating windfarms, Dynamic AC cables are currently in development and is anticipated to reach commercial scale maturity at high voltage within the coming decade.

DC considerations:

- There are a variety of HVDC systems which offer different capabilities with respect to transmission capacity and distance. See Appendix A for further details.
  - Dynamic DC cables are not currently available in the market, and the development timelines for cables in the water depths which may be required (3,300ft+ [1,000m]), are likely to be longer than dynamic AC cables.
  - Similarly, other key high voltage DC components (such as connectors, switches, breakers, etc.) are in very early stages of development with varying timelines anticipated for commercial scale application.
  - Each HVDC onshore converter station would need approx. 62,500sqm (250m x 250m) of permanent area and may also require up to 20,000sqm of temporary area during construction.

[1] We also note that depending on project specific geographical, power capacity, and site conditions, a combination of AC and DC systems may be suitable

- Onshore converter stations would also potentially need to be sited outside any tsunami hazard zones due to the critical infrastructure nature of the facility.
- The converters would need to be manufactured at a specialty facility, likely outside the North Coast. Due to their size and weight, these would potentially be integrated with the floating foundation elsewhere and towed to site with the topside attached (long-distance tow).
- Currently, HVDC cable technology can transmit a maximum of approx. 2GW per cable (500kV) per cable pair (one +ve and one -ve) at 525 kV. This capacity is not yet in service in Europe, but a number of projects have been ordered. The Tennet 2GW program appears to be setting the de-facto standard for offshore transmission (see https://electra.cigre.org/321-april-2022/technology-e2e/next-generation-offshore-grid-connection-systems-tennets-2-gw-standard.html for a technical discussion.
-

Wind Turbine Generators (WTG) & Grid Consideration:

- Current WTGs generate AC power which is collected into a project offshore substation (OSS).
  - This creates the requirement to have an AC-DC converter on the OSS if the transmission distances warrant the use of DC export cables. While the majority of HVDC converter stations have been onshore to date, they are now being more readily considered for offshore use such as the DolWin 1 project in the North Sea, Europe [2]. In these instances, the layout of the offshore substation tends to be more compact and constructed on multiple levels, in order to reduce the overall dimensions of the offshore platform. While commercial availability is currently limited, it is expected that offshore converter stations will become more popular and cost efficient over the coming decade as offshore installations increase in scale and complexity.
- Onshore transmission grids owned by utilities operate on AC and have strict technical requirements for power producers to adhere to.
- A further issue is that until it is technically/economically feasible to run DC circuits in parallel with fault discrimination (i.e. DC circuit-breakers) there is going to be a reluctance to exceed a 2GW single infeed to the onshore network.
- Though a DC link with 2x offshore converters and 2x onshore has a potential capacity of 4GW, without fault discrimination (DC Circuit Breakers) there is the potential to lose 4 GW of network infeed for a single fault. Not many networks can accommodate a 4 GW loss of infeed without serious frequency excursions.
-

Network Considerations:

- There are several different network topologies that can be considered for offshore wind power transmission.
  - These network topology options can range from a radial system to a fully meshed system and requires increased coordination between utilities/governing bodies accordingly.

[2] https://www.hitachienergy.com/about-us/case-studies/dolwin1

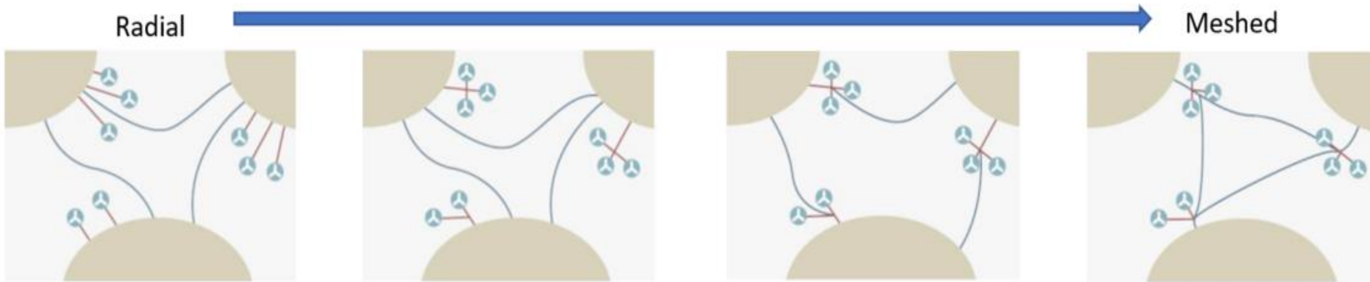


Figure 2.1 Network topology options.

Source: Mott MacDonald adapted from The North Seas Countries' Offshore Grid Initiative

- To date, radial or 'project-by-project' transmission has been the dominant method for offshore wind grid connection globally, but that trend may be shifting.
- Following studies performed for offshore wind transmission planning in NJ[3], the NJ Board of public Utilities (NJBPU) selected to solicit an onshore 'transmission corridor' to connect multiple offshore windfarms in a coordinated effort[4].
- National Grid ESO in the UK have published studies identifying that an interregional meshed approach to transmission can save up to 6Bn GBP or 18% in CAPEX in their development of 40GW of OSW by 2023.[5]
- The Department of Energy (DOE) is currently performing an Atlantic Offshore Wind Transmission Study (AOSWTS) for which they've preliminarily disclosed that an interregional (between states/ISOs) system will maximize the 'benefit-to-cost' ratio and is recommended as the most optimal transmission topology for the region[6].
- At present, HVDC can only be deployed as "links" rather than a "network" of HVDC cables. An HVDC transmission system requires converter stations at both terminals of the DC link.

Pacific Coast OSW Considerations:

- Notably for the Pacific Coast, deeper water depths will require the use of floating WTGs and likely floating OSSs[7], which will require the use of dynamic cables.
  - When considering California and Oregon's OSW development timelines, which are partly driven by state and federal electricity decarbonization goals, technology readiness of transmission components will be critical to which transmission topologies will be available and economical as key components noted above to support floating offshore wind transmission are still in early development phase.
- We also note that the industry has been discussing and is investigating the possibility of an HVDC backbone running offshore and roughly parallel to the Pacific Coast to further facilitate the transmission of offshore wind power to load centers along the coast and increase California's grid reliability.

[3]https://www.nj.gov/bpu/pdf/publicnotice/Transmission%20Study%20Report%2029Dec2020%202nd%20FINAL.pdf

[4]https://www.nj.gov/bpu/newsroom/2022/approved/20221026.html#:~:text=This%20single%20corridor%20will%20be,third%20solicitation%20in%20Q1%202023.

[5] https://www.nationalgrideso.com/document/183031/download

[6] Based on information shared at the Northwest Offshore Wind Conference held in March 2023. Note that the study referenced during the presentation at the conference is expected to be published shortly.

[7] We note that there is technology currently in being developed for submerged seabed substations to support the offshore wind industry.

- Noting California's OSW target of 25GW, we anticipate the windfarms to connect into multiple offshore platforms. We note that the weight of single converter station may be on the order of 25,000 tons or more. Grouping multiple converters on a single platform would be very large,
- The Cape Mendocino converter station(s) may need to be far offshore, in very deep water, in order to connect the cables, as noted in our routing memo there are a number of challenges navigating canyons in this area.

Summary Takeaways

Noting some of the general considerations identified in the previous section, we have summarized a set of takeaways as follows:

- AC export systems are typically used for offshore wind projects with shorter distances to POIs.
- In the immediate future, multiple point to point links may be a more likely solution adopted by the industry.
- Longer transmission distances may make use of HVDC cable more economical; however it will also require HVDC converter stations which are of significant cost. The stations may be located onshore or offshore although offshore HVDC converter stations are not yet commercially available. Floating converter stations will also require dynamic cables.
- There could be challenges with clustering at shore due to limited receptiveness of the onshore AC network; typically 2 x 2GW would be the limit for a high voltage node.
- Floating AC transmission components such as dynamic cables are likely closer to market application than DC systems which are required for floating offshore wind development on the Pacific Coast.
- Project by project (radial connections) may require HVDC to make landfall, depending on the lease area and landfall location. Based on Memo #1, there are some potential sea-space areas that would likely require longer (60mi+ [100km]) cable ashore to avoid canyons – which could limit their development until dynamic HVDC cables are available at the voltage class required for the anticipated loads (1.5GW+).
- For a larger offshore transmission network, including a backbone configuration linking multiple offshore wind farms or networks, the distances offshore necessitate the use of a HVDC system.
- The ability to have an interconnected fully offshore system is dependent on the market development of dynamic HVDC cables and other key HVDC components.
- There would likely be additional sea-space needed to provide for the converter stations for a fully offshore HVDC system.
- An alternative option would be to route the cables to shore, and then place converter stations on shore or to a fixed platform in shallower waters (removing the need for dynamic HVDC cables but requiring longer cable length). However, dynamic AC cables at the voltage class needed for OSW are also not available, and the timing of this availability relative to dynamic HVDC is not known.
- Considering the relative positions of the generation locations and the load centers, HVDC transmission is likely to be required/implemented. We note however that the technology to implement an offshore (dynamic) HVDC transmission topology is not presently available.

Next Steps

There is significant work required to finalize an offshore transmission system of this scale. The following next steps include those potential direct next steps to better qualify opportunities, quantify risks, and refine preferred scenarios for further development.

- Develop full transmission pathways considering different technology development scenarios, subsea cable routes, landfall options, and onshore routing corridors.
- Refine subsea routing constraints to and between offshore HVDC converters.
- Carry out supplier and installation contractor engagement to better understand floating transmission component technology development timelines and opportunities for acceleration.
- Develop a comprehensive Pacific Coast transmission cost-benefit analysis for different transmission topologies taking into consideration the technology readiness challenges being faced for the first set of floating offshore windfarms.
- Assess environmental and permitting considerations in coordination with transmission topology options being investigated.

Appendices

A. AC & DC Transmission

The key differentiator between HVAC and HVDC for subsea power transmission is the electrical characteristics of the power cables.

Due to their construction all cables exhibit a characteristic known as capacitance, which acts in a similar way to a small internal battery. When a cable is connected to an AC system, the voltage applied to the cable goes through a cycle many times per second (60 times per second – referred to as 60Hz – in North America). Starting from zero volts, each cycle requires the cable's internal battery to be charged to a positive peak voltage, discharged to reach a negative peak voltage, and then charged again to return to zero volts.

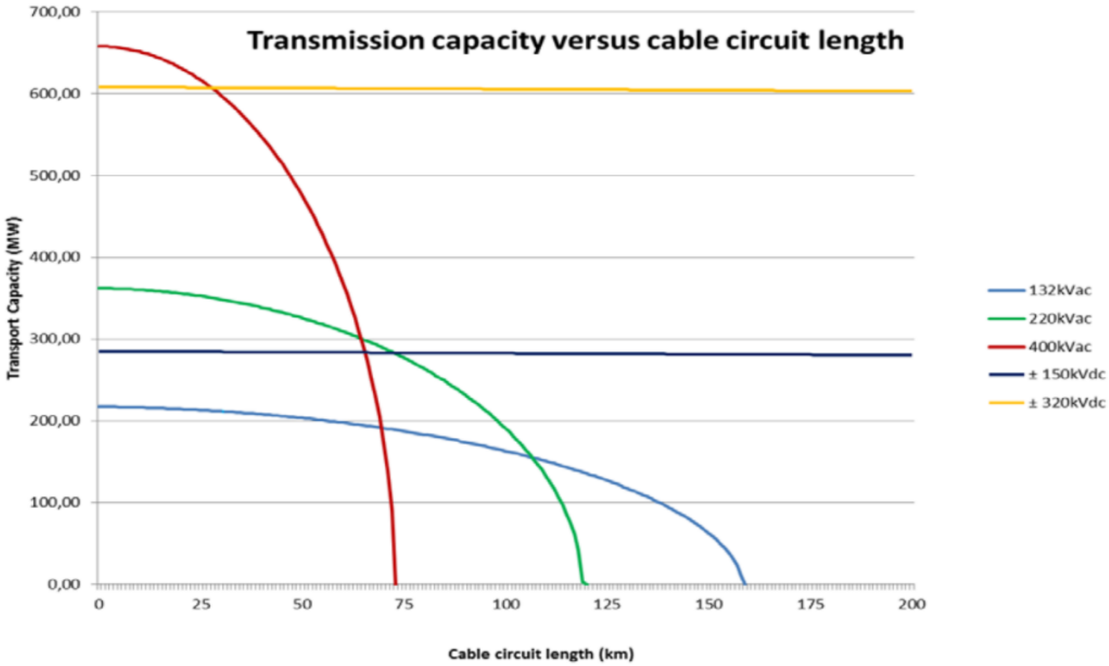
These charge/discharge events that occur 60 times each second, require electrical currents to flow within the conductor of the cable and use space that could otherwise be used for the useful transmission of real power. The conductor and cable must be designed to accommodate both the charging current and the transmission current. As the energy required to charge/discharge the internal 'battery' increases linearly with cable length, the longer the cable the higher the level of charging current is required and the larger the conductor needs to be to accommodate both the charging current and the useful current. Ultimately, there comes a point where the length of a system is so long, that all the useful capacity of the conductor is utilized for the charging currents and there is not useful space left for power transmission.

The currents required to charge/discharge the internal 'battery' are generally considered as 'reactive power'. Reactive power does not need to be produced by a conventional generator but is exchanged with other devices connected to the power network. Many TSO's impose limits on the amount of reactive power that can be exchanged with their network, thus long cables generally require compensation systems (i.e., devices that can exchange power with the internal battery of the cable) to be installed at the terminal points.

DC cables exhibit identical characteristics, but because the voltage applied to the cable does not vary, the internal 'battery' only has to be charged once when the cable is energized. They do not require compensation systems and do not experience additional losses due to reactive power exchanges.

The effect of cable charging currents (reactive power) on the active power transfer capacity of cables is illustrated in Figure A.1. This compares the active power transfers available for AC and DC cables of varying length based on a 50Hz example.

Figure A.1: Transmission Capacity Versus Cable System Length



Source: Cigre Technical Brochure 610[8]

This comparison assumes a common ampacity of 950A for all the cables, independent of voltage and AC/DC operation, and the AC cables are assumed to be compensated from one end. Consequently, considering the 220 kV AC cable, which requires a charging current of ~8A per km when connected to a 50Hz power system, the entire capacity is required to supply the charging current of a 120 km length. While this can be mitigated by compensating from both ends of the cable (i.e., feeding 475A from each terminal of a 120 km cable), the maximum practical length of a 220 kV AC cable is limited to 100-120 km if significant derating is to be avoided.

In the case of 60 Hz systems, charging current will increase for the same applied voltage and cross section of the cable due to decrease in capacitive reactance since capacitive reactance is inversely proportional to the frequency and charging current is inversely proportional to the charging current), thus reducing the practical length of 200kV AC cable for transmission of the same entire capacity to 80-95 km.

Charging currents increase with transmission voltage (since more energy is required to charge the internal 'battery' to a higher voltage); thus, in this example 400 kV cables are practically limited to a length of 50-60 km when connected to an AC system, even if both ends are compensated.

It should be noted that larger cable conductor sizes are now available, and that while charging currents increase with increasing conductor size, this is not a linear relationship. For example, the charging current of a 220 kV cable with a 1200mm² main conductor is ~8A/km, but this is only increased to ~10A/km for a 2000mm² conductor. The maximum practical length of an AC cable circuit will thus be increased through adoption of a larger conductor size, although this is not generally significant.

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[8] https://e-cigre.org/publication/610-offshore-generation-cable-connections

It can be concluded from the above that the effect of cable charging currents imposes a practical limit on the maximum length of AC cable circuits, and that this is a significant constraint at the highest transmission voltages. Consequently, implementation of long cable circuits necessitates the use of HVDC technology.

There are a number of other factors which, while less critical, impact the comparison of AC & DC cable systems:

DC current in a conductor is equally distributed through the cross section of the conductor whereas, AC current in a conductor creates an electric field which results in more current being carried close to the surface of the conductor (called skin effect) than in the center. The effect is that the AC resistance of a cable is higher than the DC resistance, thus AC losses are greater, and the cable will reach its limit temperature at a reduced current loading.

AC transmission uses three-phase connections, whereas DC transmission generally requires only two (positive and negative. Cable costs can therefore be lower.

AC transmission generally requires the provision of dedicated reactive compensation equipment to exchange reactive power with the cables. Although the costs are lower than that of the HVDC converter stations, this equipment can reduce the cost differential between AC and DC transmission.

Table A.1: Power vs Distance Matrix – Feasible Technologies

Transmission Distance	Transmission Power 250MW	Transmission Power 500MW	Transmission Power 750MW	Transmission Power 1GW	Transmission Power 1.5GW	Transmission Power 2GW	Transmission Power 2-3GW
25km	HVAC (150 kV)	HVAC (275 kV)	HVAC (400 kV)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (Bipolar VSC/LCC)	HVDC (Bipolar LCC) Multiple Cables
50km	HVAC (150 kV)	HVAC (275 kV)	HVAC (400 kV)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (Bipolar VSC/LCC)	HVDC (Bipolar LCC) Multiple Cables
75km	HVAC (150 kV)	HVAC (275 kV)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (Bipolar VSC/LCC)	HVDC (Bipolar LCC) Multiple Cables
100km	HVAC (150 kV)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (Bipolar VSC/LCC)	HVDC (Bipolar LCC) Multiple Cables
>100km	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (VSC/LCC)	HVDC (Bipolar VSC/LCC)	HVDC (Bipolar LCC) Multiple Cables
>2000kms	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Source: Mott MacDonald

The selected HVDC technology for the HV cable transmission electrical links under consideration as part of this opportunity evaluation study can further be configured in different topologies and therefore, various normally preferred topologies for combination of transmission voltage and power rating are presented in the transmission voltage vs transmission power matrix included in Table A.2 below, based on the following definitions:

- BTB means back-to-back topology which uses pair of current or voltage source converters and no cable system
- SMP means symmetrical monopolar topology which uses pair of voltage source converters and pair of MIND or XLPE cables
- RBP means rigid bipolar topology which uses pairs of voltage source converters and pair of MIND or XLPE cables
- MONO means monopolar topology which uses pair of current source converters and pair of HV and LV MIND cables

- ASMP means asymmetrical topology which uses pair of voltage source converters and pair of HV and LV MIND or XLPE cables
- BP means bipolar topology which uses pairs of current or voltage source converters and pair of HV MIND or XLPE cables plus single LV MIND or XLPE cable
- N/A means not applicable as particular combinations of transmission power and voltage are not generally considered due to technology readiness or availability.

Table A.2: "Voltage vs Power Matrix - Feasible HVDC Topologies"

Transmission Voltage	Power less than 1GW	Power 2GW	Power 3GW	Power greater than 3GW
<200kVdc	BTB / ASMP / SMP / MONO	N/A	N/A	N/A
300kVdc	MONO / ASMP / SMP	N/A	N/A	N/A
400kVdc	MONO / ASMP / SMP	RBP / BP	N/A	N/A
500kVdc	RBP / BP	RBP / BP	N/A	N/A
600kVdc	N/A	RBP / BP	RBP / BP	N/A
>600kVdc	N/A	N/A	N/A	N/A

Source: Mott MacDonald (Internal)

Appendix E: Transmission Alternative Single-Line Schematics, Maps and Offshore Transmission Configuration Diagrams

(prepared by Schatz Energy Research Center)

Alternative 7.2a - Onshore Transmission

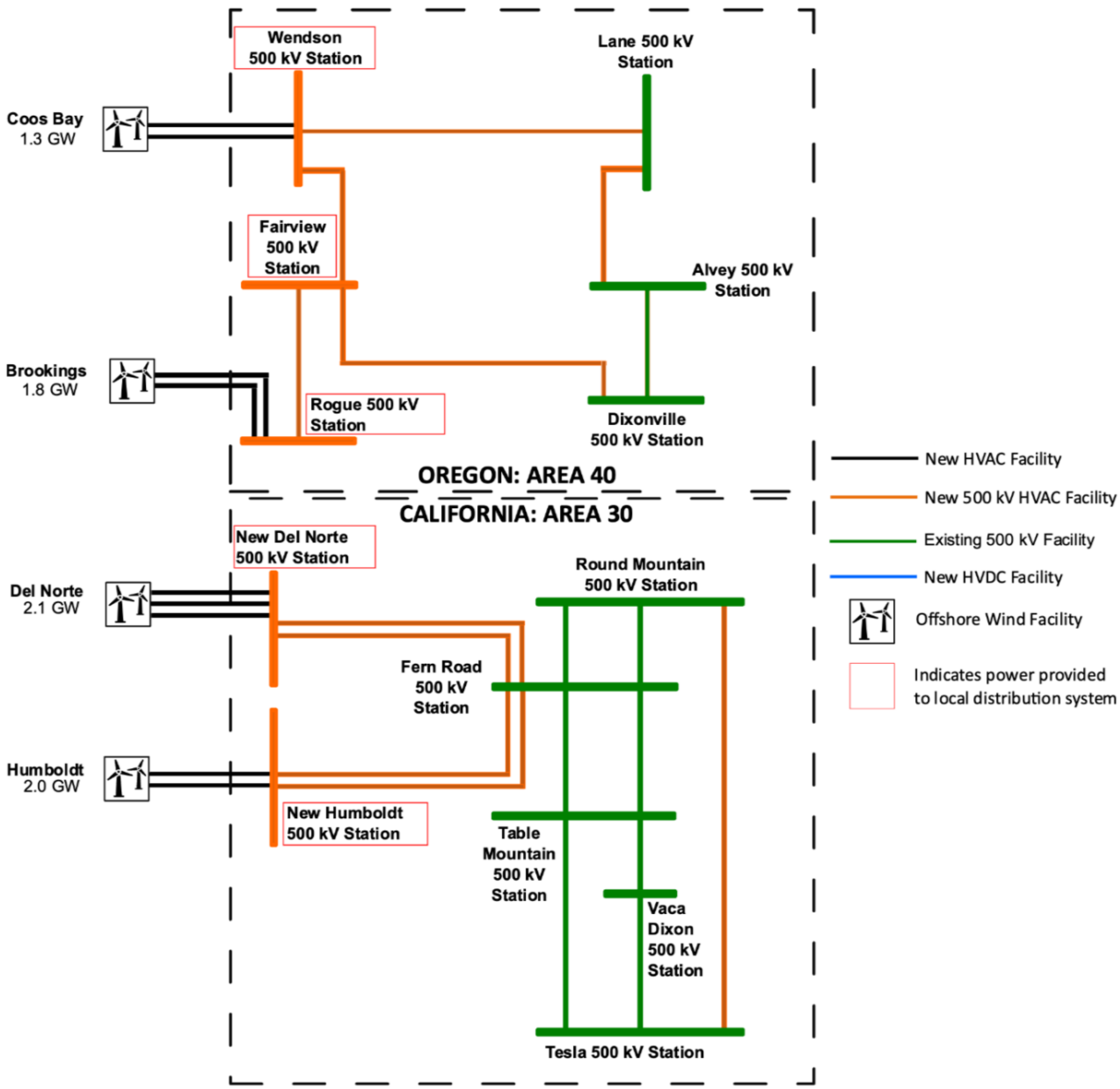

Figure E1 – Single Line Diagram for Transmission Alternative 7.2a.

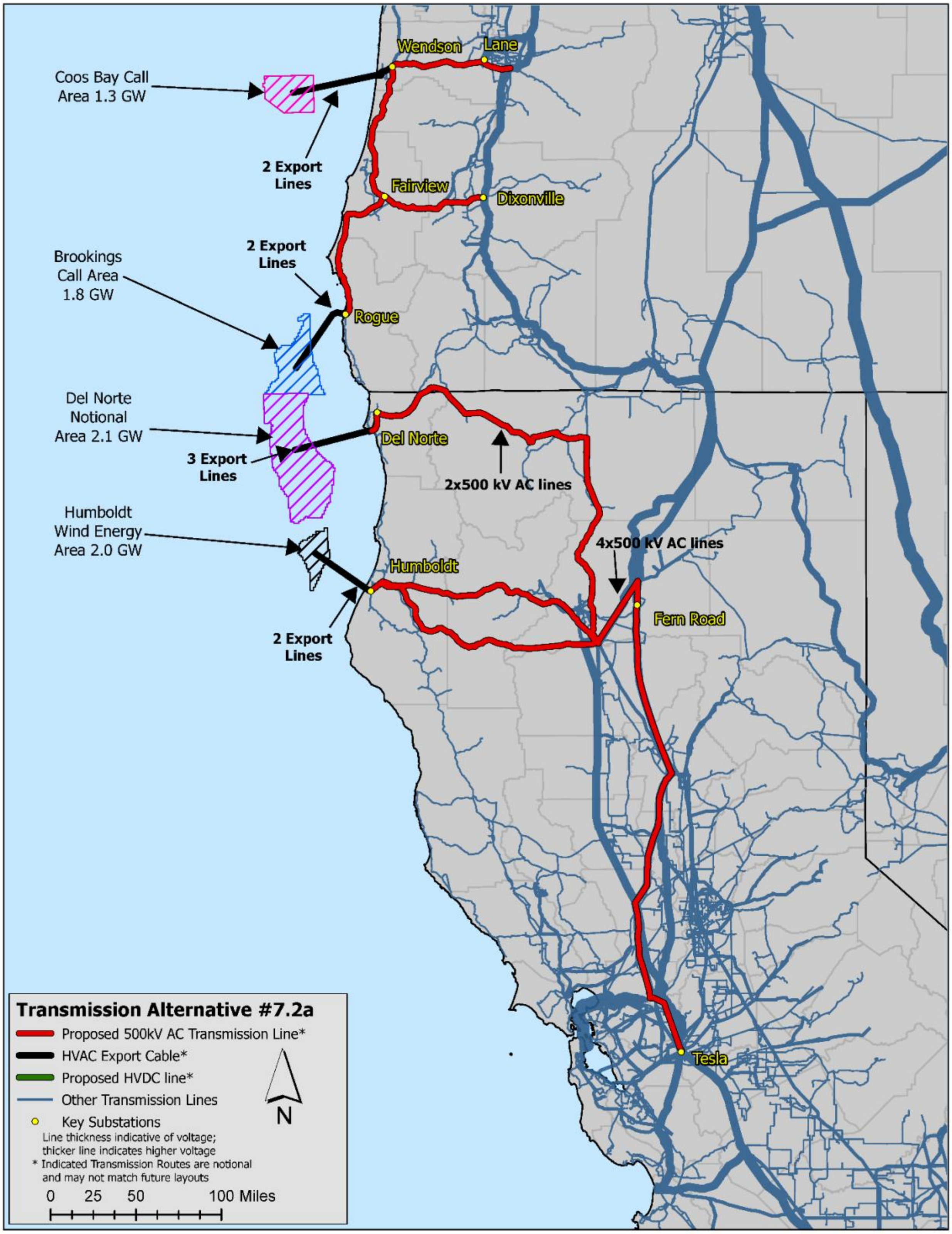

Figure E2 – Map for Transmission Alternative 7.2a.

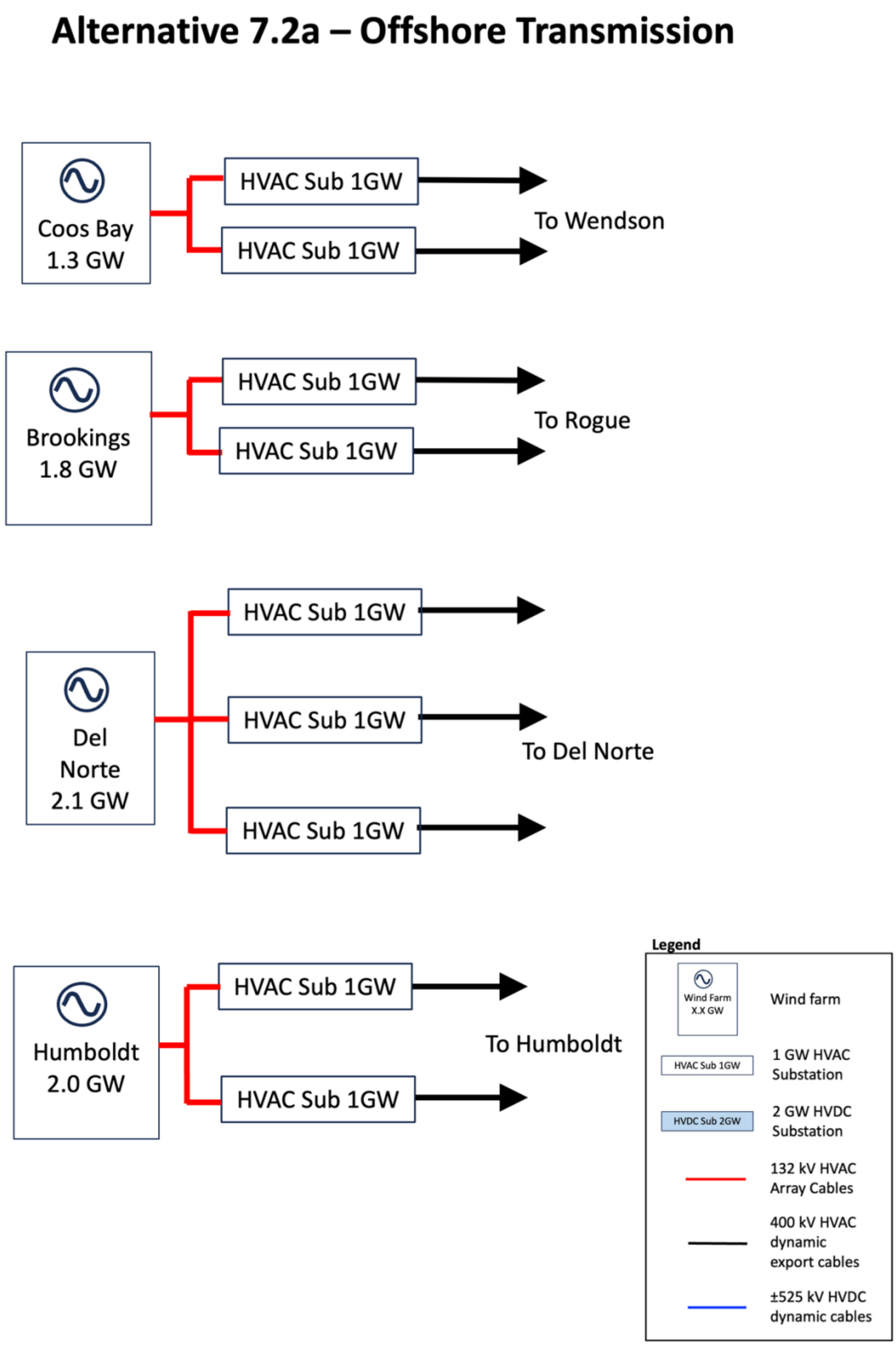

Figure E3 – Offshore Transmission Configuration for Transmission Alternative 7.2a.

Alternative 7.2b - Onshore Transmission

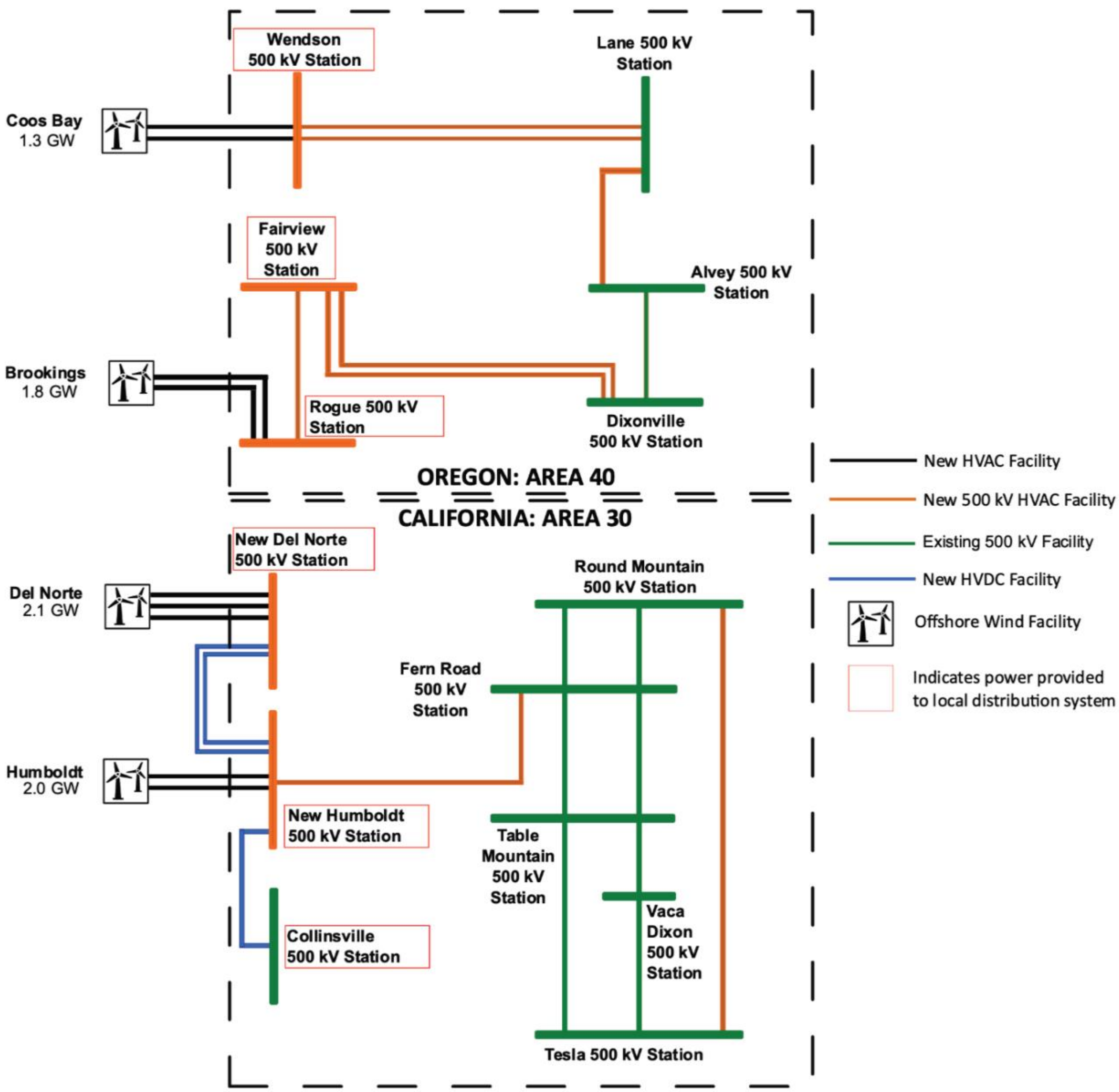

Figure E4 – Single Line Diagram for Transmission Alternative 7.2b.

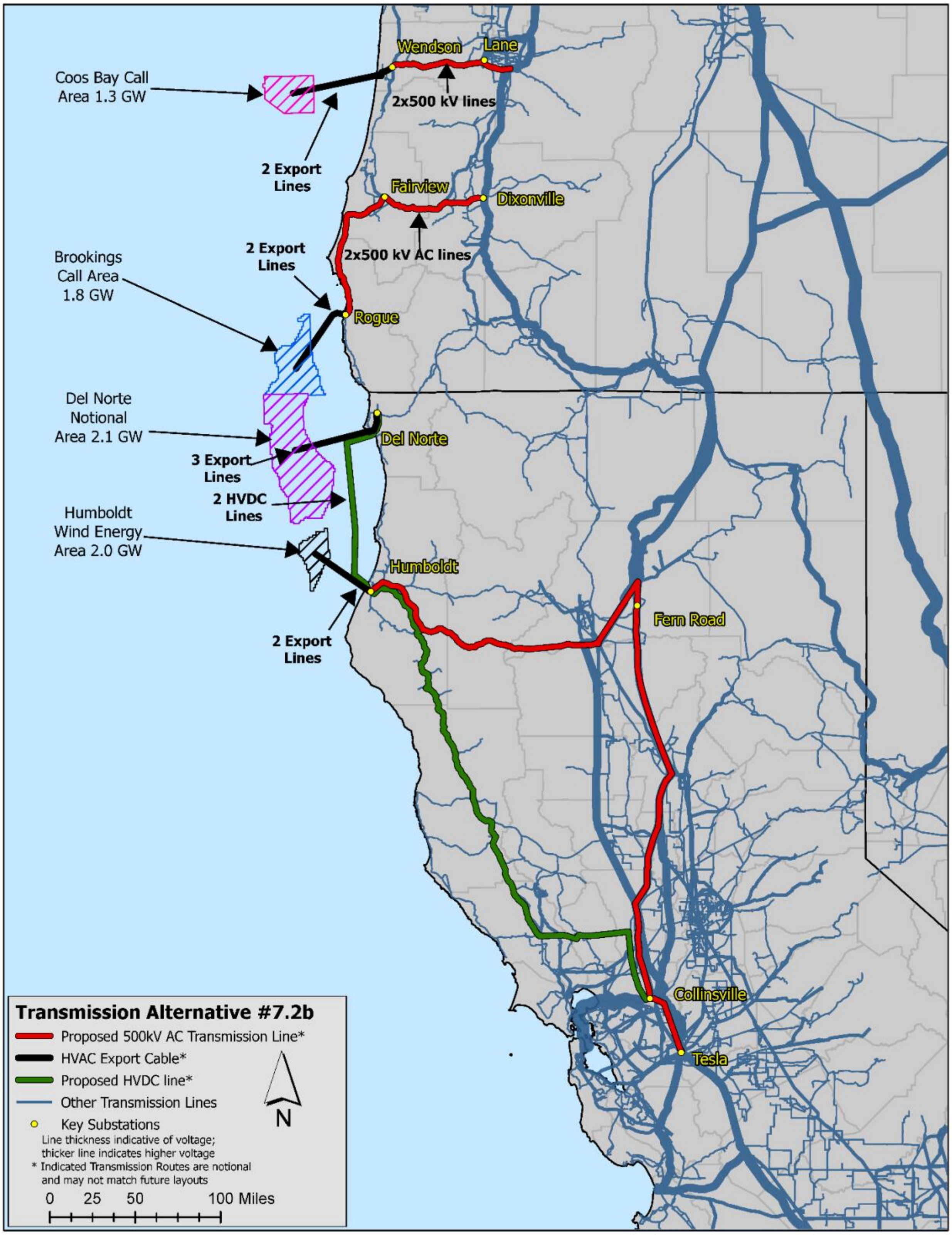

Figure E5 - Map for Transmission Alternative 7.2b.

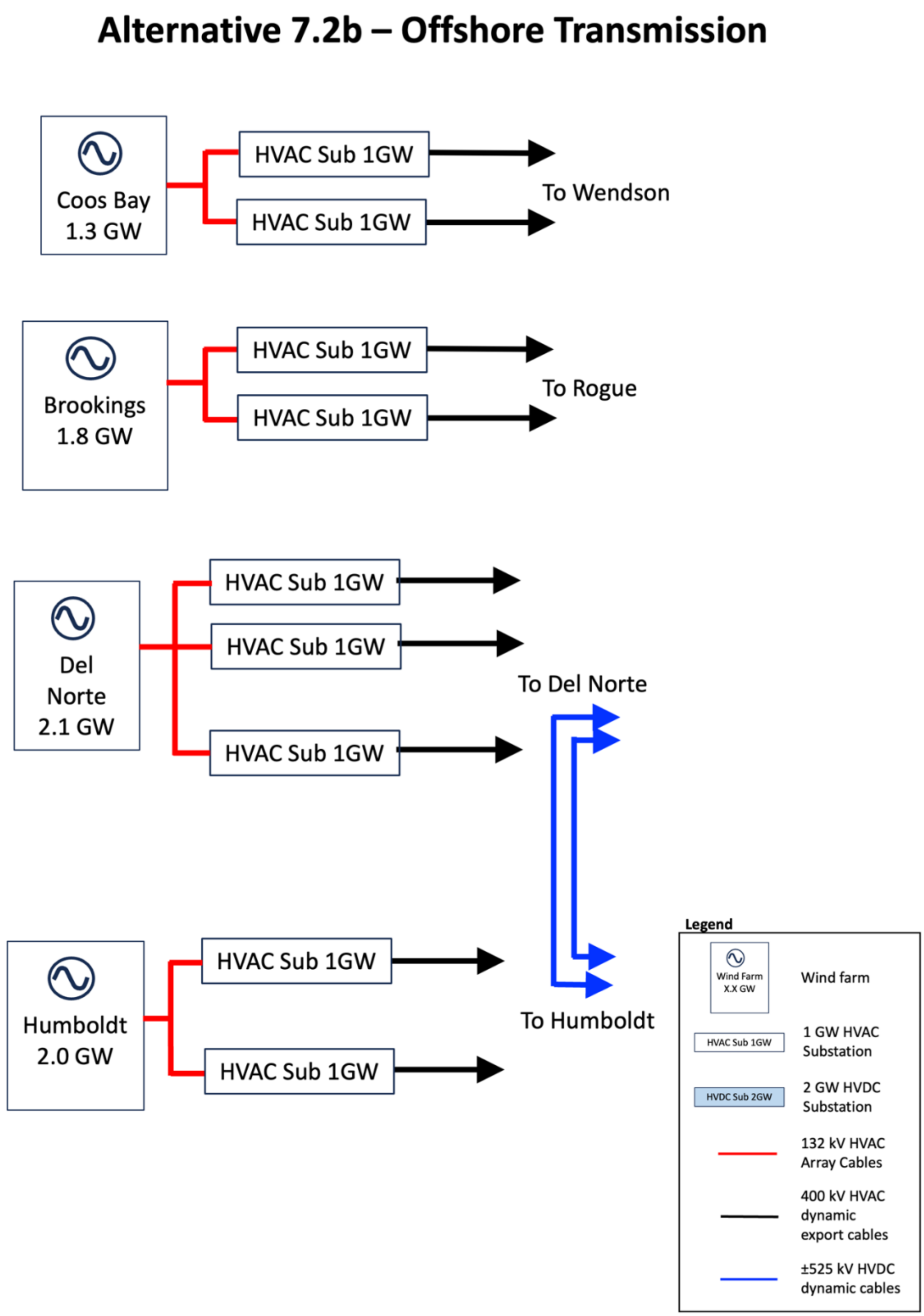

Figure E6 - Offshore Transmission Configuration for Transmission Alternative 7.2b.

Alternative 12.4a - Onshore Transmission

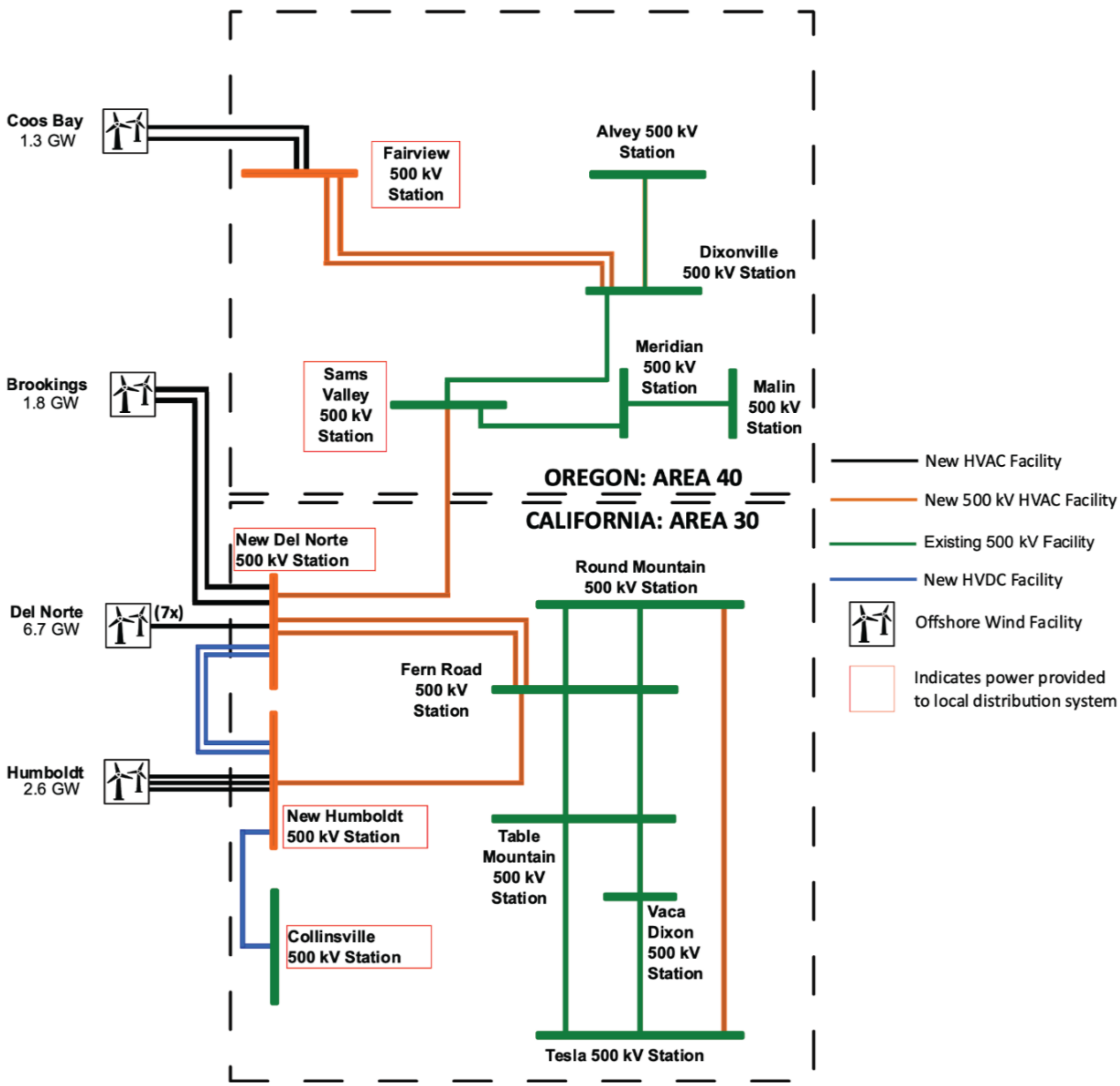

Figure E7 – Single Line Diagram for Transmission Alternative 12.4a.

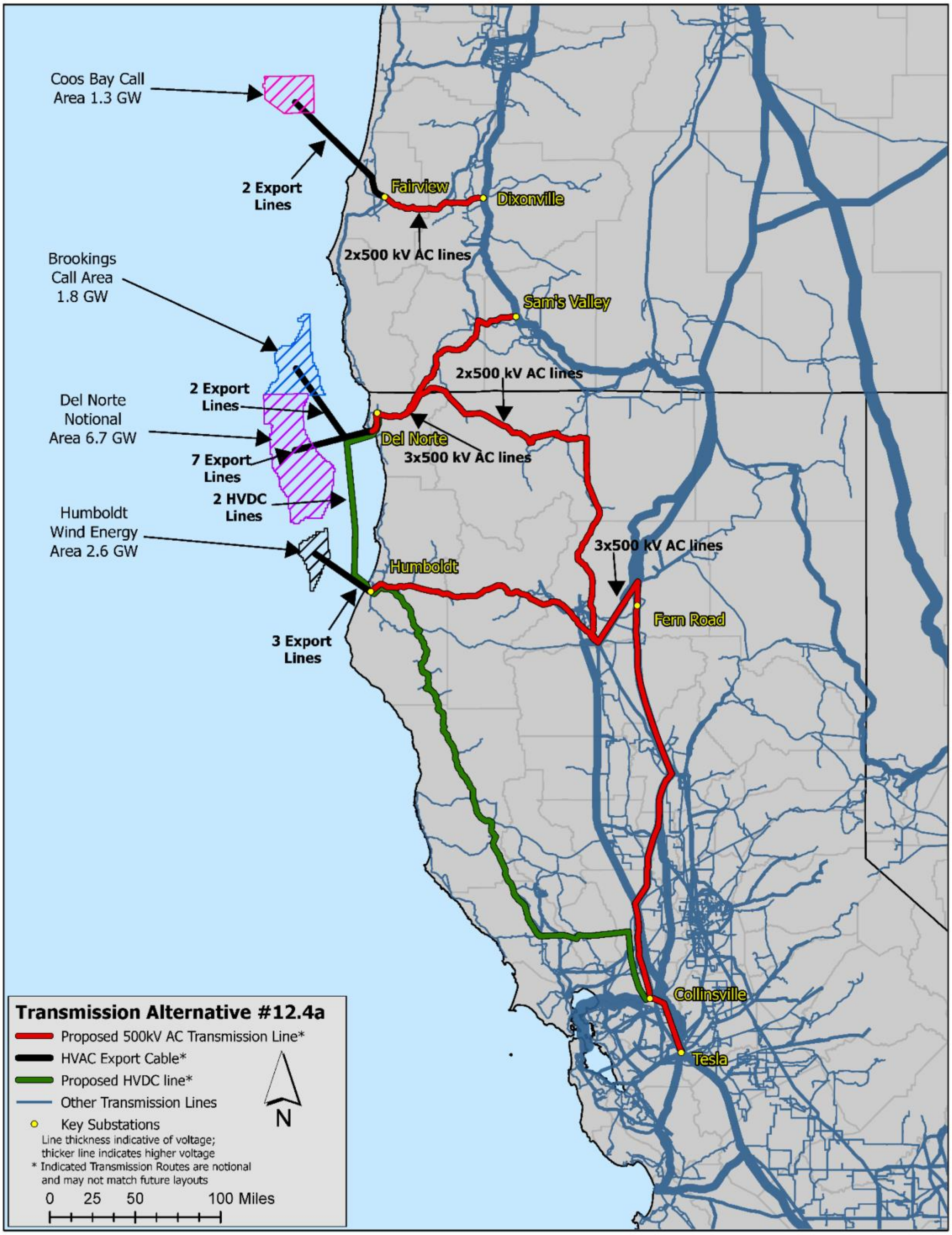

Figure E8 - Map for Transmission Alternative 12.4a.

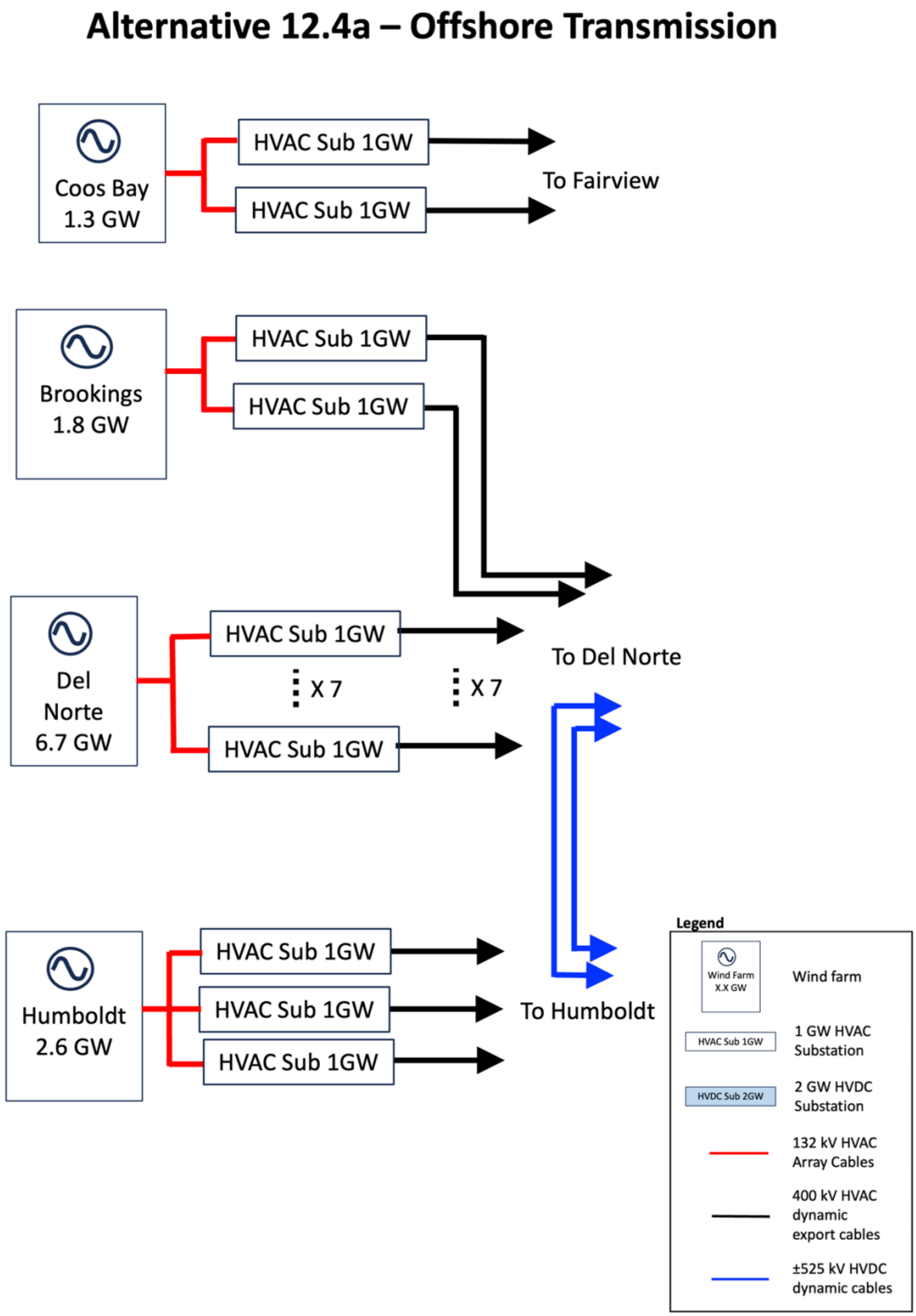

Figure E9 - Offshore Transmission Configuration for Transmission Alternative 12.4a.

Alternative 12.4b - Onshore Transmission

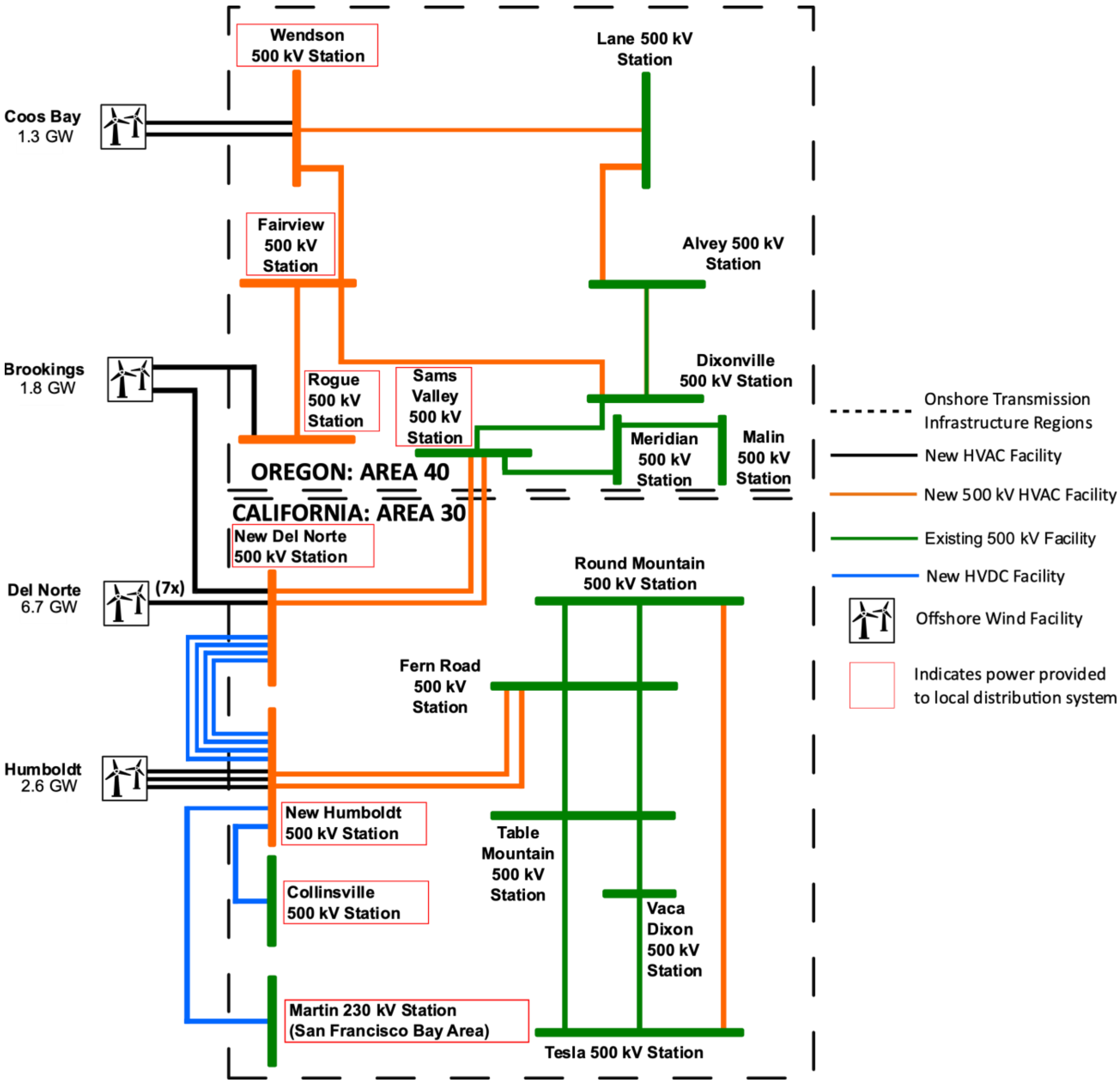

Figure E10 – Single Line Diagram for Transmission Alternative 12.4b.

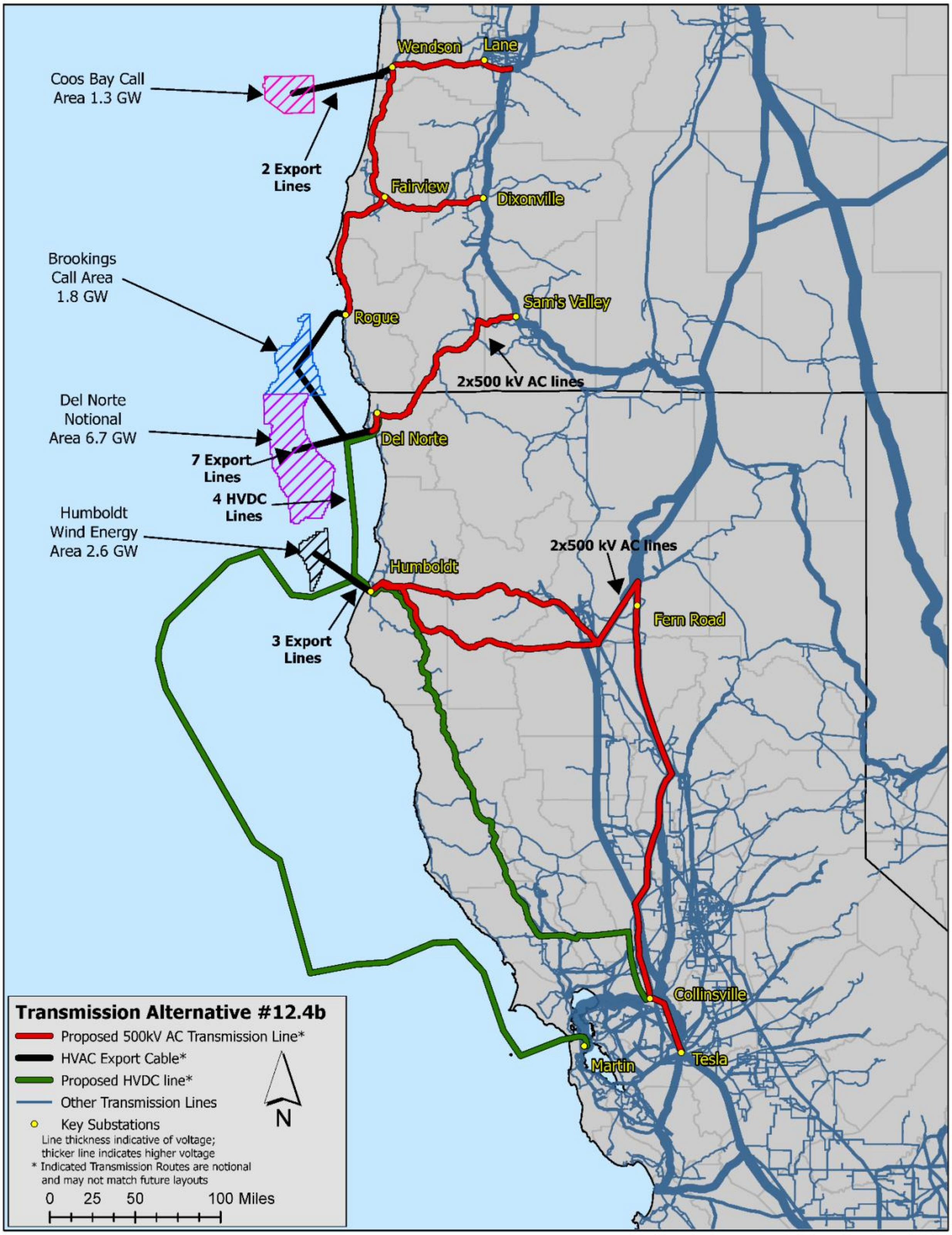

Figure E11 - Map for Transmission Alternative 12.4b.

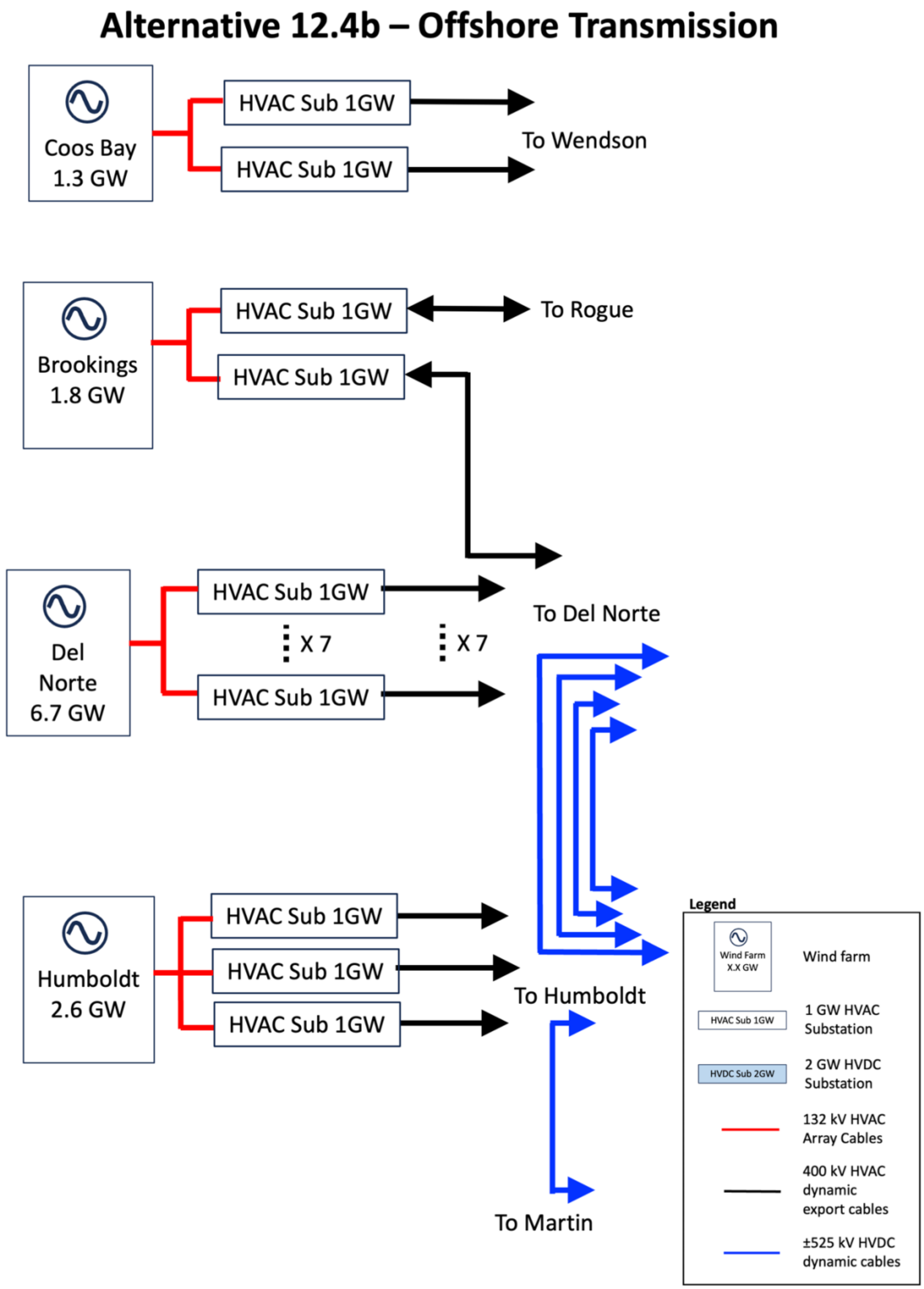

Figure E12 - Offshore Transmission Configuration for Transmission Alternative 12.4b.

Alternative 12.4c - Onshore Transmission

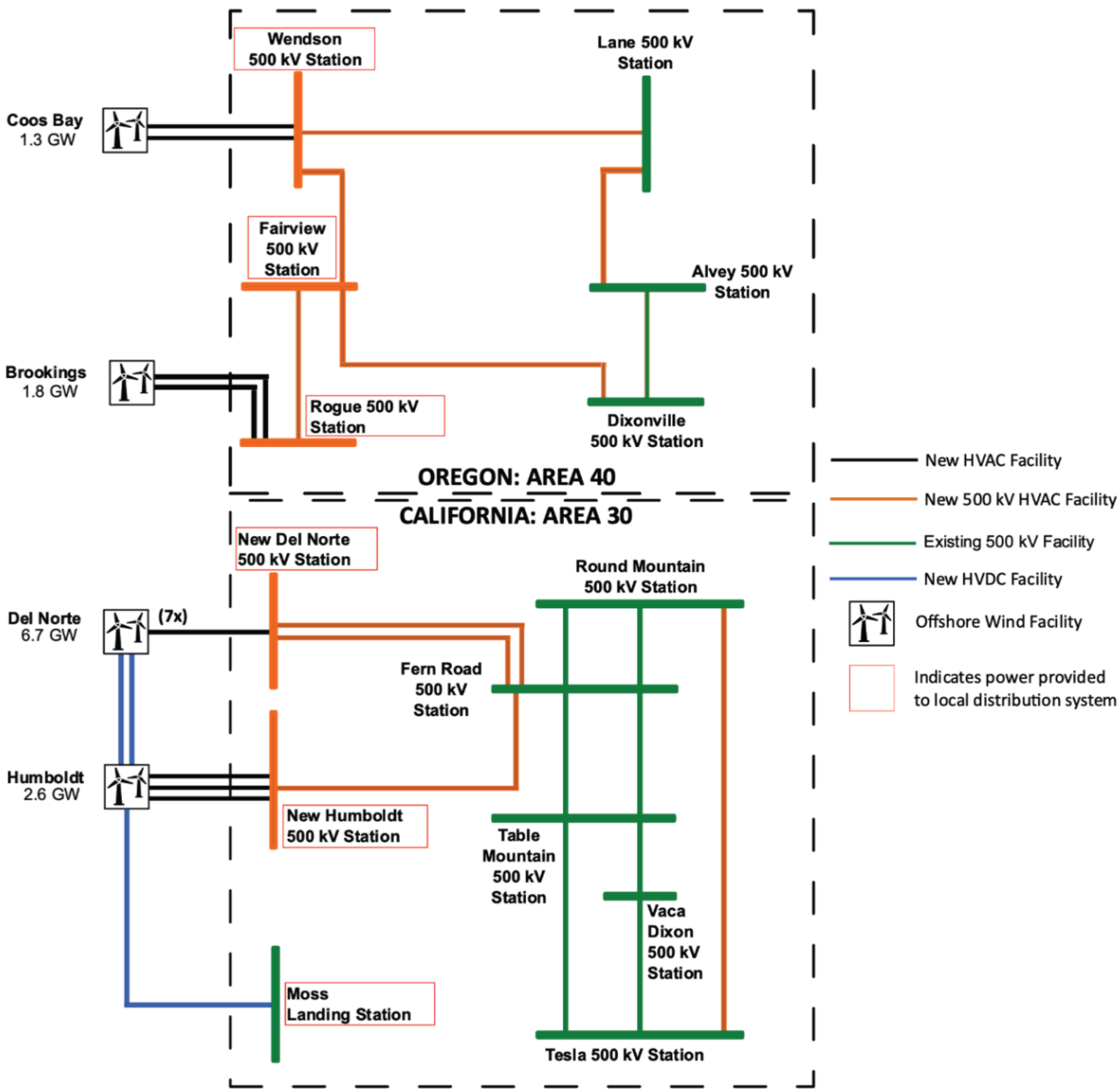

Figure E13 – Single Line Diagram for Transmission Alternative 12.4c.

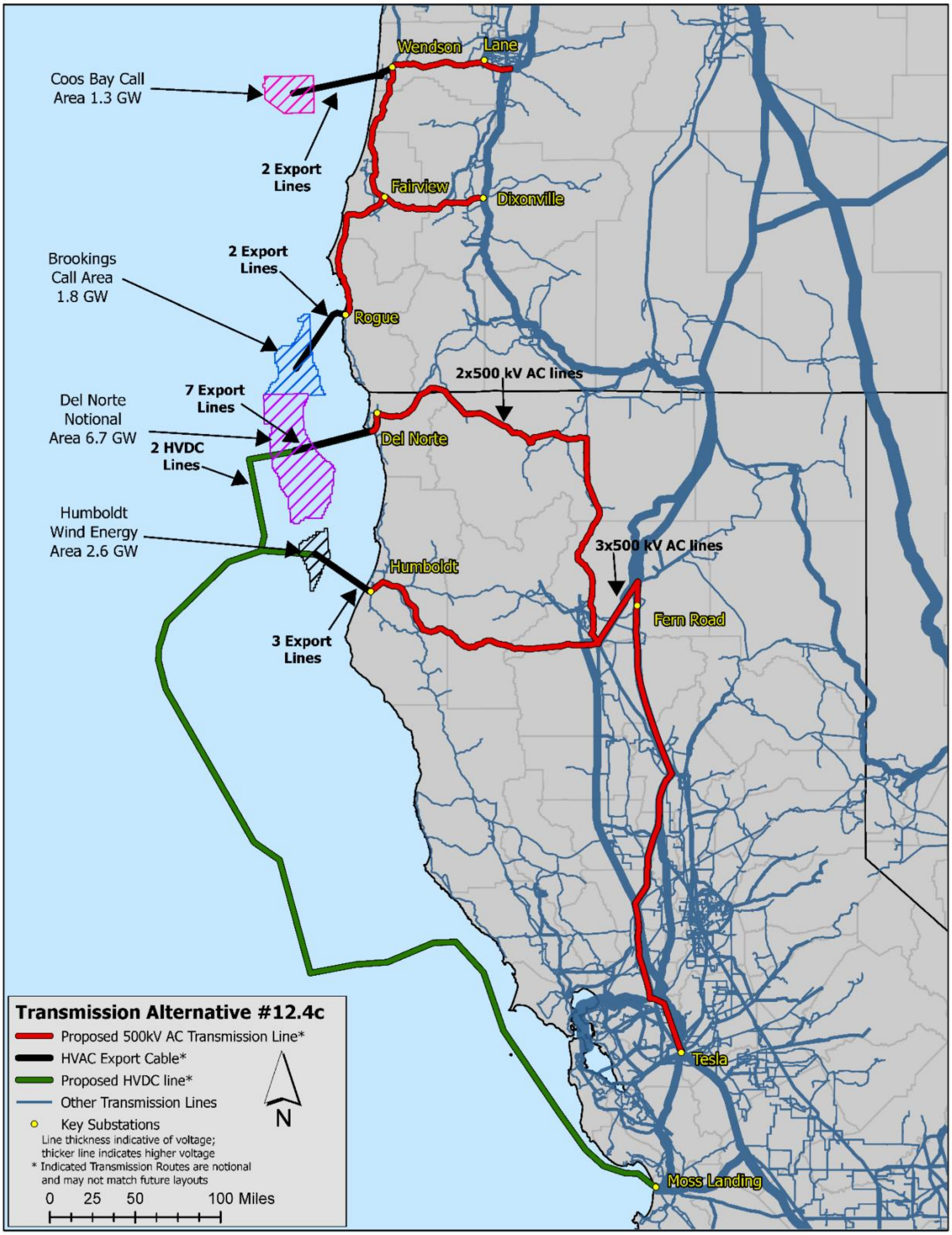

Figure E14- Map for Transmission Alternative 12.4c.

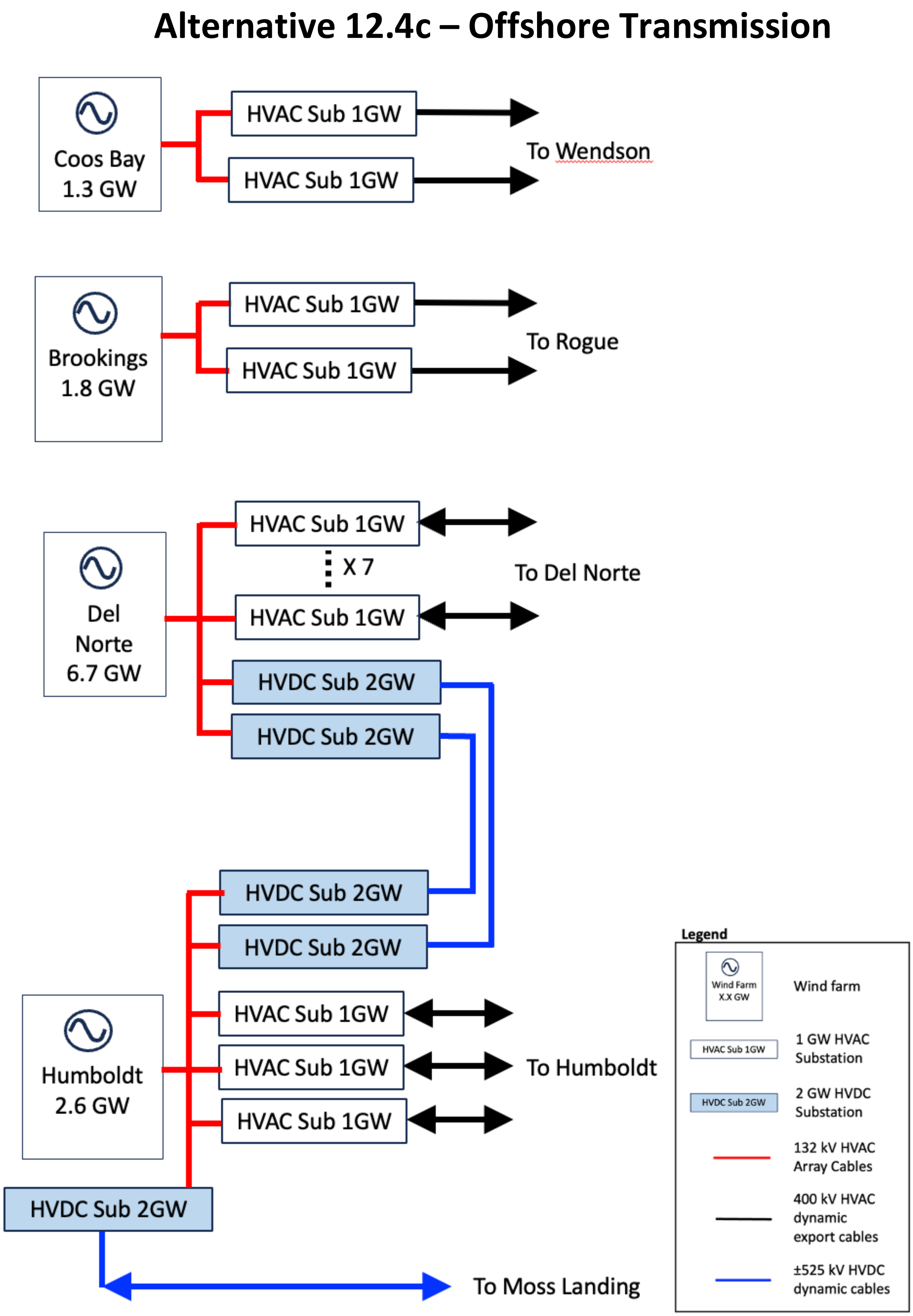

Figure E15 - Offshore Transmission Configuration for Transmission Alternative 12.4c. Note that the floating HVDC conversion stations and other technology elements are still in development. Offshore configurations may differ from what is shown here.

Alternative 12.4d - Onshore Transmission

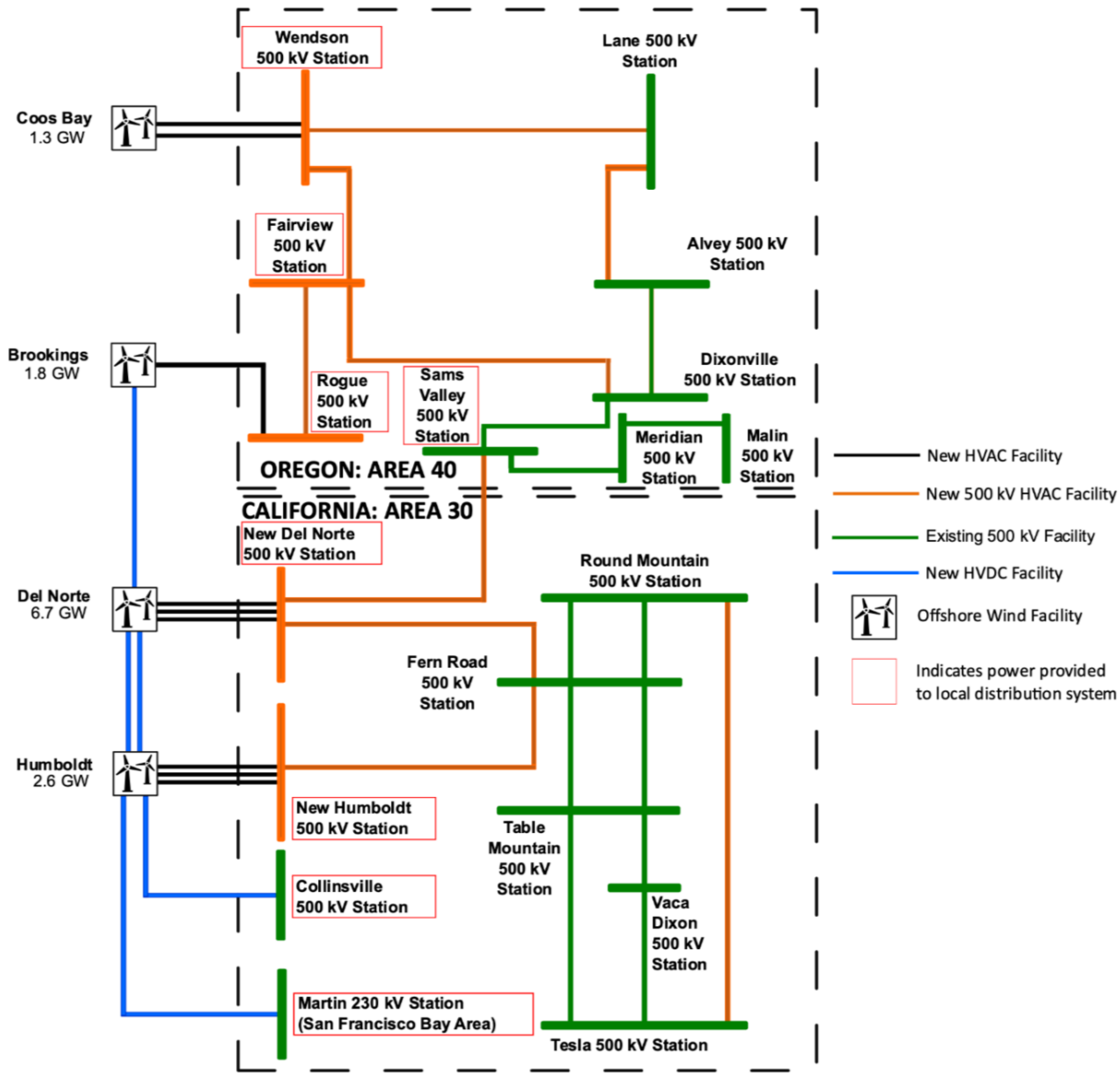

Figure E16 – Single Line Diagram for Transmission Alternative 12.4d.

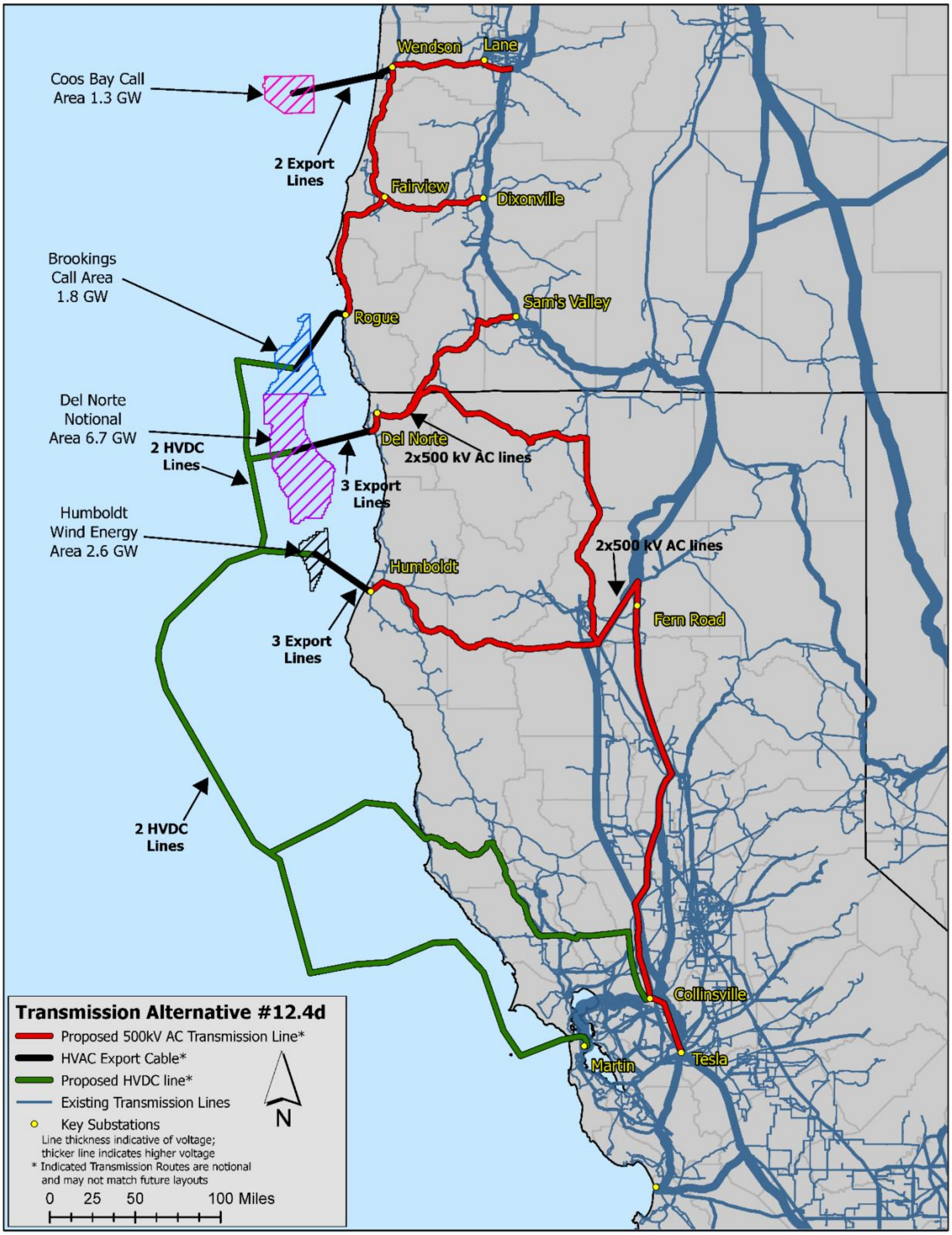

Figure E17- Map for Transmission Alternative 12.4d.

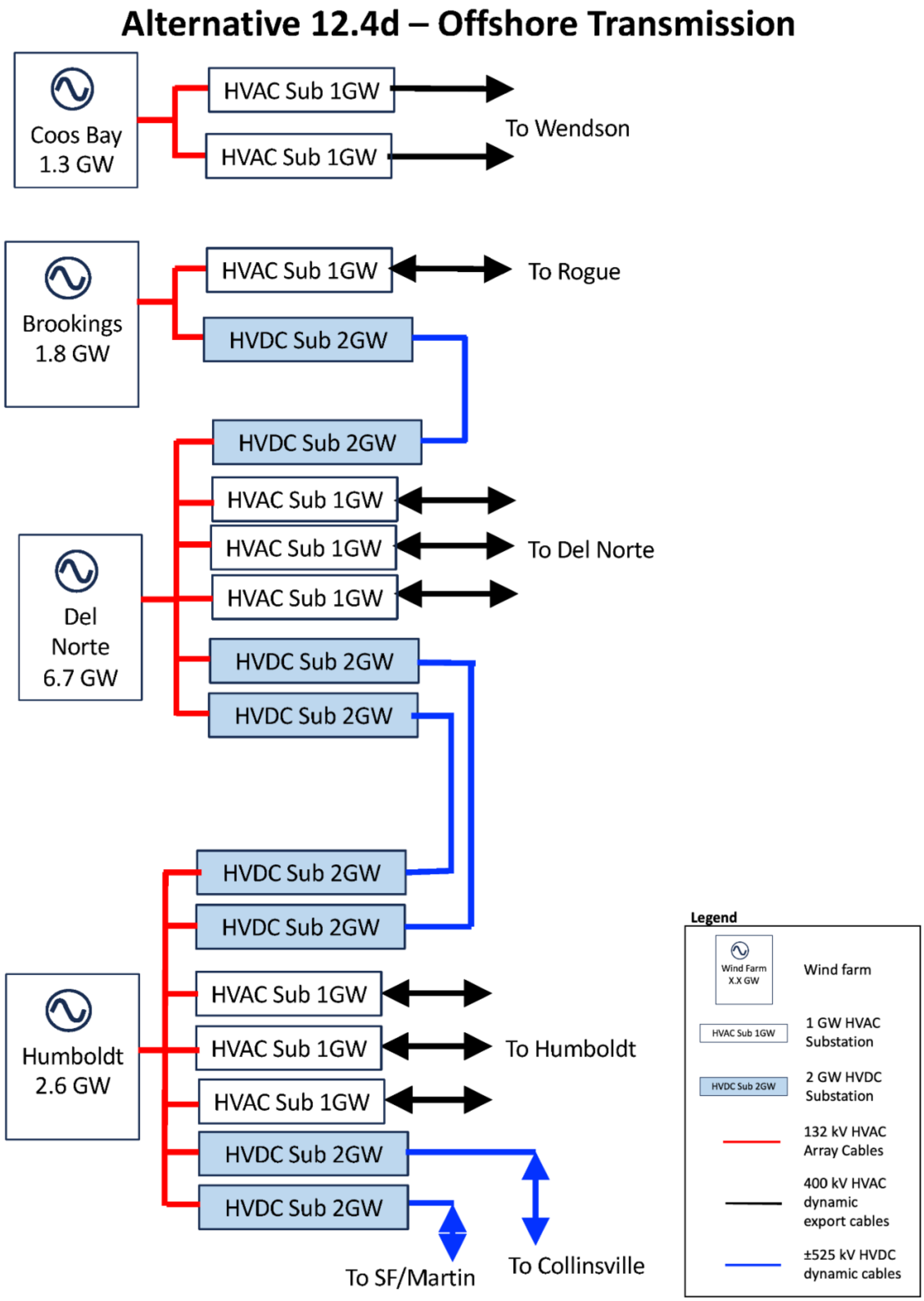

Figure E18 - Offshore Transmission Configuration for Transmission Alternative 12.4d. Note that the floating HVDC conversion stations and other technology elements are still in development. Offshore configurations may differ from what is shown here.

Alternative 12.4e - Onshore Transmission

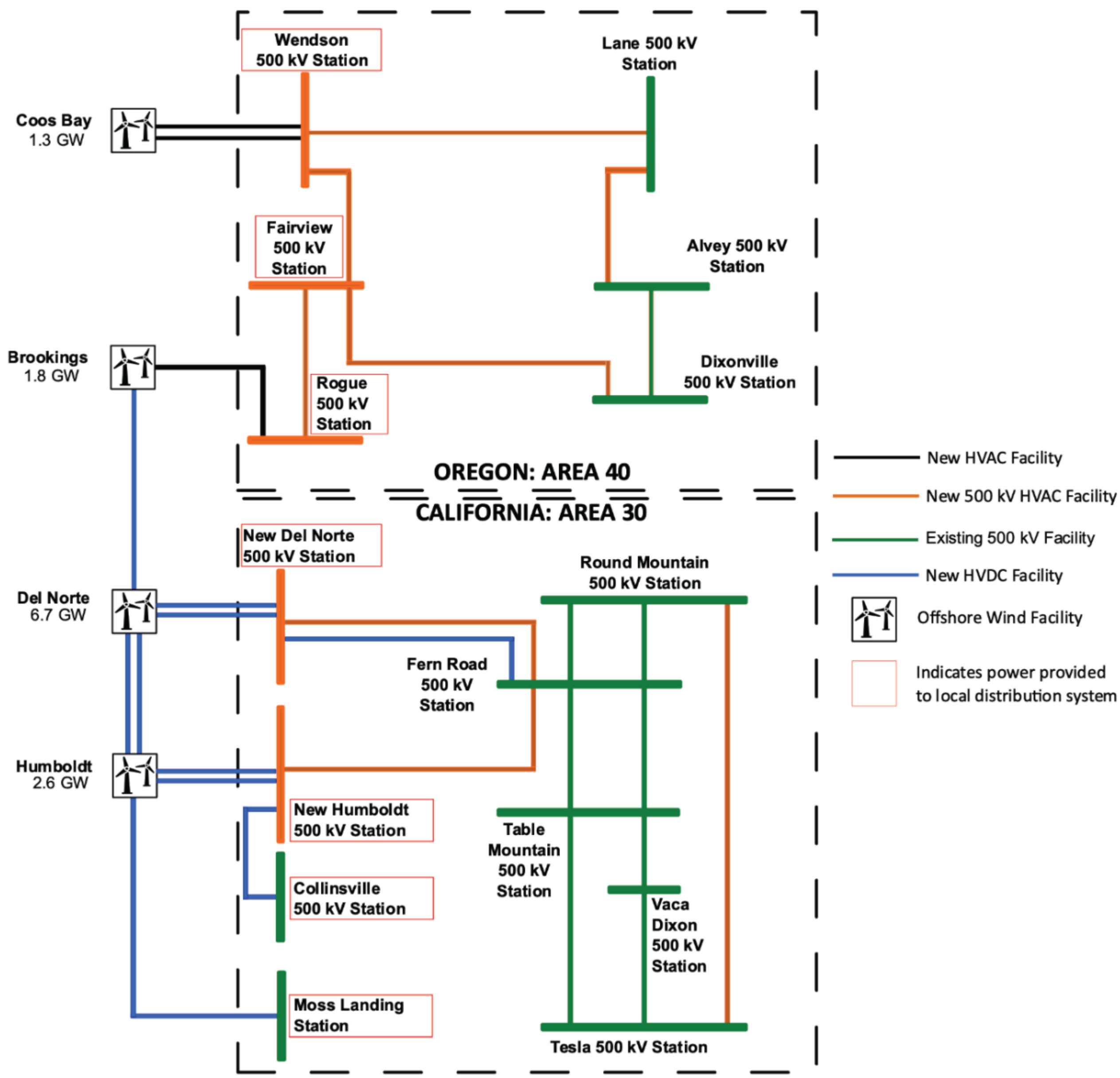

Figure E19 – Single Line Diagram for Transmission Alternative 12.4e.

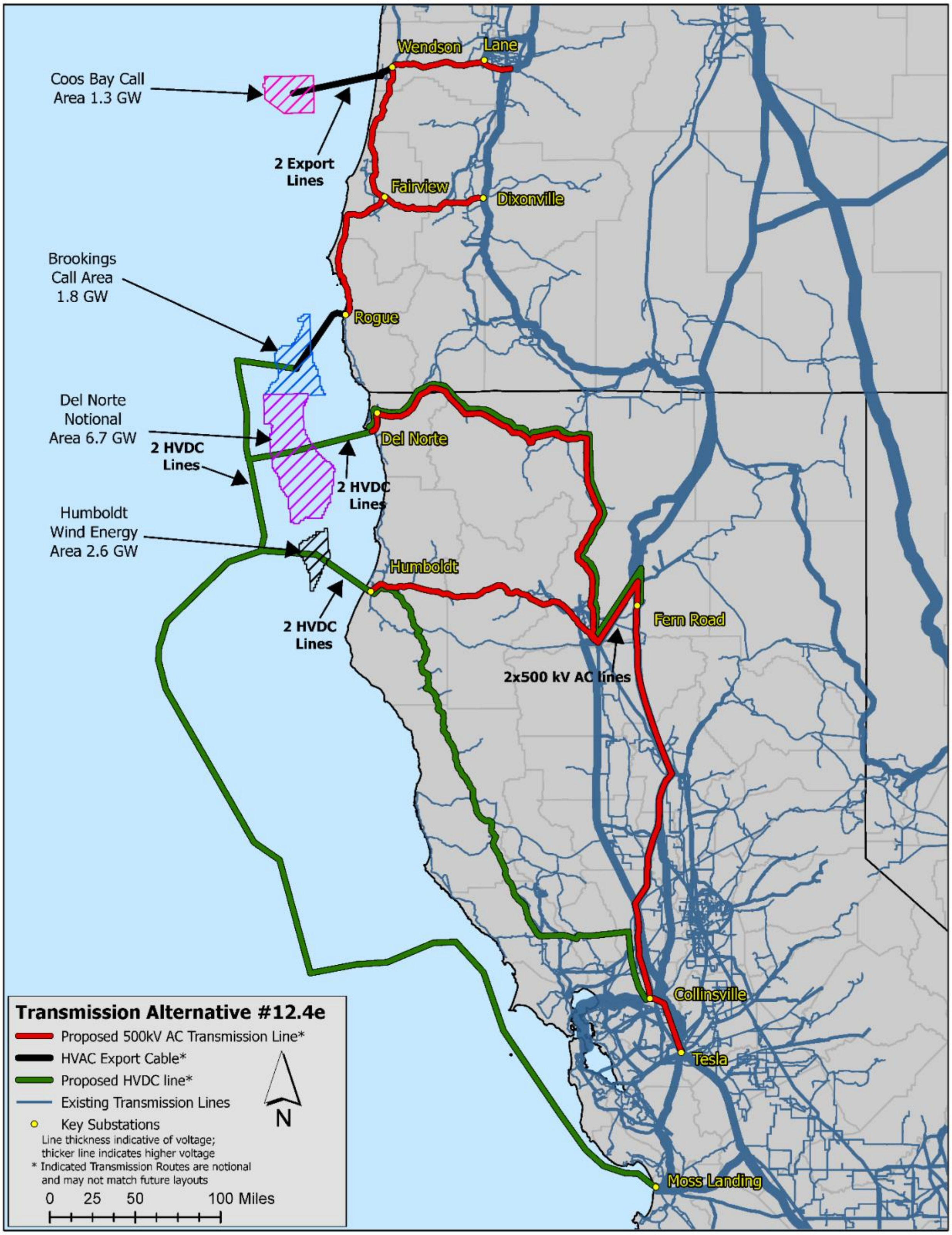

Figure E20 - Map for Transmission Alternative 12.4e.

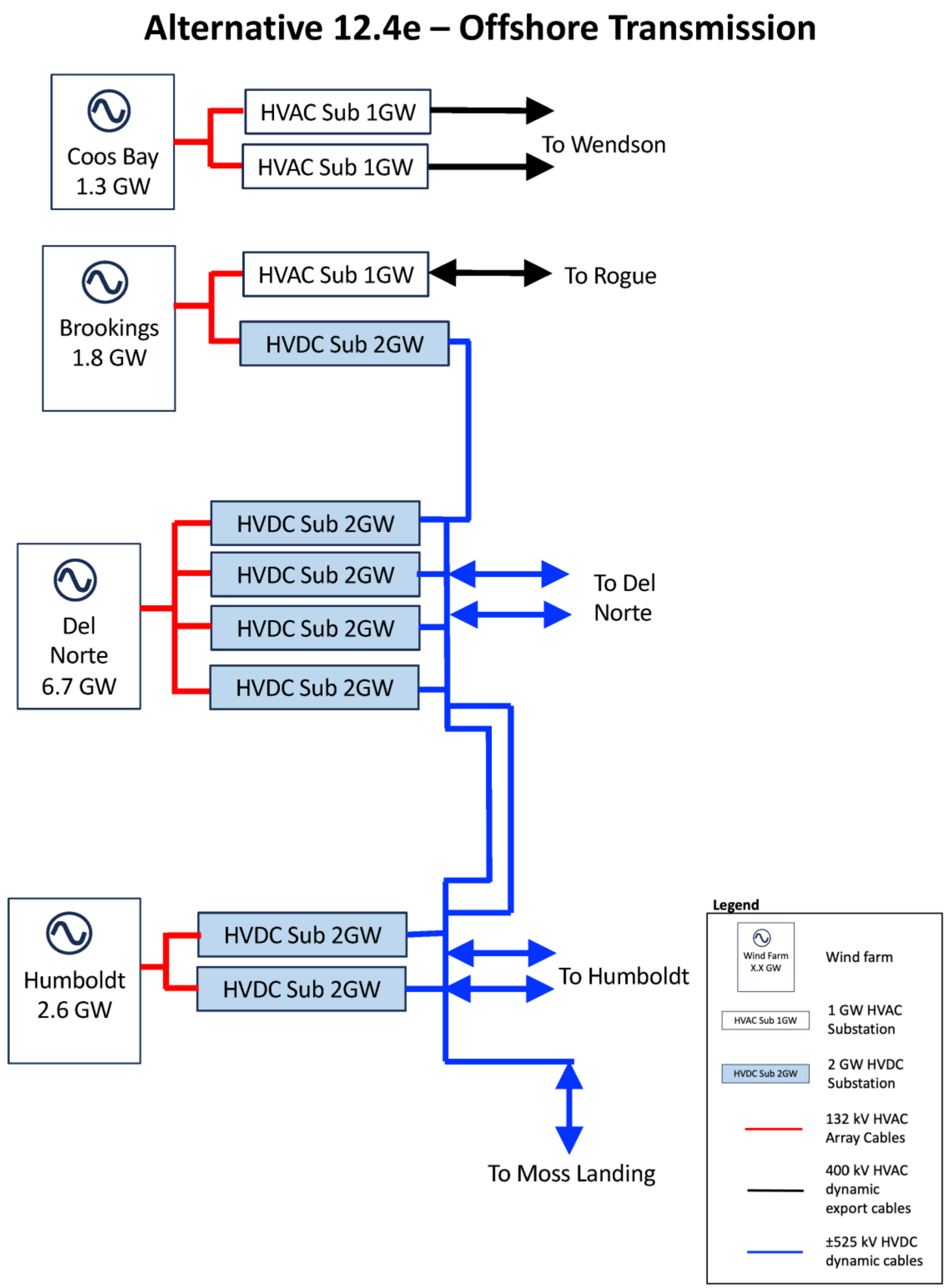

Figure E21 - Offshore Transmission Configuration for Transmission Alternative 12.4e. Note that the HVDC mesh network, floating HVDC conversion stations, and other technology elements are still in development. Offshore configurations may differ from what is shown here.

Alternative 12.4f - Onshore Transmission

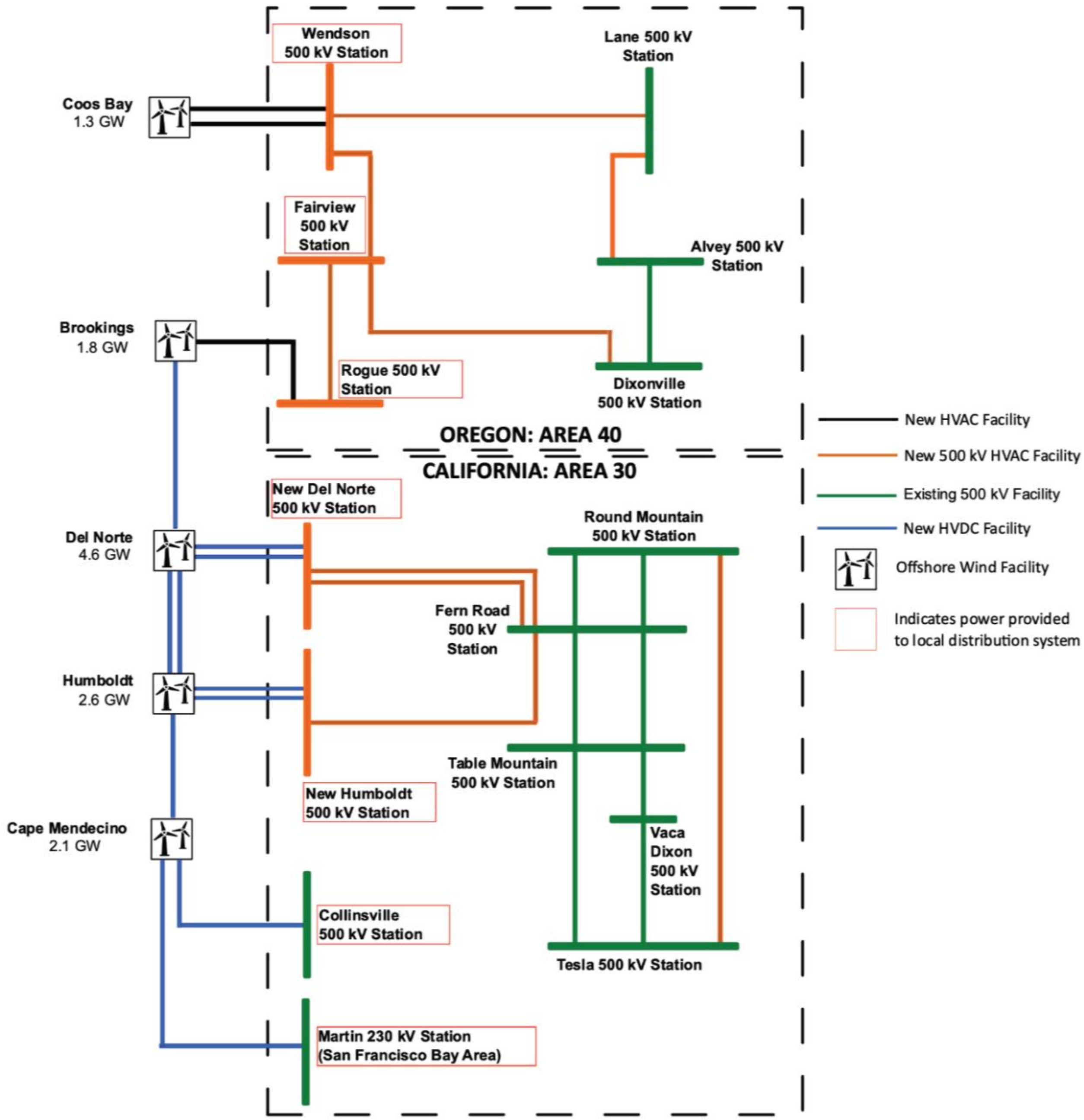

Figure E22 – Single Line Diagram for Transmission Alternative 12.4f.

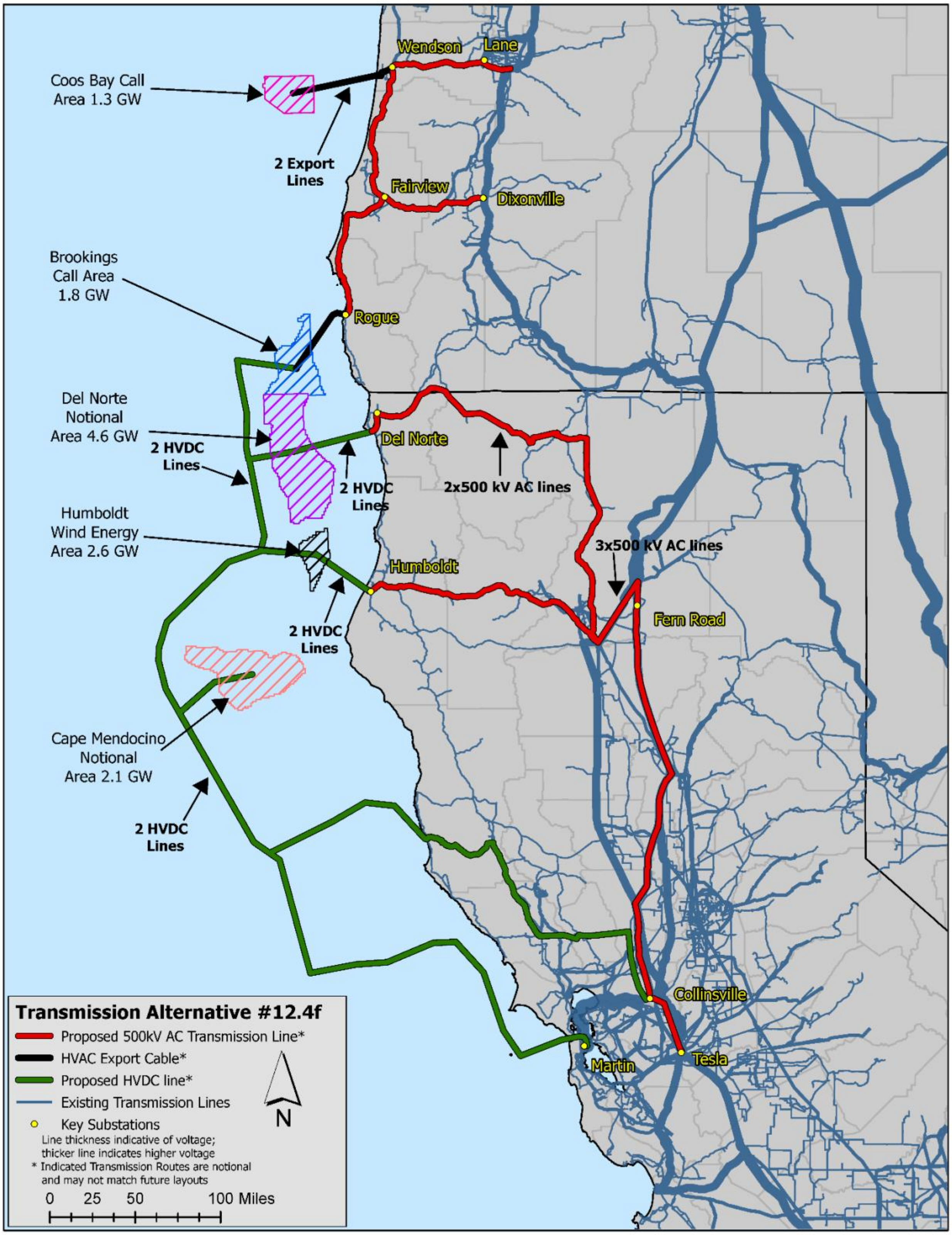

Figure E23 - Map for Transmission Alternative 12.4f.

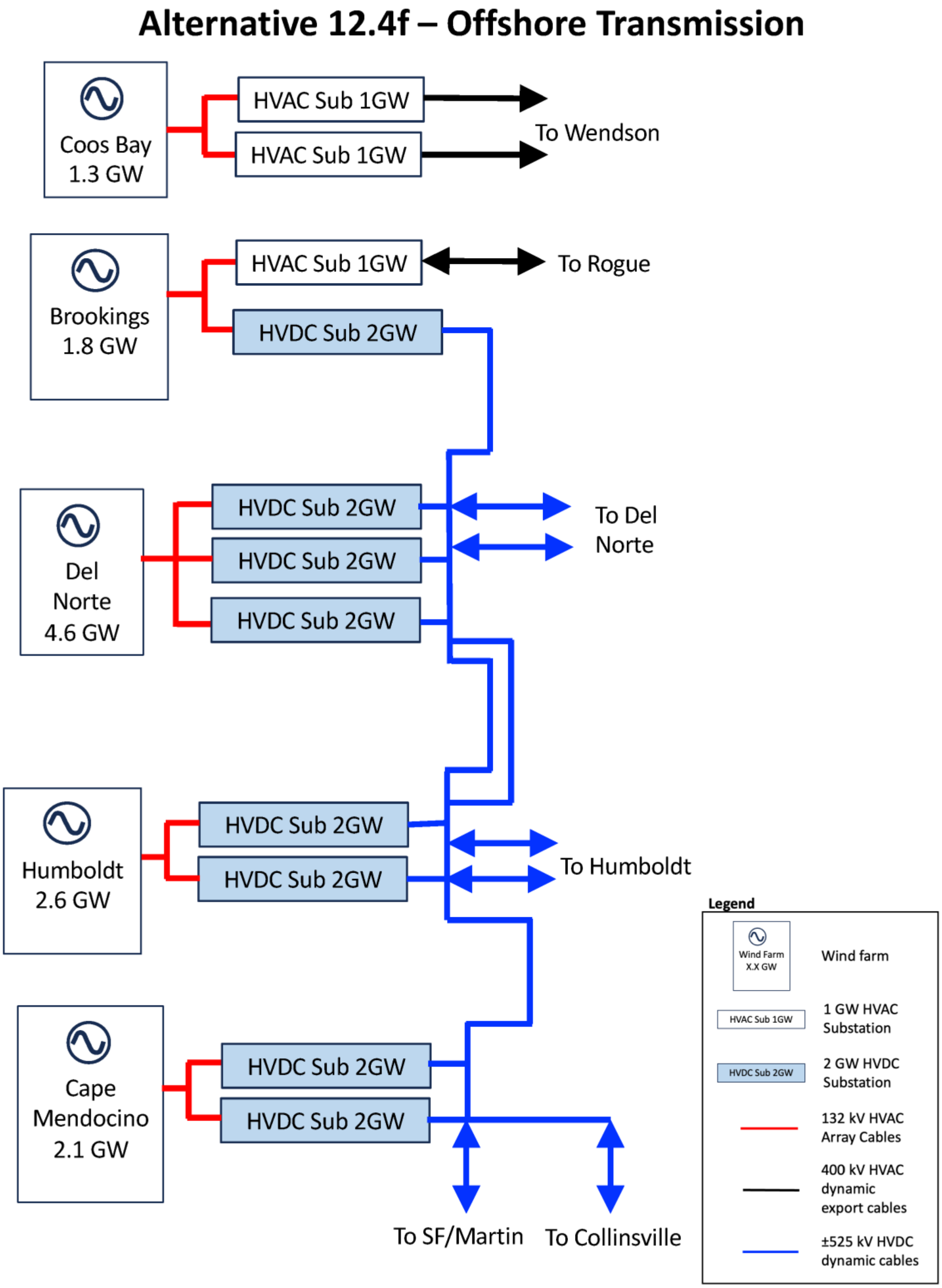

Figure E24 - Offshore Transmission Configuration for Transmission Alternative 12.4f. Note that the HVDC mesh network, floating HVDC conversion stations, and other technology elements are still in development. Offshore configurations may differ from what is shown here.

Alternative 25.8a - Onshore Transmission

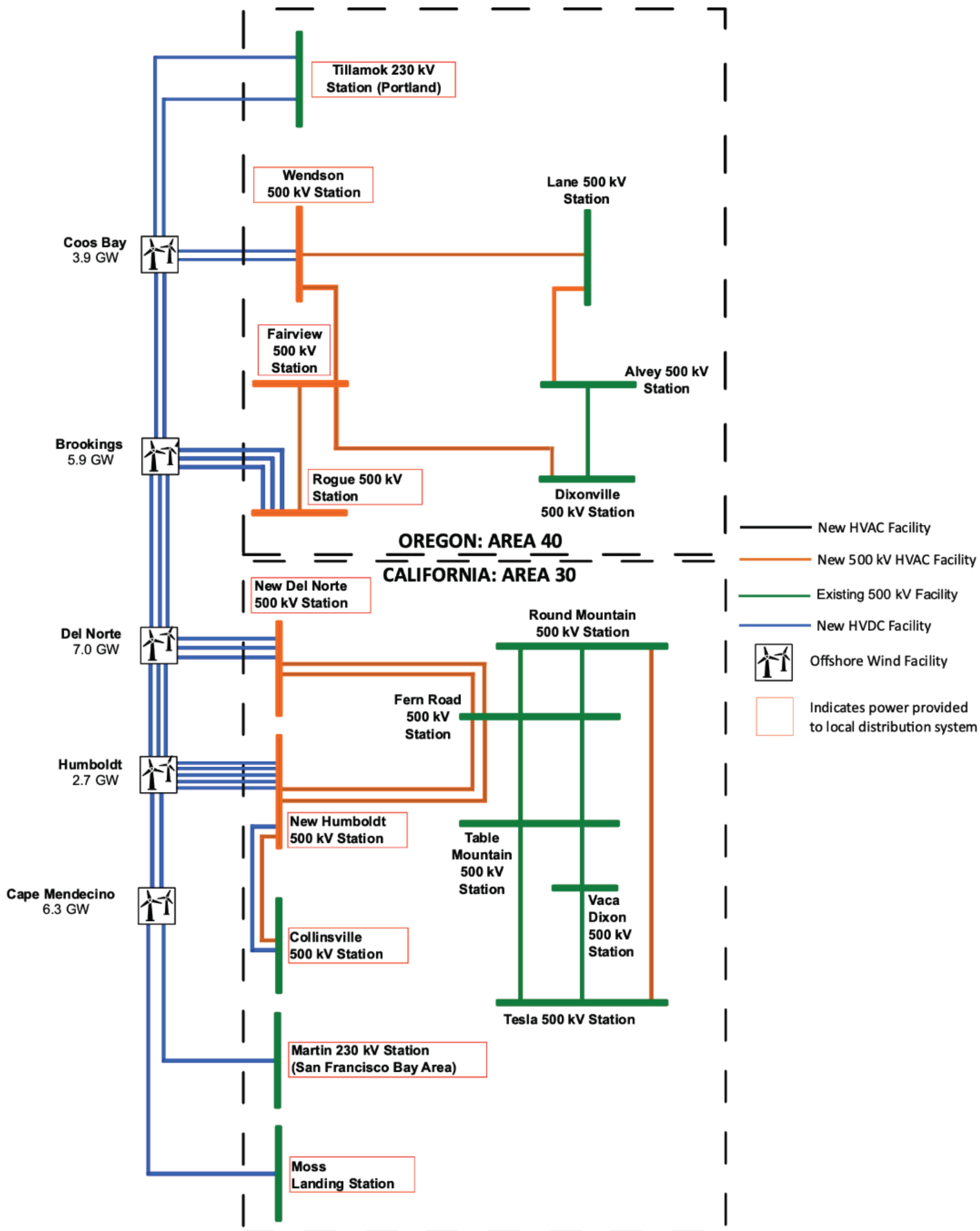

Figure E25 – Single Line Diagram for Transmission Alternative 25.8a.

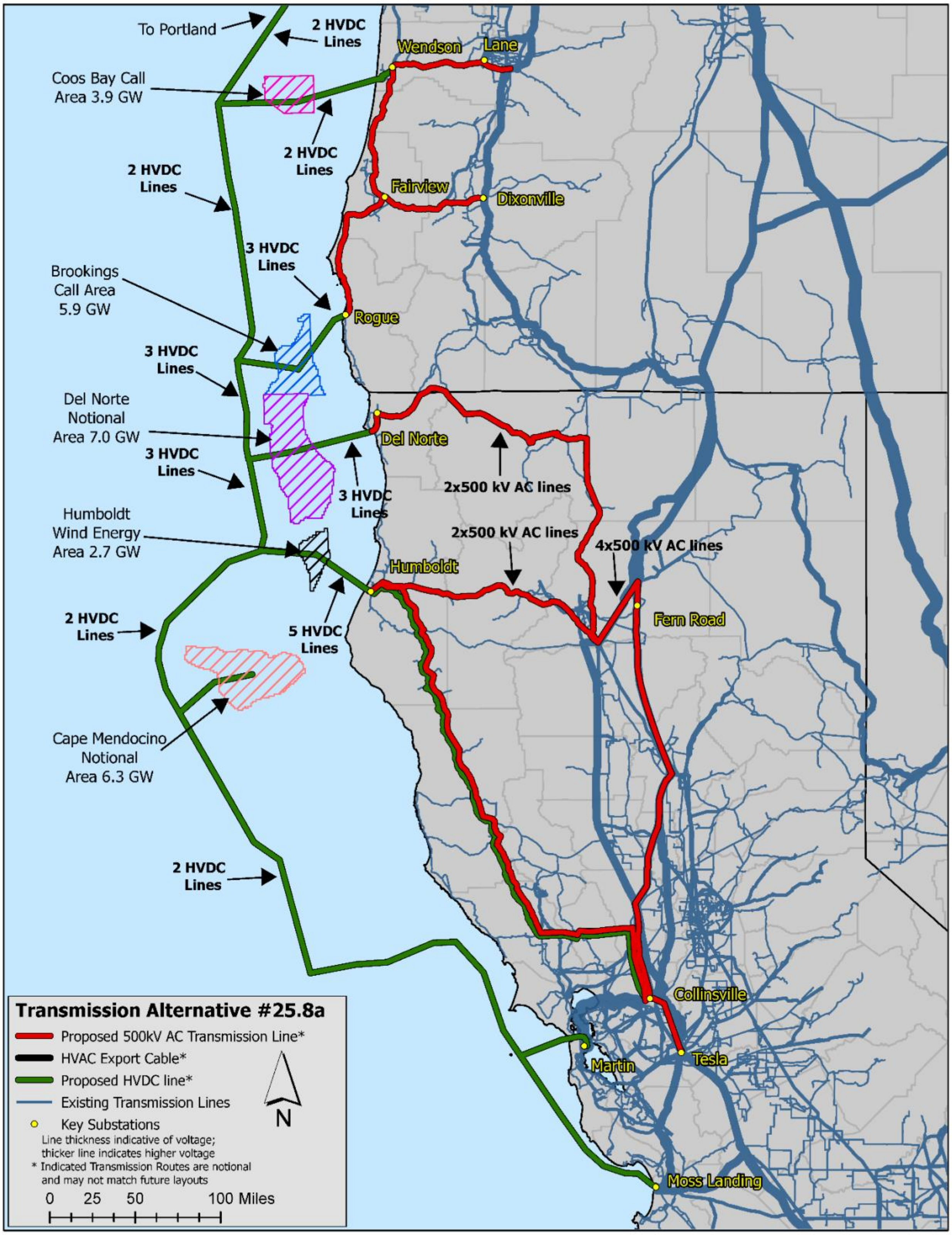

Figure E26 - Map for Transmission Alternative 25.8a.

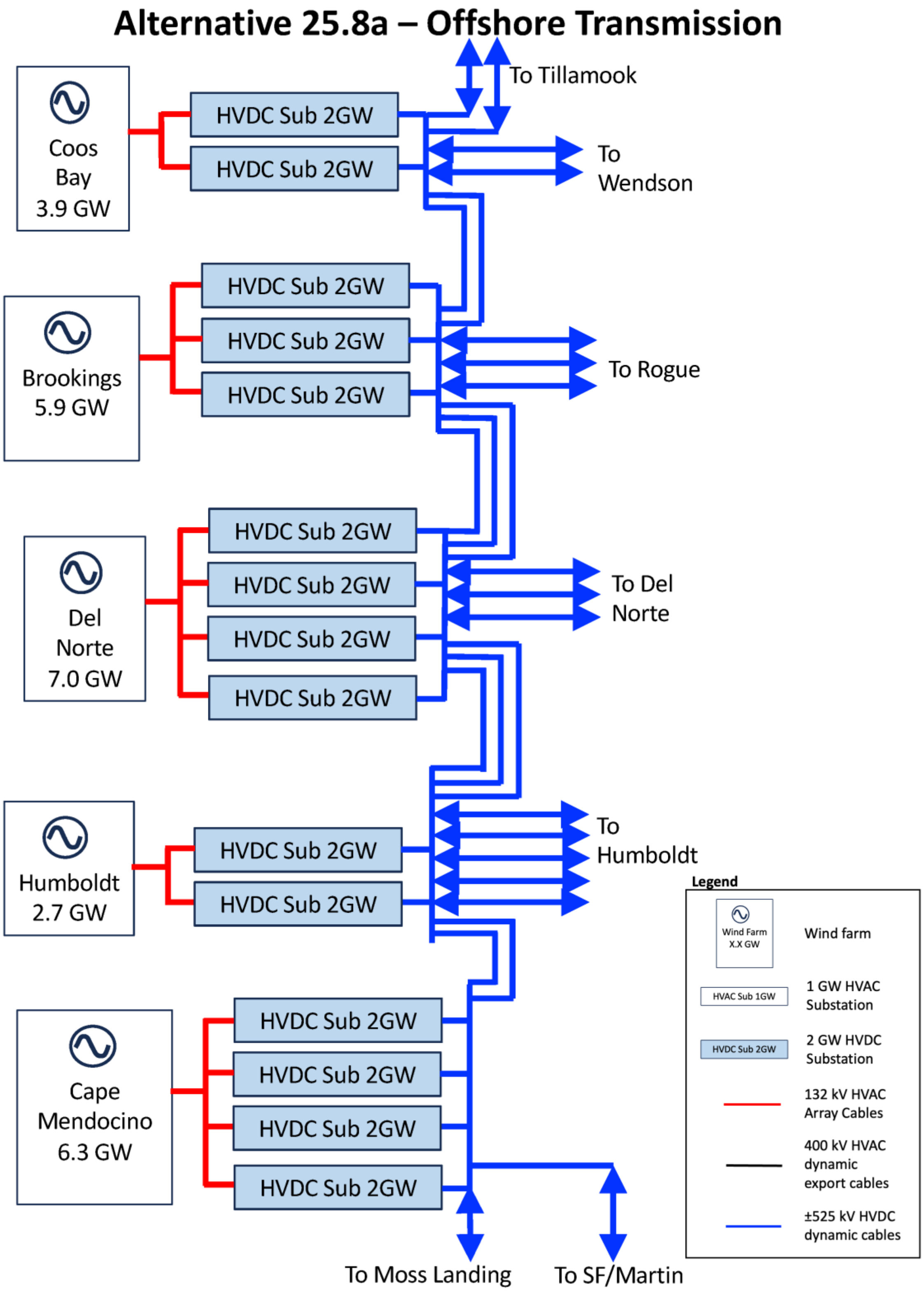

Figure E27 - Offshore Transmission Configuration for Transmission Alternative 25.8a. Note that the HVDC mesh network, floating HVDC conversion stations, and other technology elements are still in development. Offshore configurations may differ from what is shown here.

Alternative 25.8b - Onshore Transmission

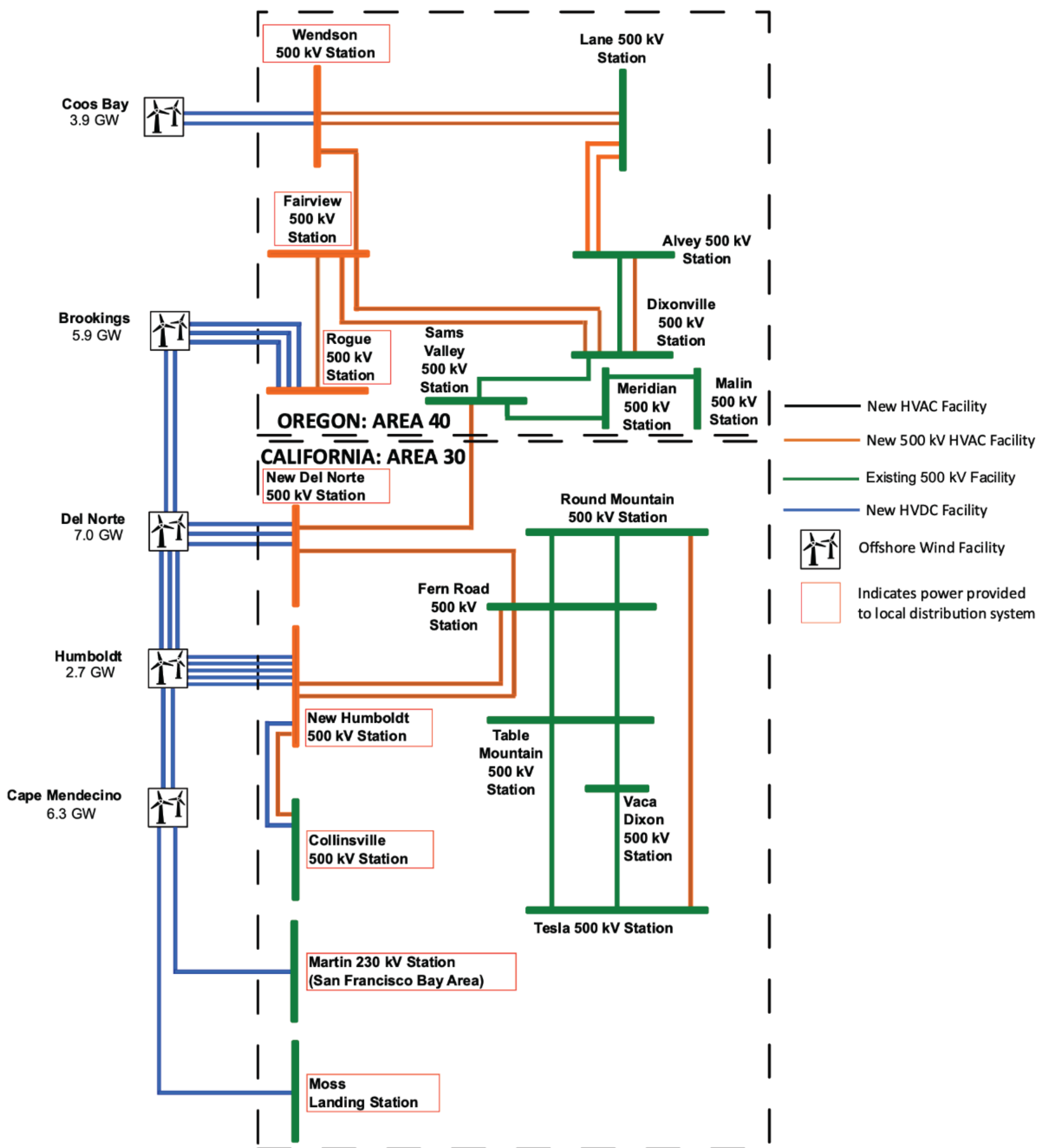

Figure E28 – Single Line Diagram for Transmission Alternative 25.8b.

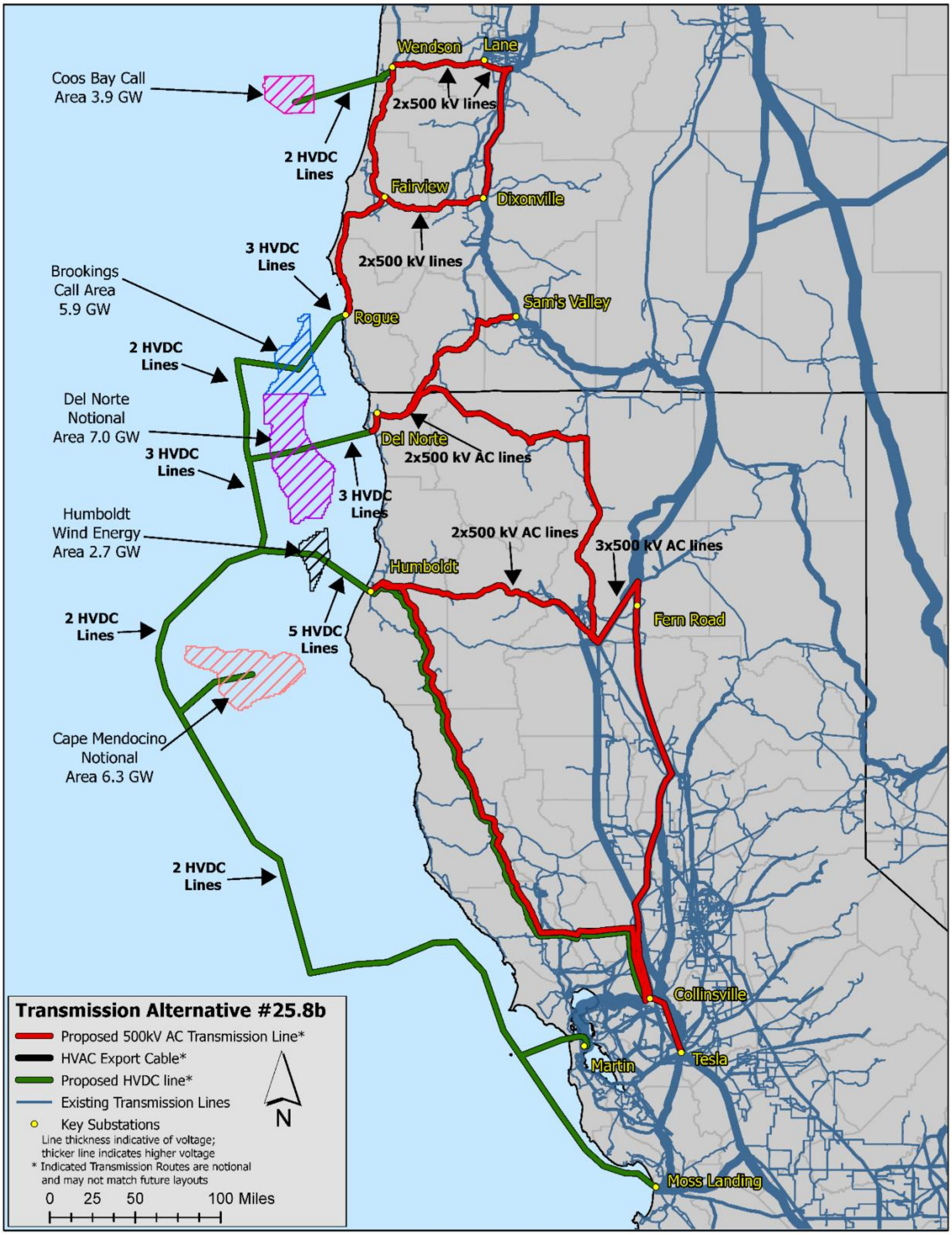

Figure E29 - Map for Transmission Alternative 25.8b.

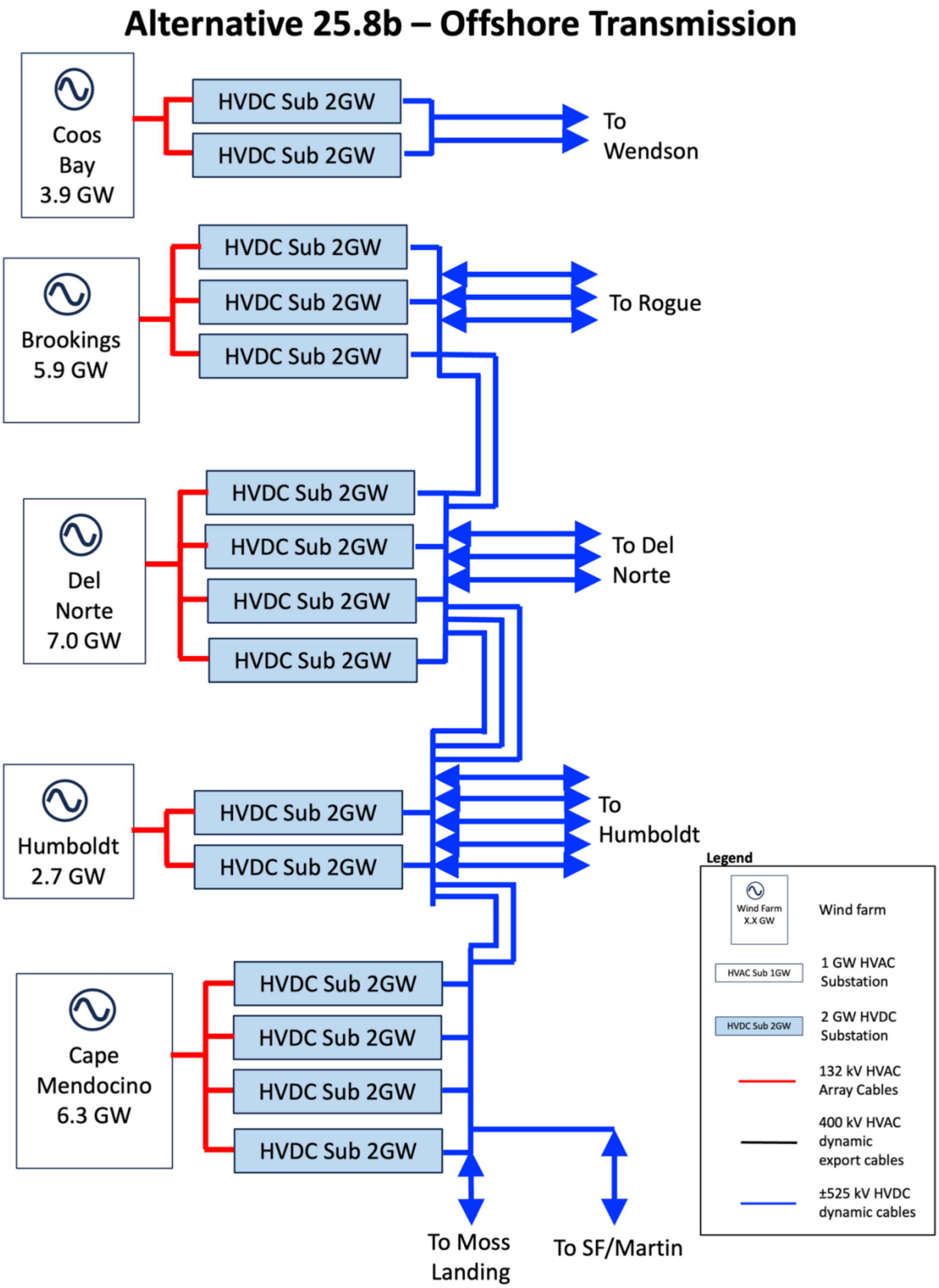

Figure E30 - Offshore Transmission Configuration for Transmission Alternative 25.8b. Note that the HVDC mesh network, floating HVDC conversion stations, and other technology elements are still in development. Offshore configurations may differ from what is shown here.

Appendix F: Transmission infrastructure environmental concerns and permitting analysis

(prepared by H. T. Harvey and Associates)

H. T. HARVEY & ASSOCIATES

Ecological Consultants

50 years of field notes, exploration, and excellence

Northern California/Southern Oregon Transmission Infrastructure: Environmental Concerns and Permitting Analysis

Project #4699-01

Prepared for:

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Prepared by:

H. T. Harvey & Associates

July 2023

Executive Summary

The overall goals and objectives of the Northern CA & Southern OR Mission Compatibility and Transmission Infrastructure Assessment Project (Project) are to develop a detailed technical analysis for transmission infrastructure limitations and opportunities, map existing transmission infrastructure, and provide technical data and assistance documents to State governments and renewable energy developers. To support this Project, we describe and evaluate the environmental and permitting/regulatory constraints for the transmission infrastructure alternatives. We identified potential high-level environmental concerns and key permitting/regulatory constraints associated with transmission infrastructure alternatives, including cable landings, subsea cable corridors, and transmission line corridors through land ownership or designation types (e.g., National Parks, Wild and Scenic Rivers, Marine Protected Areas), sensitive marine and terrestrial habitats, and potential for interactions with special-status plants and wildlife (e.g., Federal and State Endangered Species Acts). Based on severity of potential environmental interactions and ramifications for permitting, this information was used to screen, differentiate and compare the feasibility[1] of the alternatives.

Our evaluation of the segments (that comprise the potential transmission routes) was separated between terrestrial and subsea components; however the feasibility of the transmission alternatives as a whole requires considering the need for routes from the sea to connect to land, and be continuous. For each segment, we synthesized the potential high-level environmental concerns, identified high-level constraints, and rated the segments in terms of feasibility. If restrictive constraints to a segment were identified, we assessed how that would impact "downstream" interconnected segments, where appropriate. Note that the terrestrial transmission routes are notional and follow existing Rights-of-Way, and were analyzed assuming they consisted of overhead lines on towers, as opposed to underground lines.

We identified 9 segments that have numerous high-level constraints, and each of which have a potential "high" barrier to development. Of these 9, three of the segments have constraints that may be highly restrictive and therefore have a "very high" barrier to development. For these three segments, we discussed any interconnecting segments and alternative segments. Two of the segments start and end at the same interconnections and were rated as "high." Between these two, we made a recommendation as to which should be further evaluated, if only one were to move forward.

Seven segments were identified as having a "medium" barrier to development. For these segments, the number of high-level environmental concerns is average for the segments analyzed. The remaining 6 segments were rated as having a "low" barrier to development. All segments rated "medium" or "low" should continue to be analyzed in greater depth.

An in-depth analysis would be needed to further identify which transmission segments are feasible to permit and therefore could move toward development. The next phase of analysis should include any segments rated "low" or "medium" (Table 12). We also recommend segments 6, 7, 13, 14, 15, and 19, which had barriers that

1 Feasibility: capable of being accomplished in a successful manner within a reasonable period of time.

rated "high," be considered, because design considerations and potential avoidance and minimization measures could be incorporated, and may address these constraints sufficiently to support development.

A future analysis of terrestrial and subsea segments would go into greater detail and incorporate additional data, ideally with greater detail on transmission design. For example, any future analysis for subsea cable segments and subsequent routes would likely involve the use of additional existing geophysical information on the seabed and data on the abundance or presence of sensitive species and habitats, while ground truthing surveys for terrestrial segments could confirm potential habitat characteristics and presence of listed species and sensitive habitats. Terrestrial segment design must also identify greater detail on transmission towers and line spacing and height, and whether new parallel transmission lines would be developed versus upgrading or reconductoring existing lines. These would all have different, varying, degrees of impact on terrestrial habitats. For example, reconductoring would likely have far fewer potential impacts, and be easier to develop than new parallel transmission lines, which would likely require clearing new easements with more extensive habitat impacts. The specific design parameters would therefore be an important part of the terrestrial analysis, as some of the segments rated "high" may be easily developed if reconductoring or existing line upgrades are implemented. The locations and footprints of upgraded or new substations, and the location of interconnection of the subsea and terrestrial segments would need to be closely analyzed.

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Acronyms and Abbreviations

Basin Plans	Water Quality Control Basin Plans
BCDC	San Francisco Bay Conservation and Development Commission
BGEPA	Bald and Golden Eagle Protection Act
BIA	Biologically Important Area
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
CALVEG	California Vegetation
CSLC	California State Lands Commission
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
CEQA	California Environmental Quality Act
CNDDB	California Natural Diversity Database
CNPPA	California Native Plant Protection Act
DoD	Department of Defense
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESA	(Federal) Endangered Species Act
FAA	Federal Aviation Administration
FLMPA	Federal Land Policy and Management Act
FMP	Federal Fisheries Management Plan
GIS	Geographic Information System
GW	gigawatt
HAPC	Habitat Area of Particular Concern
Harbor District	Humboldt Bay Harbor, Recreation and Conservation District
IPaC	Information for Planning and Consultation
IS/MND	Initial Study/Mitigated Negative Declaration
LSAA	Lake or and Streambed Alteration Agreement
MBTA	Migratory Bird Treaty Act
MHHW	Mean higher-high water tide
MPA	Marine Protected Area
MMPA	Marine Mammal Protection Act
MOU	Memorandums of Understanding

MSA	Magnuson-Stevens Act
NEPA	National Environmental Policy Act
NF	National Forest
NHD	National Hydrography Dataset
NHPA	National Historic Preservation Act
NHRP	National Register of Historic Places
NISC	National Invasive Species Council
NMFS	National Marine Fisheries Service
NMS	National Marine Sanctuaries
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRA	National Recreation Area
NWI	National Wetlands Institute
OAR	Oregon Administrative Rules
OCS	Outer Continental Shelf
ODFW	Oregon Department of Fish and Wildlife
ORS	Oregon Removal Fill Law
OSW	offshore wind
PFMC	Pacific Fisheries Management Council
Project	Northern CA & Southern OR Mission Compatibility and Transmission Infrastructure Assessment Project
RWQCBs	California Regional Water Quality Control Boards
SERC	Schatz Energy Research Center
SMR	State Marine Reserve
SMCA	State Marine Conservation Area
SMRMA	State Marine Recreational Management Area
SP	State Park
USACE	U.S. Army Corps of Engineers
USDA	United States Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
WDRs	Water Discharge Requirements
WMA	Wildlife Management Area

1 Introduction

The overall goals and objectives of the Northern CA & Southern OR Mission Compatibility and Transmission Infrastructure Assessment Project (Project) are to develop a detailed technical analysis for transmission infrastructure limitations and opportunities, map existing transmission infrastructure and provide technical data and assistance documents to allow State governments and renewable energy developers ready access to information that identifies areas best suited for proposed offshore wind development. To support this Project, we evaluated and documented the environmental and permitting/regulatory constraints for transmission infrastructure alternatives by evaluating 22 distinct segments. The 22 *segments* (Figure 1) represent individual (line) components that collectively comprise potential transmission routes. The *transmission routes* are notional per the study and generally follow existing rights-of-way (ROW) corridors. *Transmission alternatives* consist of a collection of routes that are assembled to deliver power from the wind farms in each of the three wind generation *scenarios* considered in the study. Across the alternatives, there may be several routes made up of different combinations of segments between the same two points. The 22 segments analyzed herein represent three wind generation scenarios, and each scenario involves multiple wind farms. The first involves a 7.2 gigawatt (GW) "Low" offshore wind (OSW) development scenario from wind generation at wind farms in four different areas along the Oregon and California coasts. There are also alternatives from a 12.4 GW "Mid" OSW and 25.8 GW "High" development scenario. The 22 segments represent components of these transmission alternatives provided by Schatz Energy Research Center (SERC) at Cal Poly Humboldt.

The project area is defined by the transmission alternatives, and include 9 subsea segments, and 13 primarily terrestrial segments. The terrestrial segments follow existing transmission routes, but Right-of-Way widening may be required for some routes, and all segments may require additional temporary and/or permanent impacts in the areas for the development of the higher capacity transmission lines. In addition, depending on the ultimate suite of alternatives chosen, upgrades to existing substations, or new substations, may be required. Only overhead lines (for terrestrial segments) were considered for this analysis. We identified potential high-level environmental concerns and key permitting/regulatory constraints associated with transmission infrastructure alternatives, including cable landings, subsea cable corridors, and transmission line corridors through land ownership or designation types (e.g., National Parks, Wild and Scenic Rivers, Marine Protected Areas), sensitive marine and terrestrial habitats, and potential for interactions with special-status plants and wildlife (e.g., Federal and State Endangered Species Acts). This information was used to screen, differentiate and compare the feasibility[1] of the alternatives based on severity of potential environmental interactions and ramifications for permitting. It is also possible that widening the right of way may be required for certain terrestrial segments, but this was not considered in the analysis because we do not yet know which segments would require such work.

2 Methods

The approach used to analyze the 22 transmission segments involved mapping the segments and overlaying them with various spatial databases to identify potential areas of intersection (Figure 1, Table 1). The various spatial databases were overlaid with the transmission segments to identify areas that are best suited, in terms of limitations and opportunity, and most feasible[1] to support OSW development. The spatial databases cover three environmental topics, including special-status species, sensitive habitats and communities, and land ownerships/designations (Table 1). These environmental topics are referenced throughout this analysis and provide structure to our review and reporting process. A description of the environmental topics is discussed in more detail in the following subsections.

We identified whether each of the spatial datasets/various environmental topics intersected with the 22 segments. For the data sources related to species (e.g., listed species, critical habitat, biologically important areas), *intersection* was defined as contacting a 2.5-mile (mi) buffer on either side of the segments. For data sources that are stationary (e.g., fixed boundaries, including national parks and land use), no buffers were used and *intersection* was defined as direct contact between the spatial dataset and the segment itself. Together, this process/method made it possible to evaluate the feasibility of the alternatives by identifying the environmental concerns and permitting constraints associated with transmission infrastructure segments.

2.1 Special-Status Species

The special-status species covered in this assessment are those that are listed as threatened or endangered by either the Federal Endangered Species Act (ESA) of 1973, the California Endangered Species Act (CESA), or by the Oregon Department of Fish and Wildlife (ODFW), or fully protected by the California Fish and Game Code. The potential for occurrence of special-status plant and wildlife species along the transmission segments was analyzed using multiple data sources. The California Natural Diversity Database (CNDDB) was one data source used to identify the ESA-listed and CESA-listed species that may potentially occur along the California transmission alternatives and individual segments. CNDDB provides an inventory of the status and locations of rare plants and animals throughout California. The Information for Planning and Consultation (IPaC) is a United States Fish and Wildlife Service (USFWS) web-based tool designed to provide information to determine whether projects will have effects on federally listed species and/or their critical habitat, in addition to other USFWS sensitive resources. These data sources are referenced in Table 1.

Figure 1. Transmission Segments

Notes: Each number (bold and in white) is associated with a distinct segment, all of which constitute the transmission alternatives. Each segment is differentiated based on the color of the line. The shaded areas over the ocean represent designated, proposed, or hypothetical wind energy areas. The Humboldt Wind Energy Area off California has already been leased via the Bureau of Ocean Energy Management (BOEM). The proposed wind energy areas (Coos Bay and Brookings Call Areas off Oregon) may be leased by BOEM in the future. The hypothetical areas (Del Norte and Mendocino Areas off California) are potential locations for wind energy. The Transmission Routes (comprised of segments) are generally notional per the study, following existing Rights-of-Way Corridors, but may not represent final buildout and are subject to change.

Table 1. Environmental Topics Used to Evaluate Different Transmission Alternatives (and individual Segments), Including Examples and Sources

Evaluation Topic (Type of Data)	Data Source
Special-Status Species	
Federally Listed Species	CNDDB Maps and Data
Critical Habitat	USFWS Environmental Conservation Online System (IPaC) – Threatened & Endangered Species Active Critical Habitat Report (for species under USFWS jurisdiction) NOAA-NMFS Critical Habitat Mapper and GIS Data (for species under NMFS jurisdiction)
California State Listed Species	CNDDB Maps and Data, and CNDDB (2023)
Oregon State Listed Species	Oregon Department of Fish and Wildlife
Sensitive Habitats	
Wetlands and waterways	National Wetlands Inventory – Wetlands Data and Mapper
Sensitive Habitat Types	USDA Forest Service, Existing Vegetation Datasets CALVEG
Essential Fish Habitat	NOAA EFH Data Inventory – GIS Data for Essential Fish Habitat
Cetacean Biologically Important Areas	NOAA – Biologically Important Areas for Cetaceans within US Waters Dataset
Land Ownerships/Designations	
National Forest	USDA US Forest Service – Geospatial Data Discovery
National Parks, Monuments and Recreation Areas	NPS ArcGIS Data
State Parks and Beaches, Historic Parks and Natural Preserves	USGS National Boundary Dataset
Tribal Lands	US Census Bureau, Current Tribal Census Tract
U. S. Department of Defense Land	Homeland Infrastructure Foundation-Level Data – DoD Sites Boundaries Public
National Wildlife Refuge	USFWS National Realty Approved Acquisition Boundaries Dataset
Wild and Scenic Rivers	National Wild and Scenic Rivers System GIS Data – US Forest Service Geospatial Data Discovery
Marine Protected Areas	NOAA – The MPA Inventory: GIS Data
National Marine Sanctuaries	NOAA – National Marine Sanctuaries Geographic Information System Data

Notes: All data sources used for obtaining spatial files for mapping efforts are provided. Data sources are organized according to the appropriate environmental topic (environmental topics are the bolded terms in the first column).

Acronyms: California Natural Diversity Database (CNDDB); United States Fish and Wildlife Service (USFWS); National Oceanic and Atmospheric Administration (NOAA); National Marine Fisheries Service (NMFS); Geographic Information System (GIS); United States Department of Agriculture (USDA); California Vegetation (CALVEG); Essential Fish Habitat (EFH); National Park Service (NPS); United States Geological Survey (USGS); Department of Defense (DoD).

2.1.1 ESA-Listed Species and Critical Habitat

The Federal ESA of 1973, and subsequent amendments, provides regulations for the conservation of endangered and threatened species and the ecosystems on which they depend. The United States Fish and

Wildlife Service (USFWS) with jurisdiction over plants, wildlife, and resident fish) and National Marine Fisheries Service (NMFS) (with jurisdiction over anadromous fish and marine fish, mammals and sea turtles) oversee the implementation of the FESA. Section 7 mandates all federal agencies to consult with USFWS and NMFS if they determine that a proposed action or project may affect a listed species or its critical habitat. Under Section 7, the federal lead agency must obtain incidental take authorization or a letter of concurrence stating that the proposed Project is not likely to adversely affect federally listed species or their designated critical habitat.

Section 9 prohibits the take of any fish or wildlife species listed as endangered, including the destruction of habitat that prevents the species' recovery. *Take* is defined as any action or attempt to hunt, harm, harass, pursue, shoot, wound, capture, kill, trap, or collect a species. Section 9 prohibitions also apply to threatened species unless a special rule has been defined with regard to take at the time of listing. Under Section 9, the take prohibition applies only to wildlife and fish species; however, it prohibits the unlawful removal and possession, or malicious damage or destruction, of any endangered plant on federal land. Section 9 prohibits acts to remove, cut, dig up, damage, or destroy an endangered plant species in nonfederal areas in knowing violation of any state law or in the course of criminal trespass.

ESA listed-species, as defined by ESA 16 USC § 1531 et seq, include the following:

- Species listed as threatened or endangered under the federal ESA;
- Areas or communities identified as critical habitat under the federal ESA;
- Candidate species for listing as threatened or endangered under federal ESA; and
- Species proposed for listing as threatened or endangered under the federal ESA.
- While ESA listed-species include those that are candidates and proposed for listing, they were excluded from this review. Only those listed at the time of writing are considered.

2.1.1.1 Critical Habitat

Critical habitat is habitat required to support the recovery of species listed as threatened or endangered under the ESA. It can be designated by USFWS or NMFS: USFWS has jurisdiction over plants, wildlife and resident fishes, while NMFS has jurisdiction over anadromous and marine fish, mammals and sea turtles. The USFWS defines critical habitat as specific areas within the geographic area, occupied by the species during the time it was listed, that contain physical or biological features essential to its conservation (USFWS 2017). It can also contain areas not occupied by the species during the time of listing if it is essential to its conservation and if occupied areas alone are not enough to conserve the species (USFWS 2017). Critical habitat for species managed by NMFS is defined as specific areas within the geographical area occupied by the species at the time of listing that contain physical or biological features essential to their conservation and that may require special management considerations or protection, and specific areas outside the geographical area occupied by a species if the agency determines it is essential for conservation (NOAA 2022). While critical habitat may be established for threatened and/or endangered species, not all listed-species have designated critical habitat.

2.1.2 California ESA and Fully Protected Species

The CESA (CFGC Section 2050 et seq.) establishes state policy to conserve, protect, restore, and enhance threatened or endangered species and their habitats. CESA mandates that state agencies should not approve projects that jeopardize the continued existence of threatened or endangered species if reasonable and prudent alternatives are available that would avoid jeopardy. For projects that would affect a federal or state listed species, compliance with FESA satisfies the requirements of CESA if California Department of Fish and Wildlife (CDFW) determines that the federal incidental take authorization is consistent with CESA under CFGC Section 2080.1. If a project would result in take of a species that is only state listed, the project proponent must apply for a Section 2081(b) take permit from CDFW. CESA defines take as to hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill a CESA-listed species, but does not include harm or harass under FESA's definition of take. Take (or possession) of fully protected wildlife species is not allowed, except under narrow conditions discussed in Section 2.4.2.6.3. Most species fully protected by CDFW are also covered under FESA.

2.1.3 Oregon Department of Fish and Wildlife

Under State law the Oregon Fish and Wildlife Commission through the Department of Fish and Wildlife maintains a list of species determined to be either threatened or endangered according to OAR 635-100-0105. If a project would result in the take of a species that is only state listed, the project proponent may apply for a take permit. The Department of Fish and Wildlife may issue an incidental take permit if it is determined that such take will not adversely impact the long-term conservation of the species or its habitat.

2.2 Sensitive Habitats

Sensitive habitats are considered unique, provide specific living conditions, and thus are important for conservation. Sensitive habitats covered include Essential Fish Habitat (EFH), biologically important areas for cetaceans, wetlands and waters, and habitats such as old growth redwoods. Background on the types of special habitats and data sources used are described below.

2.2.1 Sensitive Land Cover Types

Habitats are considered sensitive if they have limited distribution, declining status, high species diversity, an unusual nature, or high productivity. Sensitive habitats also have high conservation value because the area provides physical or biological features essential to the establishment and continued existence of a species. Land cover types that represent sensitive habitats were identified along the transmission segment using U.S. Forest Service (USFS 2000 and 2007) mapping.

2.2.2 Wetlands and Waters

Any wetlands and waters that directly intersected the segments were identified. The National Wetland Inventory (NWI) data provides maps and information on the status, extent, characteristics, and functions of wetland, riparian, deepwater, and related aquatic habitats in priority areas to promote the understanding and conservation of those resources. The mapping is provided at a scale of 1:24,000 and uses the USFWS wetland definition, which differs from the three-parameter U.S. Army Corps of Engineers definition by requiring that only a single wetland parameter (hydrophytic vegetation, hydric soils, or wetland hydrology) be present to determine that an area is a wetland. The NWI mapping shows the extent of wetlands and deepwater habitats that can be determined by using remotely sensed data, and originates from 1977 to the present. Accordingly, the NWI mapping cannot be used to delineate wetlands and other waters of the United States, but it can provide useful background information on the broad types of wetland and riparian vegetation communities that occur in the area of interest. Wetlands and other waters that intersect with the transmission segments are potential waters of the United States and/or state subject to regulation under Section 404 and 401 of the Clean Water Act (USACE), the Porter-Cologne Water Quality Control Act (California Regional Water Quality Control Boards [RWQCBs]), and/or the Oregon Removal-Fill Law (OAR 196.000-196.692 and ORS 196.800-196.990). Mapping data for wetlands and other waters along the transmission segments were obtained from the NWI (NWI 2023). Stream crossing data for the transmission segments were derived from the National Hydrography Dataset (NHD) (USGS 2023). These data are available for general reference purposes and do not necessarily correspond to the actual presence or absence of jurisdictional waters or wetland.

2.2.3 Essential Fish Habitat

Essential Fish Habitat (EFH) is considered a type of sensitive habitat in this assessment. The Magnuson-Stevens Fishery Conservation and Management Act (MSA) established procedures designed to identify, conserve, and enhance EFH for those species regulated under a Federal Fisheries Management Plan (FMP). Under section 205(b) of MSA, federal agencies are required to consult with the Secretary of Commerce (represented on this issue by NMFS) on any actions that may adversely affect EFH. EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. 1802(10)). NMFS has further added the following interpretations to clarify this definition:

- "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate;
- "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities;
- "necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and
- "spawning, breeding, feeding, or growth to maturity" covers the full lifecycle of a species (50 CFR 600.10).

The Pacific Fisheries Management Council (PFMC) has designated EFH for four FMPs covering groundfish, coastal pelagic species, Pacific coast salmon, and highly migratory species.

Pacific Coast Groundfish EFH: EFH for Pacific coast groundfish is defined as the aquatic habitat necessary to allow groundfish production to support long-term sustainable fisheries for groundfish and for groundfish contributions to a healthy ecosystem. The northern California coast provides groundfish habitat from the nearshore mean higher-high water tide (MHHW) or the upstream extent of saltwater intrusion, to deep water areas (less than or equal to 3,500 meters) seaward to the boundary of the U.S. Exclusive Economic Zone (EEZ) (PFMC 2020). The groundfish FMP groups EFH into seven composite units, each of which represent a major habitat type. One of the seven components is estuarine EFH, defined as waters, substrates and associated biological communities in bays and estuaries of the U.S. Exclusive Economic Zone, from MHHW to the outer boundary of the estuary. The PFMC made more than 400 EFH designations for 83 groundfish species, and Pacific coast groundfish represent a large number of resident species along the U.S. West Coast. The PFMC further defined important habitat by species and life stage.

Coastal Pelagic EFH: Coastal pelagic species live in the water column and are found anywhere from the surface to 3,281 feet (1,000 meters) deep. The Coastal pelagic EFH covers and actively manages six species/species groups: Northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), California market squid (*Loligo opalescens*), and krill (PFMC 1998, 2021). The EFH for these species includes all marine and estuarine waters along the coast of northern California and offshore to the EEZ boundary line.

Pacific Coast Salmon EFH: EFH for the Pacific coast salmon fishery are waters and substrate necessary to support a long-term, sustainable salmon fishery. It includes all freshwater, estuarine, and marine habitats in and off Washington, Oregon, Idaho, and California, and marine waters off Alaska that are occupied by salmon stocks managed under this FMP. In the estuarine and marine environment, EFH for Pacific coast salmon extends from nearshore and tidal submerged environments in state waters to 200 nautical miles (370 kilometers) offshore (U.S. outer continental shelf). The geographic extent of freshwater EFH includes water bodies historically occupied by managed salmon. Pacific salmonids, including coho and Chinook salmon, as well as their prey species (Northern anchovy, Pacific sardine, and Pacific herring) are potentially present within the project area and covered under this EFH.

Highly Migratory Species EFH: Highly migratory species are pelagic fish species such as tunas, marlins, and sharks that occur worldwide and are highly mobile. They can be found in both the EEZ region out to 200 nautical miles (370 kilometers) from shore and the high seas.

2.2.3.1 EFH Conservation Areas

EFH conservation areas are designated areas that are defined by latitude and longitude coordinates, and are closed to specific types of fishing to minimize the adverse effects of fishing on EFH. Under the MSA, these conservation areas are required to be identified in FMPs and fishery managers must evaluate both fishing and non-fishing activities in them.

2.2.3.2 Habitat Areas of Particular Concern

Habitat Areas of Particular Concern (HAPC) are described as subsets of EFH, and are considered high priority regions for conservation, management or research (NOAA 2021a). HAPC designations do not provide additional protection nor restriction within the area, but help to prioritize conservation efforts. HAPCs are identified based on one or more of the following considerations:

- Importance of the ecological function provided by the habitat;
- Extent to which the habitat is sensitive to human-induced environmental degradation;
- Whether and to what extent development activities are, or will be stressing the habitat type; and
- The rarity of the habitat type.

HAPCs have been identified under the Pacific Coast Groundfish and Pacific Coast Salmon FMPs. Groundfish HAPCs include canopy kelp, seagrass, rocky reefs, and other discrete areas of interest (e.g., all seamounts off California, Mendocino Ridge, Cordell Bank, Monterey Canyon, and specific areas of Channel Islands National Marine Sanctuary and Cowcod Conservation Area; and Daisy Bank/Nelson Island, Thompson Seamount, and Jackson Seamount off Oregon). Salmon HAPCs include complex channels and floodplains, thermal refugia, spawning habitat, estuaries, and submerged aquatic vegetation in marine and estuarine regions.

2.2.4 Biologically Important Areas

Biologically Important Areas (BIA) for cetaceans are considered sensitive habitats. They are a tool specifically to assist in analyzing and minimizing impacts on cetaceans. BIAs are delineated to identify sites where they engage in key activities and/or populations concentrate for specific behaviors. They cover reproductive and feeding areas, migratory corridors, and small and resident populations (Calambokidis et al. 2015).

2.3 Land Ownership/Designations

Land ownership/designations are similar to special and sensitive habitats in the sense that they are intended to enhance conservation; however, they are less focused on habitat type. Land ownership/designations have fixed boundaries that are often linear. Spatial files for various designations were mapped. Since land ownership, use, and designations are stationary, direct intersection between the land-type and segment was extracted and used to evaluate and compare the various transmission scenarios.

2.3.1 National Forests

Under the National Forest Management Act, the U.S. Forest Service requires a special use permit application to evaluate the requests to use National Forest System lands, and must be consistent with the standards and guidelines in the applicable Land and Resource Management Plan.

2.3.2 National Parks, Monuments, and Reservations

Under the Organic Act of 1916, the National Park Service was created to manage the national parks and monuments then managed by the Department of Interior, and those yet to be established. The various categories of land within the National Park system are managed primarily for recreation and preservation. These include National Seashores, National Wild and Scenic Rivers, National Preserves, and National Gateway Parks. Development of transmission and related infrastructure through parks requires a special use permit, and is limited to findings by the National Park Service that there is no impairment to park resources and not incompatible with the public interest.

2.3.3 National Wildlife Refuges

The National Wildlife Refuge System was created by the National Wildlife Refuge Administration Act, and the refuges are managed by the U. S. Fish and Wildlife Service for the conservation of wildlife. Although wildlife conservation is the main criteria in refuge management, almost every other common use is allowed to some extent on refuges. Development of transmission and related infrastructure through refuges requires a special use permit, and is limited to compatible uses which will not materially interfere with or detract from the fulfillment of the National Wildlife Refuge System mission or purpose.

2.3.4 Tribal Lands

Federal tribes possess inherent sovereignty, have a government-to-government relationship with the United States, and have the right and authority to regulate activities on their respective lands. As such, any development within tribal lands must be closely coordinated with the tribe, and early communication, relationship building, and understanding the regulatory and cultural needs of the tribe are important.

2.3.5 California and Oregon State Parks

Both California and Oregon have state parks. The mission of these parks is to conserve and manage natural resources of each state. Any development in the state parks would require a use permit and comply with applicable state requirements.

2.3.6 Wild and Scenic Rivers

The National Wild and Scenic Rivers System was created to preserve certain rivers that have outstanding scenic, recreational, geologic, fish and wildlife, historic, and cultural values in a free-flowing condition. Federal agencies are barred from actions that would harm these values. California has a Wild and Scenic River Act that prohibits activities that could damage soil, water, timber, and habitat close to the designated river. State agencies are also prohibited from assisting or licensing facilities that could harm the wild and scenic values of a protected river. The Oregon Scenic Waterways Act enables federal, state, and local agencies, and landowners, to work together to protect and wisely use Oregon's special rivers.

2.3.7 Marine Protected Areas

In California State waters (offshore to 3 nautical miles), Marine Protected Areas (MPA[s]) are designated under the Marine Life Protection Act of 1999. The International Union for Conservation of Nature defines a protected area as "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature and associated ecosystem services and cultural values" (NOAA 2021b). MPAs can be reserved by Federal, State, territorial, tribal or local laws. MPAs are designed to protect and restore marine life (NOAA 2021b). State MPAs are subdivided into categories with differing fishing, boating, or access regulations and levels of protection, including State Marine Reserves (SMRs), State Marine Conservation Areas (SMCAs), State Marine Recreational Management Areas (SMRMAs), and Special Closures (CDFW 2023).

Federal MPAs vary in the level, permanence (permanent or conditional), consistency (year-round versus seasonal), and scale of protection (ecosystem versus focal resource) (NOAA 2020). U.S. MPAs also include national wildlife refuges.

In Oregon State waters (offshore to 3 nautical miles), there are five marine reserves and 9 MPAs. These 9 MPAs are adjacent to the marine reserves (ODFW 2023) and the removal of all marine life is prohibited. Ocean development is prohibited in the MPAs, although some fishing activities are allowed and there are specific rules for each site (ODFW 2023). ODFW oversees the management and monitoring of these marine reserves and MPAs.

2.3.8 National Marine Sanctuaries

National Marine Sanctuaries (NMS) have fixed boundaries, similar to MPAs. They are designated by the Secretary of Commerce under the National Marine Sanctuaries Act as "areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archaeological, educational, or esthetic qualities" (NOAA 2023).

2.4 Permitting

A summary of the potential federal and state permits, approvals or authorizations, agency consultations, regulatory requirements, is provided in Table 2 below. A brief description of select regulatory requirements follow. This is not an exhaustive list of regulatory requirements; but rather a list of those that may result in greater permitting challenges and that focus on biological resources. Other laws, such as the Clean Air Act, would be applicable for segments, and would not likely present same challenges as those requirements presented below. Not all laws and regulations will require associated permits for each segment. The potential resources along a segment, and the impacts to those resources, will guide the necessity for permitting. This synthesis is provided in the results section.

Table 2. Potentially Applicable Regulatory Requirements and Approving Agencies

Environmental Review Requirement	Approving/Lead Agency(ies)
National Environmental Policy Act	U.S. Bureau of Ocean Energy Management (offshore only)/U.S. Army Corps of Engineers
Section 401 of the Clean Water Act	U.S. Environmental Protection Agency California Regional Water Quality Control Board Oregon Department of Environmental Quality

Environmental Review Requirement	Approving/Lead Agency(ies)
Section 404 of the Clean Water Act, Section 10 of the Rivers and Harbors Appropriation Act of 1899	U.S. Army Corps of Engineers
Section 7 of the federal Endangered Species Act	U.S. Fish and Wildlife Service and National Marine Fisheries Service
National Marine Sanctuaries Act	NOAA Office of National Marine Sanctuaries
Oregon Removal-Fill Law (OAR 196.000-196.692 and ORS 196.800-196.990)	Oregon Department of State Lands
Magnuson-Stevens Fisheries Conservation and Management Act	National Marine Fisheries Service
Marine Mammal Protection Act	National Marine Fisheries Service
Migratory Bird Treaty Act	U.S. Fish and Wildlife Service
Bald and Golden Eagle Protection Act	U.S. Fish and Wildlife Service
California Environmental Quality Act	California State Lands Commission, California Public Utilities Commission, Local Agencies
Oregon Endangered Species Act	Oregon Department of Fish and Wildlife
California Endangered Species Act	California Department of Fish and Wildlife
California Fish and Game Code Section 1600 et seq.	California Department of Fish and Wildlife
California Coastal Act	California Coastal Commission, Local County and City Agencies
Coastal Zone Management Act	California Coastal Commission Oregon Department of Land Conservation and Development San Francisco Bay Conservation and Development Commission
Section 106 of National Historic Preservation Act	California Office of Historic Preservation Oregon State Historic Preservation Office
National Forest Management Act of 1976	U.S. Forest Service
Approval for Navigation Aids	U.S. Coast Guard
Obstruction Evaluation/Airport Airspace Analysis	Federal Aviation Administration
Federal Land Policy and Management Act of 1976	Bureau of Land Management
California Submerged Lands Act	California State Lands Commission
Ocean Shores Permit (Oregon Administrative Rules [OAR] 736-020	Oregon Parks and Recreation Department
Oregon Terrestrial Seas Easement for Fiberoptic and Other Cables (OAR 141-083)	Oregon Department of State Lands
Joint Permit Application (OAR 141-85)	Oregon Department of State Lands
Humboldt Bay Harbor, Recreation and Conservation Act	Humboldt Bay Harbor, Recreation and Conservation District
McAteer-Petris Act	San Francisco Bay Conservation and Development Commission

Notes: This table lists a selection of environmental regulatory requirements (and the associated regulatory agency) that may have to be considered for permitting feasibility. These requirements do not cover all that may be necessary. It represents a selection of statutes that focus on biological resources and present higher constraints.

2.4.1 Federal Statutes

The selection of federal statutes summarized below are related to biological resource and landownership or are statutes that present a higher level of challenges related to permitting.

2.4.1.1 National Environmental Policy Act

The National Environmental Policy Act (NEPA) was enacted on January 1, 1970. Under NEPA, significance is used to determine whether an environmental impact statement (EIS), or a lower level of documentation (i.e., Environmental Assessment/Finding of No Significant Impact), will be needed. NEPA requires that an EIS be prepared when the proposed federal action as a whole has the potential to significantly affect the quality of the human environment. The determination of significance is based on context and intensity. Under NEPA, once a decision is made regarding the need for an EIS, it is the magnitude of the effect that is evaluated and no judgment of its individual significance is deemed important for the text. Unlike the California Environmental Quality Act (CEQA), NEPA does not require that a determination of significant effects be stated in the environmental documents and does not require mitigation for those effects.

2.4.1.2 Executive Order 11990: Protection of Wetlands

Executive Order 11990, signed May 24, 1977, directs all federal agencies to refrain from assisting in or giving financial support to proposed actions that encroach on publicly or privately owned wetlands. It also requires that federal agencies support a policy to minimize the destruction, loss, or degradation of wetlands. A proposed action that encroaches on wetlands may not be undertaken unless the applicable federal agency has determined that: (1) there are no practicable alternatives to such construction; (2) the proposed action includes all practicable measures to minimize harm to wetlands that would be affected by its implementation; and (3) the impact will be minor.

2.4.1.3 Executive Order 12962: Recreational Fisheries

Executive Order 12962, signed June 7, 1995, and amended by Executive Order 13474 on September 26, 2008, directs all federal agencies to improve the quantity, function, sustainable productivity, and distribution of the nation's aquatic resources for increased recreational fishing opportunities—to the extent permitted by law and where practicable. This Executive Order requires evaluation and documentation of the effects caused by federally funded, permitted, or authorized actions on aquatic systems, fishing access, and recreational fisheries in NEPA analyses.

2.4.1.4 Executive Order 13112: Prevention and Control of Invasive Species

Executive Order 13112, signed February 3, 1999, directs all federal agencies to prevent and control the introduction of invasive species in a cost-effective and environmentally sound manner. The Executive Order established the National Invasive Species Council (NISC), which is composed of federal agencies and departments and a supporting Invasive Species Advisory Committee composed of state, local, and private entities. In July 2016, NISC published an updated national invasive species management plan that recommends objectives and measures to implement the Executive Order and to prevent the introduction and spread of invasive species. The Executive Order requires consideration of invasive species in NEPA analyses, including their identification and distribution, their potential impacts, and measures to prevent or eradicate them.

2.4.1.5 Clean Water Act

The CWA (33 USC 1344) addresses the issue of managing developments to improve, safeguard, and restore the quality of the nation's waters, including coastal waters, and to protect the natural resources and existing beneficial uses of those waters. For ocean waters, the EPA has Section 401 jurisdiction on the Outer Continental Shelf (OCS). Section 401 of the CWA requires that a Water Quality Certification be obtained from the state (or Territory) for actions that require a federal permit to conduct an activity, construction, or operation that may result in discharge to waters of the United States.

Section 404 of the CWA requires authorization for discharge of dredged or fill material into a wetland or other navigable water of the United States; USACE issues this permit. Authorization under Section 402 of the CWA would be required for ground-disturbing activities if those activities disturb more than 1 acre of land; this permit is also issued by USACE.

2.4.1.6 Rivers and Harbors Appropriation Act of 1899

The River and Harbors Appropriation Act of 1899 addresses activities that involve the construction outside established federal lines and excavate from or deposit material in such waters. These activities require permits from the applicable USACE District/s.

2.4.1.7 Coastal Zone Management Act

The Coastal Zone Management Act of 1972 created a partnership between state and federal agencies regarding the management of coastal resources. The Act enables states to implement coastal management programs that establish requirements for activities on coastal lands, and both California and Oregon have Coastal Management Programs. These programs identify the state agency responsible for reviewing consistency determinations, which are required for federal activities, development projects, and projects that would require the issuance of federal leases, permits, or licenses. In California, the agency is the California Coastal Commission; in Oregon it is the Oregon Coastal Management Program within the Department of Lands Conservation and Development.

2.4.1.8 National Marine Sanctuaries Act

The National Marine Sanctuaries Act directs the Secretary of Commerce to designate and manage nationally significant areas of the marine environment as national marine sanctuaries. Regulations safeguard resources within sanctuary boundaries and prohibit the conduct of some activities the NOAA Office of National Marine Sanctuaries can authorize special use permits. Activities including "the continued presence of commercial submarine cables or within the submerged lands of any national marine sanctuary," among others, may be eligible for special use permits (NOAA 2023b). The "lowering, laying, positioning, or raising any type of seabed cable or cable-laying device" is prohibited unless permitted (page 127 *in* NOAA 2023c).

2.4.1.9 Federal Endangered Species Act

The FESA of 1973, and subsequent amendments, provides regulations for the conservation of endangered and threatened species and the ecosystems on which they depend. The USFWS (with jurisdiction over plants, wildlife, and resident fish) and NMFS (with jurisdiction over anadromous fish and marine fish and mammals) oversee the implementation of the FESA. Section 7 mandates all federal agencies to consult with USFWS and NMFS if they determine that a proposed action or project may affect a listed species or its habitat. Under Section 7, the federal lead agency must obtain incidental take authorization or a letter of concurrence stating that the proposed project is not likely to adversely affect federally listed species.

Section 9 prohibits the take of any fish or wildlife species listed as endangered, including the destruction of habitat that prevents the species' recovery. *Take* is defined as any action or attempt to hunt, harm, harass, pursue, shoot, wound, capture, kill, trap, or collect a species. Section 9 prohibitions also apply to threatened species unless a special rule has been defined with regard to take at the time of listing. Under Section 9, the take prohibition applies only to wildlife and fish species; however, it prohibits the unlawful removal and possession, or malicious damage or destruction, of any endangered plant on federal land. Section 9 prohibits acts to remove, cut, dig up, damage, or destroy an endangered plant species in nonfederal areas in knowing violation of any state law or in the course of criminal trespass.

2.4.1.10 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Act requires federal agencies to consult with NMFS on all actions that may adversely affect EFH, which is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, and growth to maturity." An area within the designated EFH that is particularly important and/or sensitive is an HAPC. Regional Fishery Management Councils (e.g., PFMC), established under the Magnuson-Stevens Act, are responsible for preparing and amending fishery management plans (FMPs) for each fishery under their authority that requires conservation and management. Any federal action that might have an adverse effect on quality and/or quantity of EFHs is subject to consultation requirements with NMFS. Pursuant to the Magnuson-Stevens Act, EFH in the subsea cable segments have been designated for groundfish, salmon, highly migratory species, and coastal pelagic species, as well as HAPC for eelgrass, estuary, kelp forests, and rocky reefs.

2.4.1.11 Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) of 1972 prohibits, with certain exceptions, the "take" (defined under statute to include harassment) of marine mammals in the nation's waters and the high seas. In 1986, Congress amended both the MMPA, under the incidental take program, and the FESA to authorize incidental takings of depleted, endangered, or threatened marine mammals, provided the "taking" (defined under statute as actions which are or may be lethal, injurious, or harassing) was small in number and had a negligible impact on marine mammal populations.

Under MMPA Section 101(a)(5)(D), an Incidental Harassment Authorization can be granted by NMFS if it finds that the incidental "take" would have a negligible impact on the species or stock, or would not have an unmitigable adverse impact on the availability of the species or stock for subsistence uses (where applicable). NMFS has defined "negligible impact" as "an impact resulting from the specified activity that cannot be reasonably expected to, and would not be reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival." Incidental Harassment Authorizations include permissible methods of taking and requirements for mitigation and monitoring to ensure that takings result in the lowest practicable adverse impacts on affected marine mammal species or stocks.

2.4.1.12 Bald and Golden Eagle Protection Act

The Bald and Golden Eagle Protection Act (BGEPA) (16 USC 668–668c) was enacted in 1940 and prohibits the "taking" of bald or golden eagles, including their parts (e.g., feathers), nests, or eggs without a permit from the Secretary of the Interior. This regulation provides criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle [or any golden eagle], alive or dead, or any part, nest, or egg thereof."

2.4.1.13 Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA) (16 USC 703, Supp. I, 1989) prohibits killing, possessing, or trading in migratory birds except in accordance with regulations prescribed by the Secretary of the Interior. Under Executive Order 13186, "Responsibilities of Federal Agencies to Protect Migratory Birds," Federal agencies have been directed to take certain actions to further implement the MBTA. To this end, USFWS has entered into memorandums of understanding (MOUs) with over a dozen agencies. These MOUs, generally strengthen migratory bird conservation through enhanced collaboration and to work together to reduce negative impacts of resource development projects on migratory birds.

2.4.1.14 National Historic Preservation Act

A project authorized by BOEM and USACE must comply with Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (54 USC 300101). The NHPA sets forth national policy and procedures regarding cultural resources. Section 106 requires that every federal agency "take into account" how each of its undertakings could affect historic properties. Historic properties are districts, sites, buildings, structures, traditional cultural properties, and objects significant in American history, architecture, engineering, and culture that are included in or eligible for inclusion in the National Register of Historic Places (NRHP). To determine whether an undertaking could affect historic properties, cultural resources must be inventoried and evaluated for listing in the NRHP. Although compliance with Section 106 is the responsibility of the lead federal agency, others may undertake the work necessary to comply.

2.4.1.15 Obstruction Evaluation/Airport Airspace Analysis

The Federal Aviation Administration (FAA) oversees Title 14 of the Code of Federal Regulations Part 77: the prime objectives of the FAA are to promote air safety and the efficient use of the navigable airspace. To accomplish this mission, aeronautical studies are conducted based on information provided by proponents on an FAA Form 7460-1, Notice of Proposed Construction or Alteration, for any construction or alteration that is more than 200 ft (61 m) above ground level at its site.

2.4.1.16 National Forest Management Act

The USFS requires a special use permit application to evaluate the requests to use National Forest System lands and to manage those lands to protect natural resources, administer their use, and ensure public health and safety. This information is required to obtain or retain a benefit. The authority for that requirement is provided by the Organic Act of 1897 and the Federal Land Policy and Management Act of 1976, which authorize the Secretary of Agriculture to promulgate rules and regulations for authorizing and managing National Forest System lands. The USFS would use NEPA to determine if the transmission line upgrades require an amendment to existing regional Forest Plans.

2.4.2 California State Statutes

2.4.2.1 California Submerged Lands Act

The State Lands Commission (CSLC) has jurisdiction over all "sovereign lands," or lands held in trust by the State of California, including tidelands and submerged lands 3 miles off the coast. The CSLC has jurisdiction to dispose of or lease those lands, but must do so in accordance with California's Common Law Public Trust Doctrine. Permit applications are required for geological/geophysical surveys and leases, permits, or other entitlements for use of State lands require approvals from other public agencies, therefore the CSLC is the lead agency under CEQA.

2.4.2.2 California Environmental Quality Act

CEQA serves as the regulatory framework through which California public agencies assess, disclose, and mitigate significant environmental impacts. Impacts on biological resources are typically considered significant if they would substantially affect a rare or endangered species or the habitat of that species; substantially interfere with the movement of resident or migratory fish or wildlife; or substantially diminish habitat for fish, wildlife, or plants that would affect a population regionally. The CEQA Guidelines identify rare, threatened, and endangered species as those listed under the FESA or CESA, as well as species that meet the criteria of regulatory or local agencies (e.g., CDFW-designated SSC). If a project has the potential to result in significant effects on rare, threatened, or endangered species, the lead agency is required to prepare an Initial Study/Mitigated Negative Declaration (IS/MND) or an Environmental Impact Report (EIR) to fully analyze those impacts. The ultimate determination regarding the type of CEQA documentation is based on an evaluation of all potential project impacts, including impacts on non-biological resources.

2.4.2.3 California Native Plant Protection Act

The California Native Plant Protection Act (CNPPA), which was enacted in 1977, prohibits the importation of rare and endangered plants into California, take of rare and endangered plants, and sale of rare and endangered plants. The CESA defers to the CNPPA, which ensures that state-listed plant species are protected when state agencies are involved in projects subject to CEQA. In this case, plants listed as rare under the CNPPA are not protected under the CESA but instead under CEQA.

2.4.2.4 California Endangered Species Act

The CESA (CFGC Section 2050 et seq.) establishes state policy to conserve, protect, restore, and enhance threatened or endangered species and their habitats. CESA mandates that state agencies should not approve projects that jeopardize the continued existence of threatened or endangered species if reasonable and prudent alternatives are available that would avoid jeopardy. For projects that would affect a federally or state listed species, compliance with FESA satisfies the requirements of CESA if CDFW determines that the federal incidental take authorization is consistent with CESA under CFGC Section 2080.1. If a project would result in the take of a species that is only state listed, the project proponent must apply for a Section 2081(b) take permit from CDFW.

2.4.2.5 California Coastal Act

The California Coastal Act of 1976 requires any person proposing to undertake development in the Coastal Zone to obtain a Coastal Development Permit. The Coastal Zone extends inland anywhere from approximately 500 yards (457 m) in developed urban areas to 5 mi (8 km) in undeveloped areas. In addition, it provides for the transfer of permitting authority, with certain limitations reserved for the State, to local governments through adoption and certification of local coastal programs by the California Coastal Commission.

2.4.2.6 California Fish and Game Code

2.4.2.6.1 Lake or Streambed Alteration (Section 1600 et seq.)

CDFW regulates activities that would interfere with the natural flow of, or substantially alter the channel, bed, or bank of, a lake, river, or stream, including the disturbance of riparian vegetation under CFGC Sections 1600–1616. Project applicants must enter into a Lake or and Streambed Alteration Agreement (LSAA) from CDFW for these activities. The conditions and requirements of an approved LSAA are focused on the protection of the integrity of biological resources and water quality. Specific conditions that CDFW may require include avoiding or minimizing vegetation removal, using standard erosion control measures, limiting the use of heavy equipment, limiting work periods to avoid impacts on fisheries and wildlife resources, and restoring degraded sites or compensating for permanent habitat losses.

2.4.2.6.2 Protection of Birds and Raptors (Sections 3503 and 3503.5)

Section 3503 of the CFGC prohibits the killing of birds and destruction of their nests. Section 3503.5 prohibits killing of raptor species and destruction of raptor nests. Typical violations include the destruction of active bird and raptor nests caused by tree removal, and failure of nesting attempts (loss of eggs or young) as a result of disturbance of nesting pairs from nearby human activity.

2.4.2.6.3 Fully Protected Species (Sections 3511, 3513, 4700, and 5050)

CFGC Sections 3511, 3513, 4700, and 5050 apply to fully protected wildlife species (birds in Sections 3511 and 3513, mammals in Section 4700, and reptiles and amphibians in Section 5050) and strictly prohibit the take of these species. CDFW cannot issue a take permit for fully protected species, except under narrow conditions for scientific research or the protection of livestock, or if a Natural Community Conservation Plan has been adopted. Specifically, Section 3513 prohibits any take or possession of birds designated by the MBTA as migratory nongame birds except as allowed by federal rules and regulations pursuant to the MBTA.

2.4.2.7 Porter-Cologne Water Quality Control Act

The California Water Code addresses the full range of water issues in the state, known as the Porter-Cologne Water Quality Control Act (California Water Code Sections 13000–16104). Section 13260 requires "any person discharging waste, or proposing to discharge waste, in any region that could affect the waters of the state to file a report of discharge (an application for waste discharge requirements [WDRs])" with the appropriate RWQCB/s. Under this act, each of the nine RWQCBs must prepare and periodically update Water Quality Control Basin Plans (Basin Plans). Each Basin Plan sets forth water quality standards for surface water and groundwater, as well as actions to control non-point and point sources of pollution. Projects that affect waters of the state must meet the WDRs of the applicable RWQCB/s. Pursuant to CWA Section 401, an applicant for a Section 404 permit to conduct any activity that may result in discharge into navigable waters must provide a certification from the RWQCB/s that such discharge will comply with state water quality standards. Section 13050 of this act authorizes the State Water Board and the relevant RWQCB to regulate biological pollutants. The California Water Code generally regulates more substances contained in discharges and defines discharges to receiving waters more broadly than does the CWA.

2.4.2.8 California Public Resources Code

According to Section 21083.4 of the California Public Resource Code, a county is required "in determining whether CEQA requires an environmental impact report, negative declaration, or mitigated negative declaration, to determine whether a project in its jurisdiction may result in a conversion of oak woodlands that will have a significant effect on the environment, and would require the county, if it determines there may be a significant effect to oak woodlands, to require one or more of specified mitigation alternatives to mitigate the significant effect of the conversion of oak woodlands." If the applicable county governments determine that the transmission line upgrades may cause a substantial effect on oak woodlands in their jurisdictions, they will require mitigation alternatives to mitigate the significant effect of the conversion of oak woodlands.

2.4.3 Oregon State Laws

2.4.3.1 Ocean Shore Permit (Oregon Administrative Rules [OAR] 736-020

OAR 736-020 describes the permitting requirements that apply to applicants for permits to make improvements on the ocean shores, construct pipeline, cables or conduits across the ocean shore, or to remove products along the ocean shore. The rule implements ORS 390.605 and 390.690 to 390.770 to protect and preserve the scenic and recreational values and public rights in the ocean shore.

2.4.3.2 Oregon Terrestrial Seas Easement for Fiber optic and Other Cables (OAR 141-083)

OAR 141-083 governs the granting or renewal of easements for fiber optic and other cables on state-owned submerged and submersible land within the State territorial sea, and establishes a process for authority such easements. Any segment within the Oregon territorial sea would require such a permit.

2.4.3.3 Joint Permit Application (OAR 141-85)

OAR 141-85 prohibits fill or removal of material from waters of the State that may interference with the policy of the State to preserve the use of its waters for navigation, fish and public recreation uses; or is inconsistent with the protection, preservation and best use of waters of the State. The Joint Permit Application facilitates the coordination between the U. S. Army Corps of Engineers, Oregon Department of State Lands, and Oregon Department of Environmental Quality for review of removal or fill of wetlands and waters.

2.4.3.4 Oregon Endangered Species Act

Under State law the Oregon Fish and Wildlife Commission through the Department of Fish and Wildlife maintains a list of species determined to be either threatened or endangered according to OAR 635-100-0105. If a project would result in the take of a species that is only state listed, the project proponent may apply for a take permit. The Department of Fish and Wildlife may issue an incidental take permit if it is determined that such take will not adversely impact the long-term conservation of the species or its habitat.

2.4.4 Local Statutes

2.4.4.1 Humboldt Bay Harbor, Recreation and Conservation District Act

The Humboldt Bay Harbor, Recreation and Conservation District (Harbor District) Act empowers the board of commissioners to grant permits, franchises, and leases in areas including Humboldt Bay. In many cases, the Harbor District is also the lead agency for development projects with regard to compliance with the provisions of CEQA, and routinely works with other permitting agencies on the environmental assessment of proposed projects.

2.4.4.2 McAterr-Petris Act

The San Francisco Bay Conservation and Development Commission (BCDC), created prior to the California Coastal Act, retains oversight and planning responsibilities for development and conservation of coastal resources in the San Francisco Bay Area subject to tidal action up to the mean high tidal line, or a line five feet above mean sea level in marshlands. BCDC is specifically responsible for federal implementation of the Coastal

Zone Management Act within the limits of the San Francisco Bay. The area 100 feet inlands from the mean high tide is also within jurisdiction.

3 Results

This section begins with a summary of the special-status species from both terrestrial and marine habitats, followed by separate evaluations of the alternative terrestrial and subsea cable segments. Within each, a high-level overview of special-status species is provided, in addition to findings related to special habitats and land ownerships/designations. The terrestrial and subsea segment evaluations are separated because the information topics vary between terrestrial and marine ecosystems. In addition, there are different considerations for the terrestrial versus marine segments: the terrestrial segments follow pre-existing transmission route components or corridors, whereas the subsea cables are completely new. Lastly, there is a section on the required permits for each segment that are based on the land uses and potential resources present, along each segment.

3.1 Terrestrial Cable Transmission Segments

Several maps were created to visualize the potential alternatives and delineate considerations for the terrestrial transmission segments. The following maps can be referenced to visualize the alternatives and how they relate to various permitting and regulatory constraints:

- Terrestrial Critical Habitat (Figure 2), provides the geographic location of ESA-listed species' critical habitat;

- Land Use Designations along the Transmission Alternatives (Figure 3). This figure provides the geographic location of terrestrial national parks, monuments, recreations areas, wilderness areas and national forests; tribal lands; federal and state designated Wild and Scenic Rivers, and State Parks; and

- Anadromous Fish Critical Habitat (Figure 4), provides the geographic location of ESA-listed fish species' critical habitat in riverine systems.

3.1.1 Terrestrial Special-Status Species

Ground-disturbing activity, including tower pad preparation and construction, grading of new access roads, tower removal, and use or improvement of existing access roads, has the potential to disturb terrestrial wildlife species. In addition, helicopter construction would generate noise, vibration, dust, air turbulence, and visual disturbance.

A list of special-status wildlife species documented along any of the transmission alternatives (and individual segments) in California was compiled by conducting a search of the CNDDB. The query resulted in a list of wildlife species that are federally of state listed as endangered, threatened, or fully protected species by the CDFW that have been recorded within 2.5 miles of the segments. A list of federally threatened or endangered species potentially occurring in the project area in Oregon and California was also obtained from the IPaC online portal (USFWS 2023).

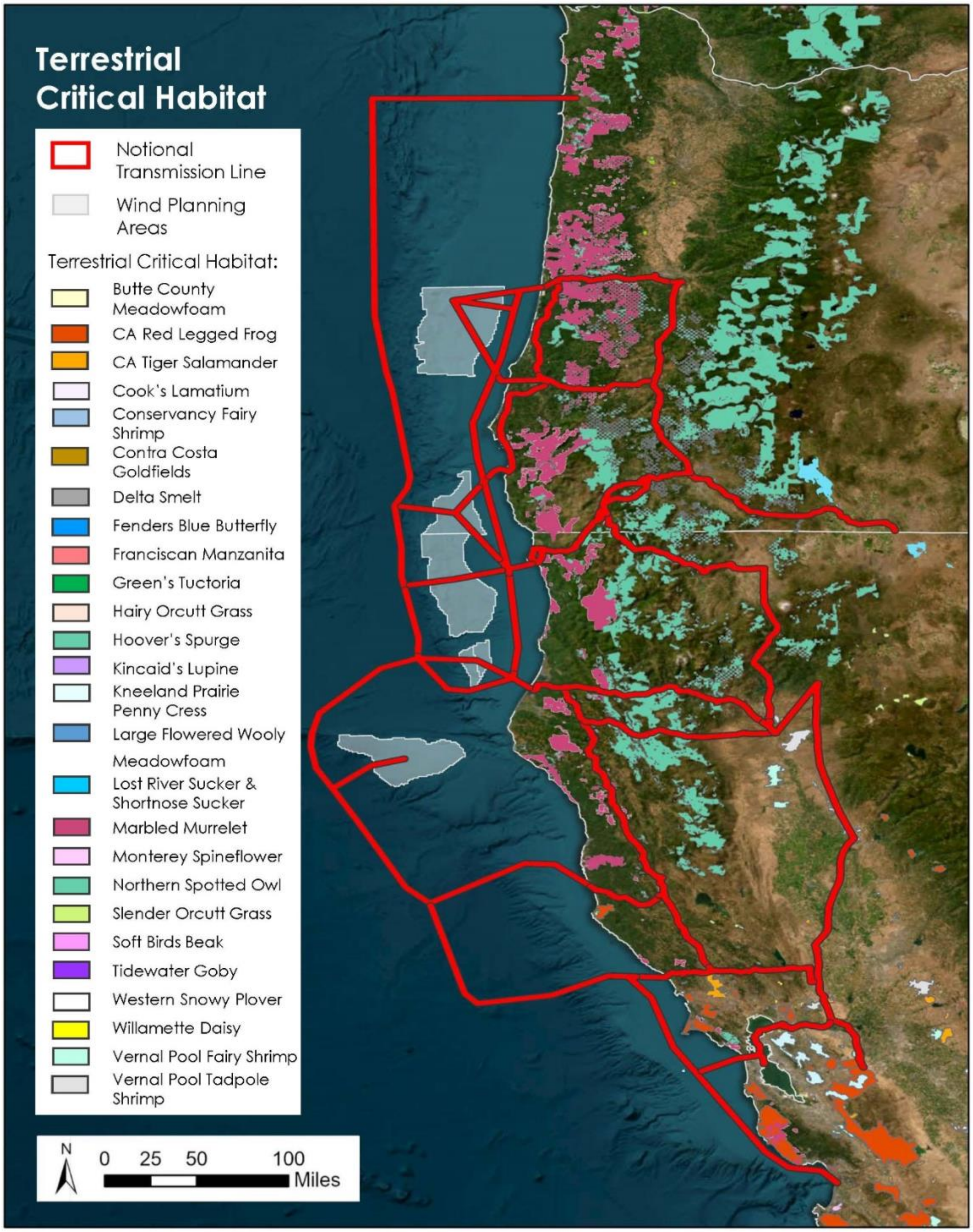

Figure 2. Critical Habitat – Terrestrial Species

Notes: This map provides a visualization of critical habitat, as defined under the Endangered Species Act (ESA), for all terrestrial ESA-listed species. Each color block corresponds to a different species. The red lines indicate the transmission line (including all the distinct segments) and the blocks offshore with diagonal lines represent the hypothetical, proposed, and established wind energy areas. The Transmission Routes (in red, comprised of segments) are notional per the study, generally following existing Rights-of-Way Corridors, but may not represent final buildout and are subject to change. Salmonids and other ESA-listed fishes with critical habitat (tidewater goby, green sturgeon and eulachon) are provided in Figure 4 and are covered in Section 3.2.

The special-status wildlife and plant species with potential to occur along the transmission segments, in addition to their listing status and habitat preferences, are provided in Table 3. A selection of these species have designated ESA-Critical Habitat intersecting with the terrestrial segments. These species have an asterisk next to their common name in Table 3 below. Figure 2 provides the geographic location of ESA-listed species' critical habitat. Note that salmonids are not included in Table 3, despite their presence in streams. All terrestrial segments intersect with salmonid EFH. More details related to salmonids are provided in the subsea cable sections. Other estuarine fishes are also covered in the subsea cable sections.

Table 3. Special-Status Species with Potential to Occur in the Terrestrial Cable Segments

Common Name	Scientific Name	Status	Habitat
Birds			
Marbled Murrelet*	*Brachyramphus marmoratus*	FT, SE, OR-SE	Near-shore marine waters, dense, old-growth forests.
Western Snowy Plover*	*Charadrius nivosus nivosus*	FT, OR-ST	Nearshore, sandy beaches, bays, estuaries, rivers.
Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*	FT, SE	Dense riparian deciduous forests.
Northern spotted owl*	*Strix occidentalis caurina*	FT, ST, OR-ST	Multilayered old-growth coniferous forest.
Bald eagle	*Haliaeetus leucocephalus*	SE, CDFW_FP	Undisturbed forest near bays, rivers, lakes.
Tricolored blackbird	*Agelaius tricolor*	ST	Wetlands, grasslands, riparian areas.
Bank swallow	*Riparia riparia*	ST	Cliffs, bluffs, riverbanks, lowland, riparian areas, grasslands, croplands.
Greater sandhill crane	*Grus canadensis tabida*	ST	Prairies, marshes, grasslands, agricultural fields, bogs, swales.
Willow flycatcher	*Empidonax traillii*	SE	Riparian areas, streams, wetlands, willow thickets, woodlands near water.
Swainson's hawk	*Buteo swainsoni*	ST	Grasslands, farmlands, riparian areas.
California black rail	*Laterallus jamaicensis coturniculus*	ST, CDFW_FP	Tidal marshes.
California Ridgway's rail	*Rallus obsoletus*	FE, SE	Marshland in the San Francisco Bay.
Mammals			
Humboldt marten	*Martes caurina humboldtensis*	FT, SE	Closed-canopy, mesic coniferous forest.
Wolverine	*Gulo gulo*	ST, OR-ST	High elevation forested or tundra habitats such as arctic, subarctic and alpine areas.
San Joaquin kit fox	*Vulpes macrotis mutica*	FE, ST, OR-ST	Grasslands/ grassy open areas with loose- textured sandy soils.

Common Name	Scientific Name	Status	Habitat
Salt- marsh harvest mouse	*Reithrodontomys raviventris*	FE, SE	Pickleweed marshes, brackish dikes marshes around San Francisco Bay Estuary/ Suisun Bay.
Canada lynx	*Lynx canadensis*	FT	Boreal spruce-fir forests and subalpine forests.
Gray wolf	*Canis lupis*	FE, SE	Adapted to a wide range of habitats such as temperate forests, mountains, tundra, taiga, grasslands and desert.
Pacific Marten Coastal DPS*	*Martes caurina*	FT	Mixed conifer coastal forests or forests with old growth characteristics such as multiple layers.
Reptiles and Amphibians			
California tiger salamander- Sonoma County DPS*	*Ambystoma californiense*	FE, ST	Seasonal wetlands, vernal pools in lowland and foothill grasslands.
California tiger salamander- central California DPS	*Ambystoma californiense*	FT, ST	Seasonal wetlands, vernal pools in lowland and foothill grasslands.
California red-legged frog*	*Rana draytonii*	FT	Streams, ponds, wetlands, riparian zones, forested areas.
Scott Bar salamander	*Plethodon asupak*	ST	Old-growth slopes in mixed evergreen forests in the Klamath Mountain Range.
Siskiyou Mountains salamander	*Plethodon stormi*	ST	Old-growth forest habitats in the Klamath Mountain Range.
Shasta salamander	*Hydromantes shastae*	ST	Temperate forests with rocky habitats, caves, springs within the cascade Range.
Foothill yellow-legged frog- north Sierra DPS/ Feather River DPS	*Rana boylii*	ST	Low gradient, rocky streams, rivers, riparian zones.
Giant gartersnake	*Thamnophis gigas*	FT, ST	Ponds, lakes, streams, marshes, sloughs, wetland areas.
San Francisco garter snake	*Thamnophis sirtalis tetrataenia*	FE, SE	Ponds, marshes, pools, canals with dense vegetation.
Oregon spotted frog	*Rana pretiosa*	FT	Large shallow wetland systems associated with a stream or stream network.
Invertebrates/Insects			
Vernal pool fairy shrimp*	*Branchinecta lynchi*	FT	Vernal pools, on-site seasonal wetlands.
Vernal pool tadpole shrimp*	*Lepidurus packardi*	FE	Vernal pools, swales, seasonal wetlands.

Common Name	Scientific Name	Status	Habitat
California freshwater shrimp	*Syncaris pacifica*	FE, SE	Low-elevation, low-gradient streams with woody debris.
Trinity bristle snail	*Monadenia setosa*	ST	Occurs in riparian corridors and upland conifer forests with deciduous understories.
Conservancy fairy shrimp*	*Branchinecta longiantenna*	FT	Vernal pools in California's Central Valley.
Fenders blue butterfly*	*Icaricia icarioides fender*	FT	Upland prairie and wet prairie habitats.
Franklin's bumble bee	*Bombus franklini*	FE	Grassy coastal prairies, coast range mountains, seeps, and other wet meadow environments.
Oregon silverspot butterfly	*Speyeria zerene hippolyta*	FT	Open grasslands in coastal dunes, bluffs and nearby glades with patches of its hostplant, the blue violet.
Taylor's checkerspot	*Euphydryas editha taylori*	FE	Prairie and grassland habitats, coastal bluffs, dunes, and small forest openings.
Fish			
Bull trout	*Salvelinus confluentus*	FT, OR-SE	Absent from California, but present in Oregon. Found primarily in cold, clean, complex and connected habitats in high mountainous areas with snowfields and glaciers. Primarily present in deep pools.
Lost river sucker*	*Deltistes luxatus*	FE, SE, OR-SE	Deeper water of lakes and reservoirs, and tributaries, within the upper Klamath River Basin.
Shortnose sucker*	*Chasmistes brevirostris*	FE, SE, OR-SE	Turbid, shallow, lakes that are cool, deeper water of lakes and reservoirs within the upper Klamath River Basin.
Tidewater Goby*	*Eucyclogobius newberryi*	FE	Found primarily in shallow lagoons, estuaries, and marshes at the intersection of freshwater tributaries where there is brackish water. Breeds in silt, muddy or rocky substrate.
Plants			
San Joaquin Valley Orcutt grass	*Orcuttia inaequalis*	FT, SE	Vernal pools.
Slender Orcutt grass*	*Orcuttia tenuis*	FT, SE	Vernal pools and wetlands.
Willamette daisy*	*Erigeron decumbens*	FE, OR-SE	Seasonally flooded prairies, well-drained upland prairies.

Common Name	Scientific Name	Status	Habitat
Kincaid's lupine*	*Lupinus oreganus*	FT, OR-ST	Seasonally-wet native prairies.
Cook's lomatium*	*Lomatium cookii*	FE, OR-SE	Vernal pools, seasonally-wet grassy meadow.
Monterey spineflower*	*Chorizanthe pungens*	FT	Chaparral, Cismontane woodlands, coastal dunes/ scrubland, foothill grasslands.
Large-flowered woolly meadowfoam*	*Limnanthes pumila ssp. Grandiflora*	FE, OR-SE	Vernal pools or swales within the Agate Desert region.
McDonald's rockcress	*Arabis macdonaldiana*	FE, SE, OR-SE	Serpentine, magnesium, silica, iron and nickel rich soils.
Western lily	*Lilium occidentale*	FE, SE, OR-SE	Coastal areas.
Yreka phlox	*Phlox hirsuta*	FE, SE	Dry, serpentine soils from 2,700 to 4,400 feet elevation.
Indian Valley brodiaea	*Brodiaea rosea*	SE	Open areas along drainages in chaparral/ conifer forests.
Menzies' wallflower	*Erysimum menziesii*	FE, SE	Coastal sand dunes.
Beach layia	*Layia carnosa*	FT, SE	Coastal sand dunes.
Roderick's fritillary	*Fritillaria roderickii*	SE	Coastal bluffs, prairies, valley and foothill grasslands.
North Coast semaphore grass	*Pleuropogon hooverianus*	ST	Shaded meadow openings within forests, woodlands with standing water.
Burke's goldfields	*Lasthenia burkei*	FE, SE	Vernal pools, swales.
Sonoma sunshine	*Blennosperma bakeri*	FE, SE	Vernal pools, wet grasslands.
Milo Baker's lupine	*Lupinus milo-bakeri*	ST	Small streams, roadsides, ditches.
Delta button-celery	*Eryngium racemosum*	SE	Vernal pools, wetlands.
Colusa grass	*Neostapfia colusana*	FT, SE	Vernal pools, alkaline basins.
Boggs Lake hedge-hyssop	*Gratiola heterosepala*	SE	Lakes, vernal pools.
Crampton's tuctoria or Solano grass	*Tuctoria mucronata*	FE, SE	Vernal pools with annual grasslands.
Butte County meadowfoam*	*Limnanthes floccosa ssp. Californica*	FE, SE	Vernal pools, swales.
Pitkin Marsh paintbrush	*Castilleja uliginosa*	SE	Riparian, marsh, bog, woodland, and grasslands.
Tidestrom's Lupine	*Lupinus tidestromii var. tidestromii*	FE, SE	Coastlines, sand dunes.
Vine Hill manzanita	*Arctostaphylos densiflora*	SE	Chaparral or shrub habitats, rocky ridges.
Vine Hill clarkia	*Clarkia imbricata*	FE, SE	Chaparral, valley grasslands, Sonoma Barrens.

Common Name	Scientific Name	Status	Habitat
Calistoga popcornflower	*Plagiobothrys strictus*	FE, ST	Hot springs, geysers, annual grasslands high in boron, arsenic, sulfates.
Sebastopol meadowfoam	*Limnanthes vinculans*	FE, SE	Vernal pools.
Clara Hunt's milk-vetch	*Astragalus claranus*	FE, SE	Grassland, blue oak/ manzanita woodlands with rocky, serpentine clay soils.
Many-flowered navarretia	*Navarretia leucocephala ssp. plieantha*	FE, SE	Vernal pools.
Pitkin Marsh lily	*Lilium pardalinum ssp. pitkinense*	FE, SE	Marsh wetlands, riparian habitats with sandy soils.
Monterey gilia	*Gilia tenuiflora ssp. arenaria*	FE, ST	Coastal dunes, inland maritime chaparral habitats.
White-rayed pentachaeta	*Pentachaeta bellidiflora*	FE, SE	San Mateo County in an area known as the "Triangle."
Marsh sandwort	*Arenaria paludicola*	FE, SE	Marshes, swamps, year-round wet areas.
Presidio manzanita	*Arctostaphylos montana ssp. ravenii*	FE, SE	Serpentine outcrops in maritime chaparral-coastal prairie plant communities.
Presidio clarkia	*Clarkia franciscana*	FE, SE	Serpentine soils in shady grassland, coastal scrub communities.
San Francisco lessingia	*Lessingia germanorum*	FE, SE	Highly-urbanized San Francisco peninsula.
Marin western (dwarf) flax	*Hesperolinon congestum*	FT, ST	Serpentine grasslands, bluffs, scrublands.
Antioch Dunes evening-primrose	*Oenothera deltoides ssp. howellii*	FE, SE	Pure sand habitats.
San Francisco popcorn flower	*Plagiobothrys diffusus*	SE	Moist areas/ seeps in coastal prairies/ valleys/ foothill grasslands.
Contra Costa wallflower	*Erysimum capitatum var. angustatum*	FE, SE	Sand dunes along the San Joaquin River.
Kneeland prairie penny-cress*	*Thlaspi californicum*	FE	Native coastal prairie on serpentine soil.
Contra Costa goldfields*	*Lasthenia conjugens*	FE, SE	Vernal pools in freshwater wetlands, valley grassland, and wetland-riparian communities.
Hoover's spurge*	*Chamaesyce hooveri*	FT	Vernal pools in freshwater wetlands, valley grassland, and wetland-riparian communities.
Hairy orcutt grass*	*Orcuttia Pilosa*	FE, SE	Vernal pools in freshwater wetlands, valley grassland, and wetland-riparian communities.

Common Name	Scientific Name	Status	Habitat
Greene's tuctoria*	*Tuctoria greenei*	FE	Vernal pools in freshwater wetlands, valley grassland, and wetland-riparian communities.
Franciscan manzanita*	*Arctostaphylos franciscana*	FE	Northern coastal scrub.
Soft bird's beak*	*Cordylanthus mollis ssp. mollis*	FE	Wetlands in coastal salt marsh and wetland-riparian communities.

Notes: The Status column summarized the federal and State listing statuses at the time of report writing.

Federal Status: Listing status under the federal Endangered Species Act. FE (endangered); FT (threatened).

California Status: Listing status under the California Endangered Species Act -S E (endangered); ST (threatened); California Department of Fish and Wildlife Fully Protected (CDFW_FP).

Oregon Status: Listing status under the Oregon Endangered Species Act – OR-S E (endangered); OR-ST (threatened).

Other table notes:

*: Indicates that Critical Habitat intersects with a segment.

DPS: Distinct population segment.

3.1.2 Terrestrial Sensitive Habitats and Communities

The ground disturbance that would occur during implementation of the transmission line upgrades and HDD activities would be the primary effect mechanism for sensitive natural communities. On the basis of the available data from CALVEG for California, 8 of the transmission line segments intersect with sensitive natural communities. Almost all the terrestrial overland segments with natural communities contain an oak woodland (blue oak woodland and valley oak woodland) while the more northern segments also contain redwood.

Wetland and riparian land cover types mapped in CALVEG along the overland transmission segments were also characterized (Table 4) as sensitive habitats because federal, state, and local agencies consider them important (e.g., for wildlife foraging). Oak woodlands are also designated as sensitive under Section 21083.4 of the California Public Resource Code. Old growth redwoods would also be considered sensitive under the California Public Resource Cods. Because the CALVEG data does not differentiate between young, and old growth, redwoods, all CALVEG redwood data was included in this analysis. The overland transmission segments may traverse additional areas of sensitive habitat that are subject to regulation. For example, riparian habitats associated with creeks and streams are typically claimed by CDFW under CFGC Section 1602 because they offer unique resources for wildlife. CDFW's jurisdiction typically extends to the top of bank or to the outer edge of the riparian tree canopy. Riparian habitats, waters, and wetlands could also be subject to Sections 404 and 401 of the Clean Water Act, and require federal and state (California or Oregon) permitting. Segment-specific analysis would be required to characterize and map these habitats.

Table 4. CALVEG Sensitive Natural Communities Identified along the Terrestrial Transmission Segments

Sensitive Natural Community Type	Segments
Redwood	3, 13, 14, 15, 16, 17, 19

Sensitive Natural Community Type	Segments
Blue Oak Woodland	12, 13, 14, 17, 18, 19, 21
Valley Oak Woodland	12, 13, 14, 17, 18, 19, 21
Riverine	3,12, 13, 14, 17, 18, 19, 20, 21
Lacustrine	3, 12, 13, 14, 16, 17, 18, 19, 20, 21
Estuarine	18, 20, 21
Montane Riparian	3, 12, 13, 14, 16, 17, 18, 19, 21
Valley Foothill Riparian	12, 13, 14, 17, 18, 19, 20, 21
Saline Emergent Wetland	3, 13, 14, 15, 18, 19, 20, 21
Fresh Emergent Wetland	18, 19, 20, 21

Notes: This table lists the sensitive natural community types from CALVEG (a spatial dataset containing information on existing vegetation) present along specific segments.

3.1.2.1 Wetlands and Waters

Wetlands and other waters in the terrestrial component of the Project area may be affected by ground disturbance if it results in hydrological interruption or the discharge of fill materials into aquatic resources. Runoff from construction areas (e.g., storm water, fuel, or motor oil) could also result in adverse effects on wetlands and other waters by degrading water quality. On the basis of the available data from NWI and NHD, the transmission line segments north of Cape Mendocino would result in relatively higher environmental effects on aquatic resources than south of Cape Mendocino. The nearshore areas of these segments, coupled with the topography north of Cape Mendocino contain a substantially greater number of potentially jurisdictional wetlands and waters subject to Clean Water Act Sections 404, 401, the Porter-Cologne Act, and the Oregon Removal-Fill Law. Wetland and water types identified along the segments are:

- Estuarine and marine deepwater
- Estuarine and Marine Wetlands
- Freshwater Ponds
- Freshwater Emergent Wetlands
- Freshwater Forested/Shrub Wetlands
- Riverine
- Freshwater Ponds
- Lakes

3.1.3 Terrestrial Land Ownership/Designations

Terrestrial land use designations identified include national parks, national recreation areas, national forests, tribal land, California or Oregon state parks, federal and State designated Wild and Scenic Rivers, and California

Coastal Zone. Five segments do not intersect with any of the identified land use designations (Figure 3). No federal land managed by the Bureau of Land Management (BLM) was intersected by any of the terrestrial segments, nor were any federally designated Wilderness Areas. Table 5 provides an overview of the land use designations by segment. Those that are highlighted in blue have no intersect with a land use designation; the majority of these segments are marine based, and land use designations and constraints are discussed in the subsea segments section.

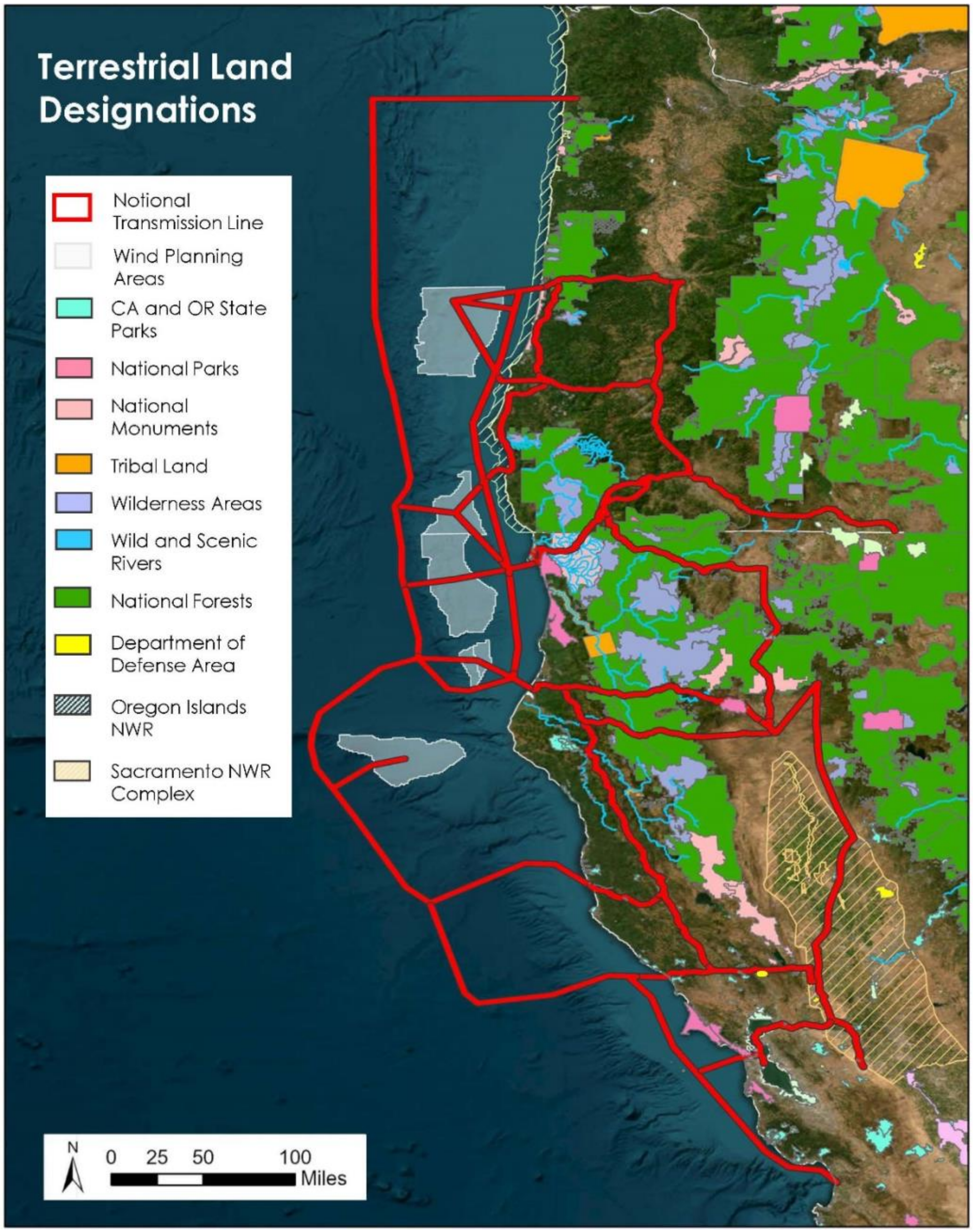

Figure 3. Terrestrial Land Designations

Notes: This map visualizes certain land ownerships and designations in terrestrial habitats. These designations have fixed boundaries that are often linear. Each color block represents a different designation. The Transmission Routes (in red, comprised of segments) are notional per the study, generally following existing Rights-of-Way Corridors, but may not represent final buildout and are subject to change. The white blocks offshore represent the hypothetical, proposed, and established wind energy areas. The white blocks offshore represent the hypothetical, proposed, and established wind energy areas. The Oregon Islands National Wildlife Refuge (NWR) includes thousands of rocks, reefs, islets and islands within three miles of the Oregon coastline. All pieces of offshore lands above the line of mean high tide are protected as part of the Oregon Islands National Wildlife Refuge NWR (and Oregon Islands Wilderness). Since many of these features are unnamed and unsurveyed, it is challenging to map their exact location. For this analysis, Oregon Islands NWR was mapped along the entire Oregon coastline; however, a finer scale and more detailed mapping effort would be required to visualize where the features of the NWR are located. Within the Sacramento NWR Complex, there are five NWR and three wilderness management areas (WMA). The layer mapped encompasses the boundary around all land designations within the larger Complex.

Table 5. Terrestrial Segment Land Designations

Segment	U.S. Department of Defense	National Park/National Seashore/ National Gateway Parks/ National Monument	National Recreation Area (NRA)	National Forest (NF)	CA Coastal Zone	State Park (SP)	Wild and Scenic Rivers (Federal or State)	Tribal Lands	USFWS Facilities (e.g., National Wildlife Refuges [NWR])	Notes
1										Primarily subsea
2				Siuslaw NF	Yes	Joaquin Miller SP		Yes	Oregon Islands NWR[1]	
3		Redwood National Park		Six Rivers NF Rogue River-Siskiyou NF	Yes	Del Norte Coast Redwoods SP Jedediah Smith Redwoods SP Tolowa Dunes SP Rough and Ready State Natural Site Illinois River Forks SP	Smith River, California Illinois River, Oregon	Yes		Jedediah Smith Redwoods SP contains state wilderness area
4				Siuslaw NF		William M. Tugman SP	Elk River, Oregon	Yes		
5					Yes				Oregon Islands NWR	Primarily subsea
6					Yes			Yes	Oregon Islands NWR	
7					Yes	Humbug Mountain SP Geisel Monument State Heritage Site		Yes	Oregon Islands NWR	
8										Primarily subsea
9										Primarily subsea
10										Primarily subsea
11										Primarily subsea
12				Klamath NF Shasta-Trinity NF Rogue River-Siskiyou NF		Castle Crags SP	Klamath River, California	Yes		
13			Whiskeytown-Shasta-Trinity NRA	Six Rivers NF Shasta-Trinity NF	Yes		Trinity River, California	Yes	Humboldt Bay NWR	
14					Yes	Grizzly Creek Redwoods SP	Trinity River, California	Yes	Humboldt Bay NWR	
15					Yes				Humboldt Bay NWR	Primarily subsea
16					Yes			Yes		
17								Yes		
18				Lassen NF Shasta-Trinity NF Mendocino NF	Yes	Bethany Reservoir SP		Yes	Sacramento NWR Complex[2]	
19					Yes	Sugarloaf Ridge SP Sonoma Coast SP			N Sacramento NWR Complex	
20					Yes	Moss Landing SB				Primarily subsea

Segment	U.S. Department of Defense	National Park/National Seashore/ National Gateway Parks/ National Monument	National Recreation Area (NRA)	National Forest (NF)	CA Coastal Zone	State Park (SP)	Wild and Scenic Rivers (Federal or State)	Tribal Lands	USFWS Facilities (e.g., National Wildlife Refuges [NWR])	Notes
21	Military Ocean Terminal Concord		Golden Gate NRA		Yes				Sacramento NWR Complex	Primarily subsea
22							Jenny Creek, Oregon			

Notes: This table lists the specific land use designations that intersect with each of the 22 segments. Visualizations of where and the extent to which these segments intersect with a particular land use designation are provided in Figure 3.

[1] – The Oregon Islands National Wildlife Refuge (NWR) includes thousands of rocks, reefs, islets and islands within three miles of the Oregon coastline. All pieces of offshore lands above the line of mean high tide are protected as part of the Oregon Islands NWR (and Oregon Islands Wilderness). Since many of these features are unnamed and unsurveyed, it is challenging to map their exact location. For this analysis, segments noted to intersect with the Oregon Islands NWR intersect with the 3-mile boundary of the Oregon coastline, and may potentially intersect with specific features. A finer scale and more detailed mapping effort would be required to determine the segments that intersect with specific features within the broader region.

[2] – Sacramento NWR Complex encompasses five NWR and three wilderness management areas (WMA). The layer mapped includes the boundary around all land designations within the larger Complex. A finer scale and more detailed mapping effort would be required to determine the segments that intersect with specific land designations within the Complex.

3.1.4 Terrestrial Results Summary

A summary of all the evaluation topics reviewed in analyzing the feasibility of the terrestrial segments is provided in Table 6. This table is high-level, and further detail on the topics marked as intersecting with a given segment can be looked into in greater detail by reviewing the previous subsections and Figures 2 and 3.

Table 6. Summary of Key Environmental Topics by Segment Focused on Terrestrial Segments

Segment	Special-Status Species	Species with Critical Habitat	Special Habitats	Federal Lands	Tribal Lands	Wild/ Scenic Rivers	State Parks	Notes
1		X	X					Primarily subsea
2		X	X	X	X		X	
3	X	X	X	X	X	X	X	
4		X	X	X	X	X	X	
5	X	X						Primarily subsea
6		X	X		X			
7		X	X		X		X	
8								Primarily subsea
9								Primarily subsea
10								Primarily subsea
11								Primarily subsea
12	X	X	X	X	X	X	X	
13	X	X	X	X	X	X		
14	X	X	X	X	X	X		
15	X	X	X					Primarily subsea
16	X	X	X					
17	X	X	X		X			
18	X	X	X	X	X	X	X	
19	X	X	X			X	X	
20	X	X	X			X	X	Primarily subsea
21	X	X	X	X		X		Primarily subsea
22		X	X					

Notes: This table provides a high-level overview of the environmental topics that intersect with each of the 22 segments. Each segment is represented by a different row, and the numerical segment in the first column corresponds to the segments in Figure 1. Each column (besides the *Segment* column) represents a given environmental topic and spatial dataset. Cells highlighted in grey with an "X" in the cell indicate that the given environmental topic (representing a distinct spatial dataset) intersects with the segment. All federal lands, including U.S. Department of Defense, National Parks, Forests, Recreation Areas, Wildlife Refuges and Wildlife Management Areas are compiled together in the Federal Lands column.

3.2 Subsea Cable Segments

3.2.1 Marine Special-Status Species

A total of 31 special-status species have potential to overlap with the subsea cable portion of the transmission segments in either bay, estuarine, or marine habitats. These include one invertebrate, 9 species of fishes, 7 birds, 11 marine mammals and three marine reptiles. The listing status, preferred habitat, and relevant notes for each species are provided in Table 7. Those with ESA-Critical Habitat intersecting with the subsea segments have an asterisk next to their common name (Figures 4 and 5).

Table 7. Special-Status Species with Potential to Occur in the Subsea Cable Segments

Common Name	Scientific Name	Status	Habitat	Notes
Invertebrates				
Black abalone*	*Haliotis cracherodii*	FE	Rocky intertidal and subtidal reefs.	
Fish				
Coho Salmon*				
Southern Oregon-Northern California Coastal ESU	*Oncorhynchus kisutch*	FT, ST	Adults use marine waters to feed and grow, in preparation for their upstream spawning migration. Adults transit through bays and estuaries on their upstream spawning migration, and smolts do so on their seaward migration.	
Central California Coast ESU		FE, SE	Same habitat as above	
Oregon Coast ESU		FT	Same habitat as above	
Lower Columbia River ESU		FT, OR-E	Same habitat as above	
Chinook Salmon*				
Sacramento River winter-run ESU	*Oncorhynchus tshawytscha*	FE, SE	Adults use marine waters to feed and grow, in preparation for their upstream spawning migration. Adults transit through bays and estuaries on their upstream spawning migration, and smolts do so on their seaward migration. Exact spawning locations differ between each ESU.	
Central Valley spring-run ESU		FT, ST	Same habitat as above	
California coastal ESU		FT	Same habitat as above	
Upper Klamath and Trinity Rivers ESU		ST	Same habitat as above	

Common Name	Scientific Name	Status	Habitat	Notes
Upper Willamette River ESU		FT	Same habitat as above	
Snake River ESU, fall and spring/summer run		FT, OR-ST	Same habitat as above	
Steelhead*				
Northern California DPS (summer-run)	*Oncorhynchus mykiss irideus*	FT, SE	Anadromous. Adults use marine waters to grow and return to freshwater to spawn in gravel-bottomed, fast-flowing rivers and streams. Adults migrate through bays and estuaries on their upstream migration.	
Northern California DPS (winter-run)		FT	Same habitat as above	
Central Valley DPS			Same habitat as above	
Central Coast DPS			Same habitat as above	
Green Sturgeon Southern DPS*	*Acipenser medirostris*	FT	Anadromous. Spawn and rear in rivers, and migrate to saltwater to feed, grow and mature.	
Delta Smelt*	*Hypomesus transpacificus*	FT, SE	Found only in the San Francisco Bay Estuary. Spawns in freshwater, tidally influenced backwater sloughs and channel edgewaters.	
Longfin Smelt	*Spirinchus thaleichthys*	ST	Adults spawn and larvae rear in lower reaches of coastal rivers, brackish water estuaries, and marshes. Individuals become increasingly tolerant of higher salinity as they age, moving into coastal waters.	The San Francisco Bay Estuary DPS is proposed for listing under ESA.
Eulachon*	*Thaleichthys pacificus*	FT	Anadromous, spending 95% of their time in marine waters, and	

Common Name	Scientific Name	Status	Habitat	Notes
			returning to natal grounds in lower reaches of coastal rivers for spawning.	
Tidewater Goby*	*Eucyclogobius newberryi*	FE	Found primarily in shallow lagoons, estuaries, and marshes at the intersection of freshwater tributaries where there is brackish water. Breeds in silt, muddy or rocky substrate.	
Bull trout	*Salvelinus confluentus*	FT	Absent from California, but present in Oregon. Found primarily in cold, clean, complex and connected habitats in high mountainous areas with snowfields and glaciers. Primarily present in deep pools.	
Birds				
Black-footed albatross	*Phoebastria nigripes*	CDFW_FP	Pelagic habitats throughout the North Pacific, including along the edges of the continental shelf.	
Short-tailed albatross	*Phoebastria albatrus*	FE, OR-SE	Pelagic; spend most of their lives at sea, returning to their nesting grounds only for breeding, but no nesting occurs in the U.S.	
Hawaiian petrel	*Pterodroma sandwichensis*	FE	Highly migratory over pelagic waters. Nests in remote locations outside of the continental U.S. West Coast.	
Brown pelican	*Pelecanus occidentalis californicus*	CDFW_FP, OR-E	Non-breeding individuals are distributed throughout estuarine, marine, subtidal, and marine pelagic waters.	

Common Name	Scientific Name	Status	Habitat	Notes
American peregrine falcon	*Falco peregrinus anatum*	CDFW_FP	Occurs in nearshore environments and open waters nearshore, and open country.	
Marbled murrelet*	*Brachyramphus marmoratus*	FT, SE, OR-SE	Lower montane coniferous forest, old growth Redwood; feeds nearshore and nests in old-growth redwood-dominated forests, up to six miles inland, often in Douglas-fir; Can also be found drifting into offshore habitats.	
Scripps's and Guadalupe murrelet	*Synthliboramphus hypoleucus/scrippsi* and *Synthilobramphus hypoleucus*	ST	Pelagic; no breeding nearby.	
Marine Mammals[1]				
Cetaceans				
Blue whale	*Balaenoptera musculus*	FE, OR-SE	Offshore and along the continental shelf break near productive coastal upwelling features; occasionally inshore.	*BIAs:* There are 9 feeding area BIAs along the U.S. West Coast. Three of which overlap with the project area. These include waters between Point Arena and Fort Bragg (primary occurrence in August to November), Gulf of the Farallones (primary occurrence in July to November), and Monterey to Pescadero (between July and October).
Fin whale	*Balaenoptera physalus*	FE, OR-SE	Continental slope and occasionally nearshore; Occur in nearshore and pelagic waters in temperate and subpolar oceans.	*BIAs:* None designated because of limiting and/or conflicting information; however, they would likely occur in regions of peak predicted mean density, some of which overlap with the project area.

Common Name	Scientific Name	Status	Habitat	Notes
Sei whale	Balaenoptera borealis	FE, OR-SE	Continental shelf and slope species	
Humpback whale*	Megaptera novaeangliae	FT or FE, depending on the DPS, OR-SE	Highly migratory, preferring nearshore and continental shelf habitats.	*BIAs*: There are 7 designated feeding BIAs along the U.S. West Coast. These include waters between the Gulf of the Farallones and Monterey Bay (July to November), Fort Bragg to Point Arena (July to November), and Point St. George (July to November)
North Pacific right whale	*Eubalaena japonica*	FE, OR-SE	Generally scarce throughout its range, and highly pelagic.	
Sperm whale	*Physeter macrocephalus*	FE, OR-SE	Highly pelagic, but potentially present along the continental shelf.	
Killer whale* (Southern Resident DPS)	*Orcinus orca*	FE	Primarily found along the continental shelf.	
Gray whale (Eastern North Pacific DPS)	*Eschrichtius robustus*	OR-SE	Primarily found nearshore and along the continental shelf.	*BIAs*: There are 6 designated feeding BIAs along the U.S. West Coast. Excluding the ones in Washington, these include Depoe Bay, Cape Blanco and Orford Reef in Oregon (June to November) and Point St. George, California (June to November). Migratory BIAs also exist for gray whales along the entire coast, extending between 5 and 10 kilometers offshore depending on the phase of migration.
Pinnipeds and mustelids				
Southern sea otter	*Enhydra lutris nereis*	FT, CDFW_FP, OR-ST (Northern sea otter)	Nearshore, shallow coastal waters; affinity for kelp forests; Range does not extend north of San Francisco Bay.	

Common Name	Scientific Name	Status	Habitat	Notes
Guadalupe fur seal	*Arctocephalus townsendi*	FT, ST, CDFW_FP	Oceanic and continental slope species; Forage along the continental shelf seasonally; Rarely seen north of Sonoma County.	
Northern elephant seal	*Callorhinus irsinus*	CDFW_FP	Oceanic and continental slope; Migrate 4x annually; Breeding and molting occurs at Ano Nuevo (southern part of the project area).	
Marine Reptiles				
Loggerhead sea turtle (North Pacific DPS)	*Caretta caretta*	FE, OR-ST	Primarily found in subtropical and temperate waters. Rare and generally out of range.	
Green sea turtle (East Pacific DPS)	*Chelonia mydas*	FT, OR-SE	Migratory as adults, but hatch in coastal regions and forage in nearshore, shallow coastal habitats. Rare and generally out of range.	
Leatherback sea turtle (Western Pacific DPS)*	*Dermochelys coriacea*	FE, OR-SE	Highly pelagic and migratory. Hatch in coastal regions. Rare, but the most likely to occur of all marine reptiles.	

Notes: The Status column summarized the federal and State listing statuses at the time of report writing.

Federal Status: Listing status under the federal Endangered Species Act. FE (endangered); FT (threatened).

California Status: Listing status under the California Endangered Species Act -S E (endangered); ST (threatened); California Department of Fish and Wildlife Fully Protected (CDFW_FP).

Oregon Status: Listing status under the Oregon Endangered Species Act – OR-S E (endangered); OR-ST (threatened).

Other table notes:

1: All marine mammals are protected by the national Marine Mammal Protection Act;

*: Indicates that Critical Habitat intersects with a segment;

DPS: Distinct population segment; ESU: Evolutionarily significant unit;

BIA: Biologically important areas are locations delineated to identify sites where cetaceans engage in activities at certain times of the year that are crucial for the health and fitness of individuals, and the fecundity and survivorship of the larger population (Calambokidis et al. 2015).

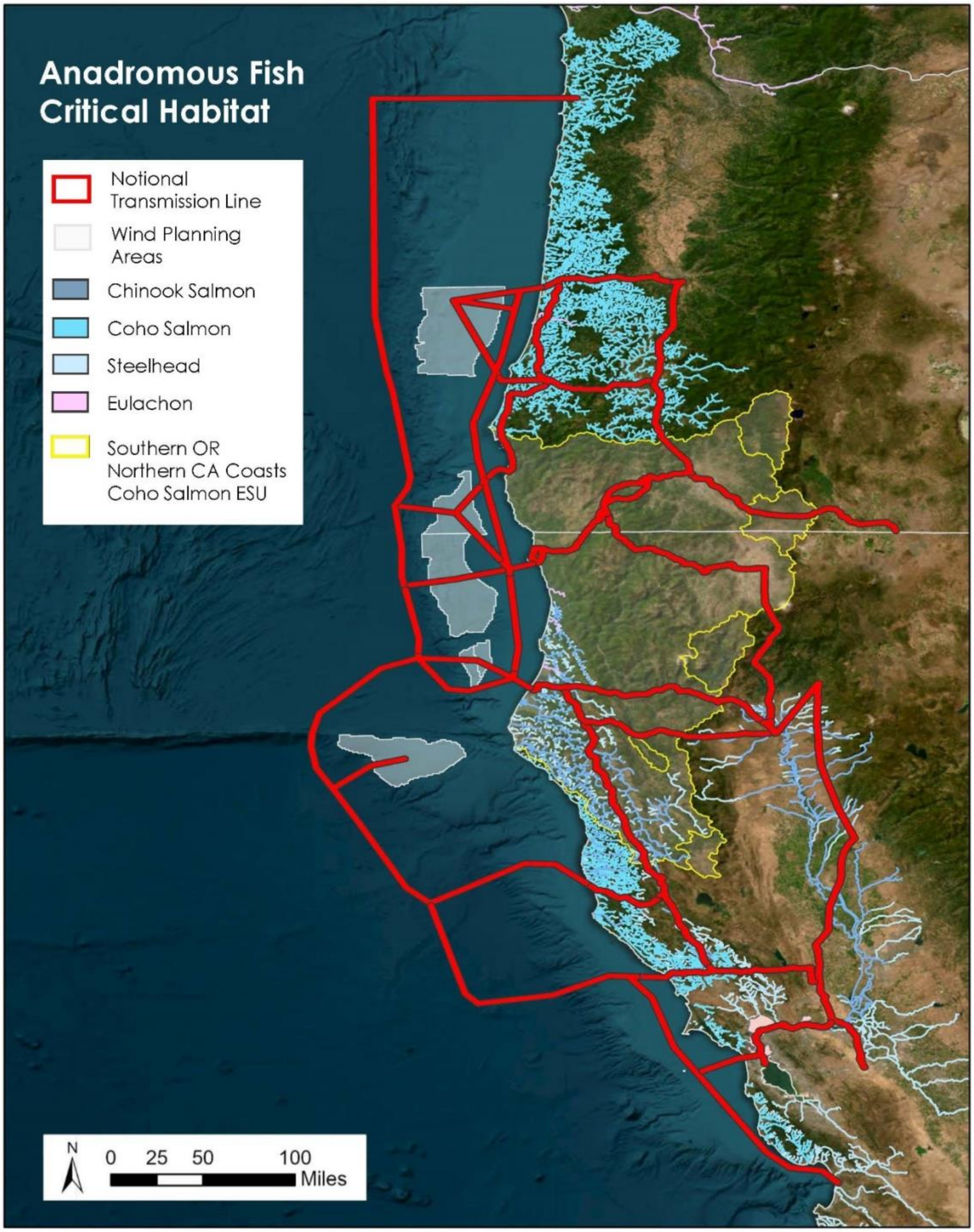

Figure 4. Critical Habitat – Anadromous Fishes

Notes: This map provides a visualization of critical habitat, as defined under the Endangered Species Act (ESA), for anadromous fishes. Each color block corresponds to a different species. Southern Oregon Northern California Coastal Coho Salmon have designated critical habitat in rivers, but there was no layer available for mapping. The hydrologic unit codes of regions where they are potentially present were mapped instead (yellow). Green sturgeon technically are anadromous, but are covered in Figure 5. The white blocks offshore represent the hypothetical, proposed, and established wind energy areas. Terrestrial construction is unlikely to affect the critical habitat in streams for these anadromous fishes, because the work is land-based and not aquatic. The Transmission Routes (in red, comprised of segments) are notional per the study, generally following existing Rights-of-Way Corridors, but may not represent final buildout and are subject to change.

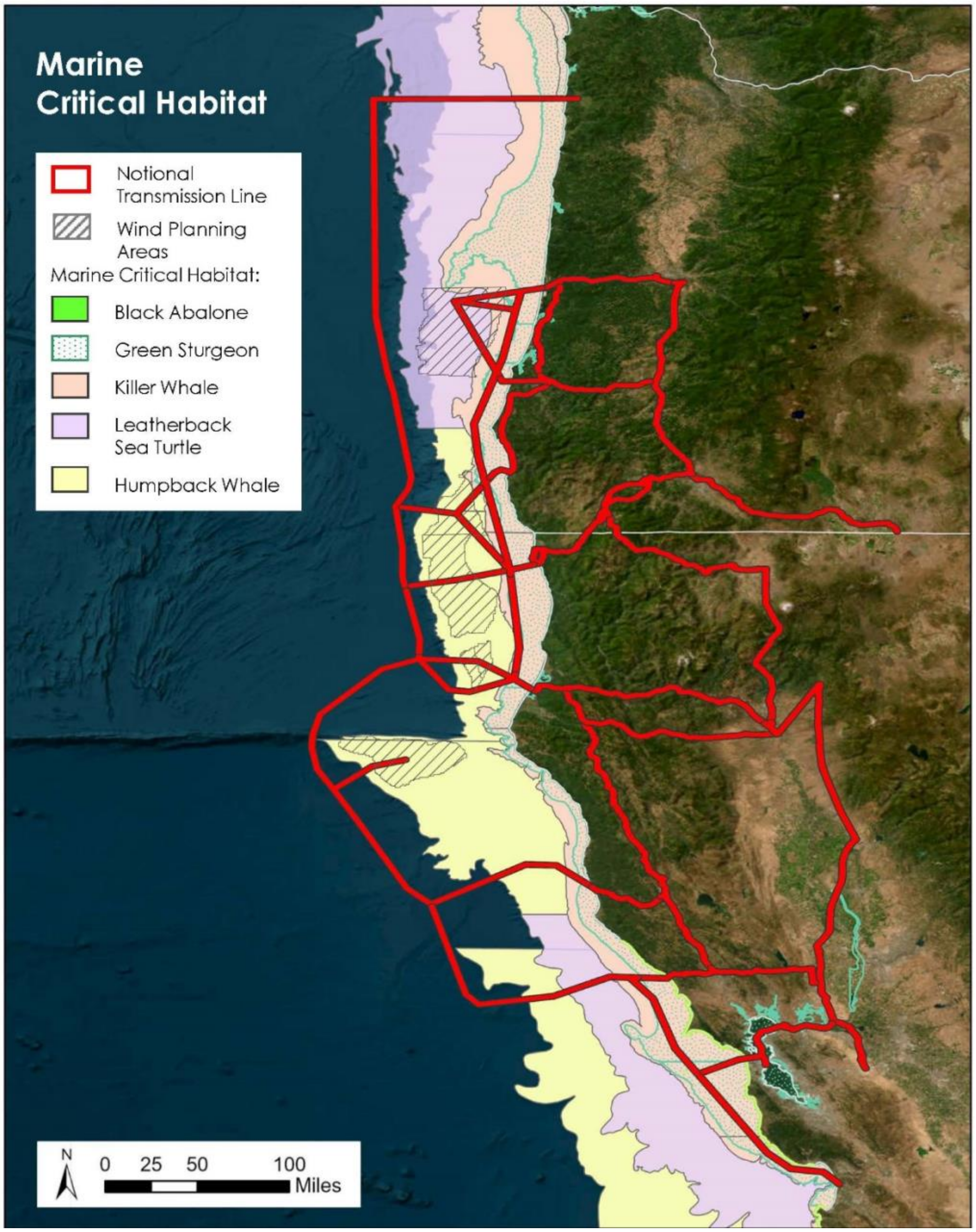

Figure 5. Critical Habitat – Marine Species

Notes: This map provides a visualization of critical habitat, as defined under the Endangered Species Act (ESA), for marine mammals (killer and humpback whale), leatherback sea turtles, green sturgeon, and black abalone. Each color block corresponds to a different species. There is considerable overlap between killer whale, humpback whale, and leatherback sea turtle critical habitat that are not perfectly visualized here. Within the project area, killer whale critical habitat (peach) extends longitudinally from Monterey Bay north through Oregon, between the 6.1-meter (m) and 200-m depth contour (NMFS 2021). Within the project area, leatherback sea turtle critical habitat (pink/lilac) includes waters east of the 3,000-m depth contour from Monterey Bay to Point Arena in California, and east of the 2,000-m depth contour from Cape Blanco north in Oregon (NMFS 2012). Within the project area, critical habitat for humpback whales (light yellow) extends from Monterey Bay in California to the border of Oregon, between the 50-m and up to 3,700-m isobath depending on the geographic location (NMFS 2021b). Within the project area, critical habitat for humpback whales extends along the entire coastline in Oregon, from the 50-m isobath offshore to either the 1,200-m or 2,000-m isobath depending on the geographic location (NMFS 2021b). The blocks offshore with diagonal lines represent the hypothetical, proposed, and established wind energy areas. The Transmission Routes (in red, comprised of segments) are notional per the study, generally following existing Rights-of-Way Corridors, but may not represent final buildout and are subject to change.

3.2.2 Marine Sensitive Habitats and Communities

The sensitive habitats and communities in bay, estuarine and aquatic environments include EFH and BIAs. EFH and BIAs that directly intersect with any of the subsea cable segments are outlined in Table 8. The exact geographic boundaries of EFH sensitive habitats and communities are visualized in Figure 6. The EFH in marine environments, including the four FMPs managed under MSA were not mapped because they are expansive and dynamic; however, all subsea segments contain EFH. EFH also extends into riverine systems in terrestrial habitats (Figure 6). These EFH overlap with anadromous fish critical habitat and consultation for critical habitat would thus cover EFH. We do not expect consultation to be needed for EFH for any of the terrestrial segments because any new development and/or updates to existing lines will not require in-water work, and thus it is unlikely to impact EFH. Biologically important areas (BIAs) are also considered sensitive habitats and are included in Table 8. The geographic locations of the BIAs are available in Figure 7.

Table 8. Sensitive Habitats Crossed by the Subsea Cable Segment Alternatives

Sensitive Habitat Designation	Name
Essential Fish Habitat	
	Rocky Reefs (HAPC)
	Estuaries (HAPC)
	Seagrass (HAPC)
	Kelp Canopy (HAPC)
	Deep-Sea Ecosystem Conservation Area
	Mendocino Ridge EFH Conservation Area
	Cordell Bank/Biogenic Area EFH Conservation Area
	Astoria Canyon EFH Conservation Area
	Rogue Canyon EFH Conservation Area
	Eel River Canyon EFH Conservation Area
	Half Moon Bay EFH Conservation Area
	Deepwater off Coos Bay EFH Conservation Area
Biologically Important Area (BIA)	
	Harbor Porpoise – small and resident population
	Blue Whale – feeding BIA
	Gray Whale – feeding BIA
	Humpback Whale – feeding BIA

Notes: All Essential Fish Habitats (EFH) that intersect with a subsea cable segment are noted here. Habitat Areas of Particular Concern (HAPC) are a subset of EFH, as are EFH Conservation Areas. The four marine EFHs managed under the Fishery Management Plans are excluded from this table because of their dynamic nature. Biologically Important Areas are delineated to identify sites where cetaceans engage in activities at certain times of the year that are crucial for the health and fitness of individuals, and the fecundity and survivorship of the larger population.

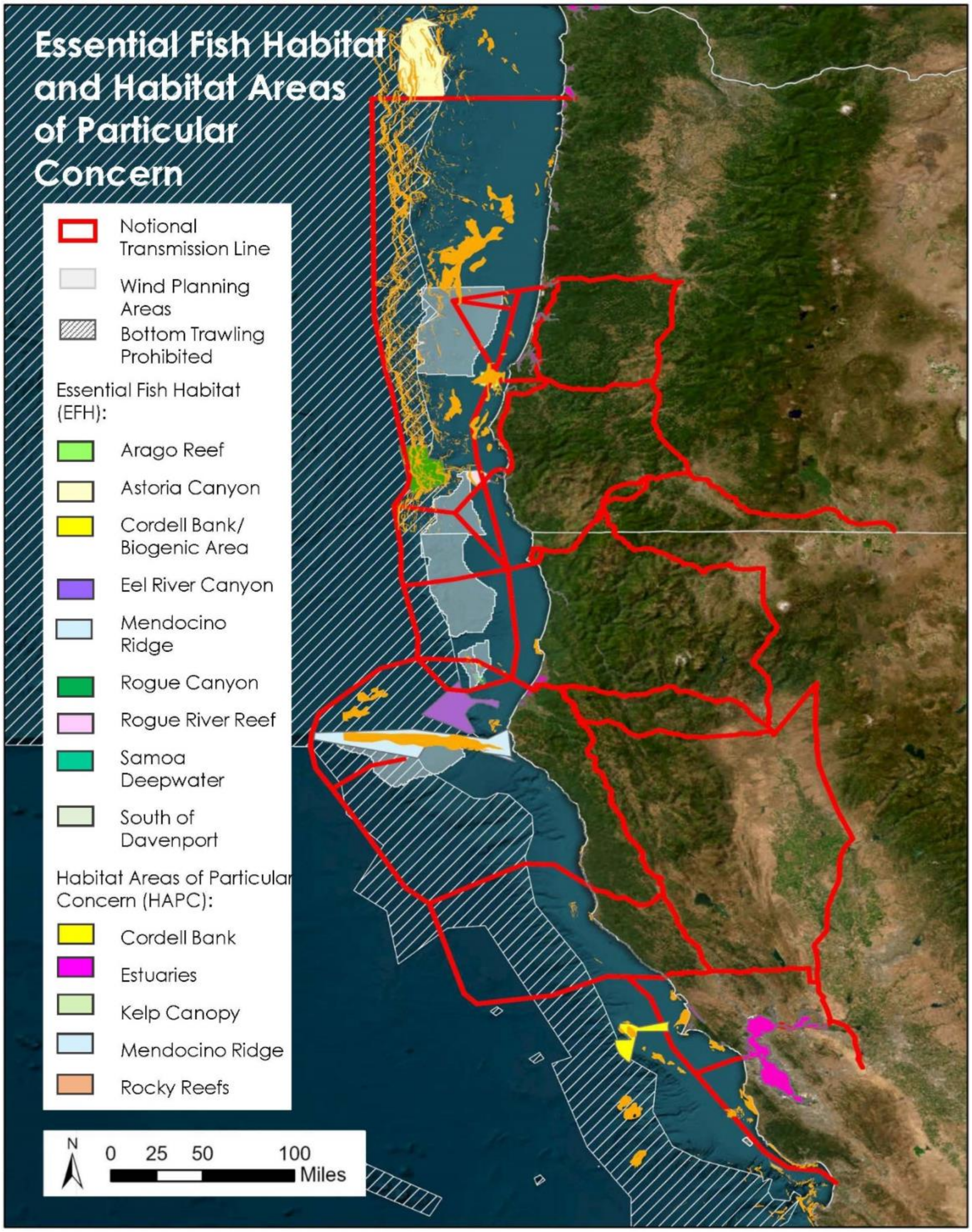

Figure 6. Sensitive Habitats in the Marine Environment

Notes: The non-terrestrial (i.e., marine) sensitive habitats include Essential Fish Habitats (EFH). Habitat Areas of Particular Concern (HAPC) are a subset of EFH under the Magnuson-Stevens Act. The geographic boundary of each of these sensitive habitats is represented by a different color. Coastal Pelagic Species, Pacific Coast Salmon, Pacific Coast Groundfish, and Highly Migratory Species EFH are excluded from this visualization because of their broad and general coverage. The Transmission Routes (in red, comprised of segments) are notional per the study, generally following existing Rights-of-Way Corridors, but may not represent final buildout and are subject to change. The white blocks offshore represent the hypothetical, proposed, and established wind energy areas.

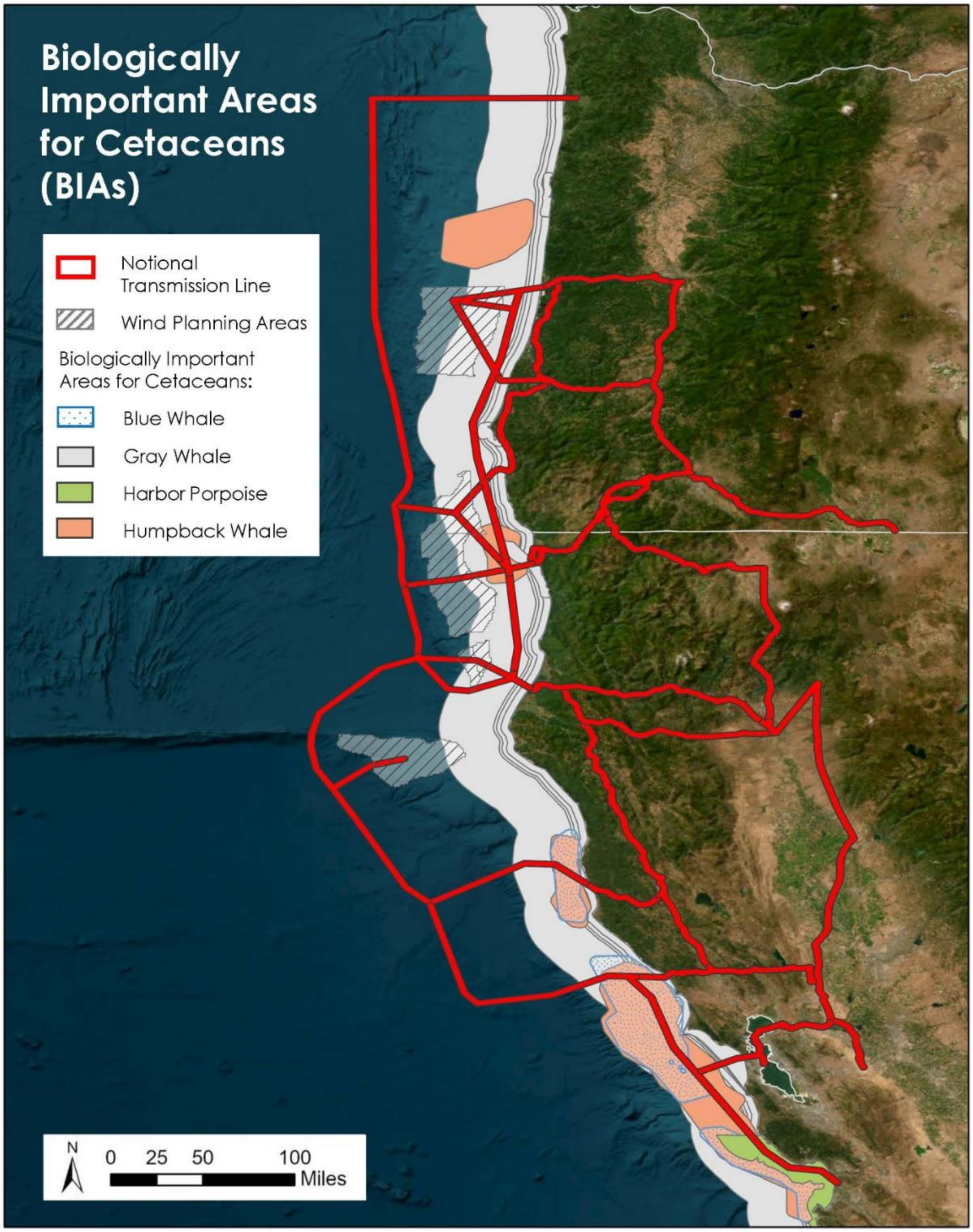

Figure 7. Biologically Important Areas for Cetaceans

Notes: This map outlines where designated Biologically Important Areas (BIAs) for cetaceans are located. BIAs are sites where cetaceans engage in activities at certain times of the year that are crucial for the health and fitness of individuals, and fecundity and survivorship of the population (Calambokidis et al. 2015). The Transmission Routes (in red, comprised of segments) are notional per the study, generally following existing Rights-of-Way Corridors, but may not represent final buildout and are subject to change. The white blocks offshore with diagonal lines represent the hypothetical, proposed, and established wind energy areas.

3.2.3 Marine Land Ownership/Designations

Bay, estuarine, and marine land use designations include MPAs and NMS. Table 9 lists the names of the MPAs and NMS that intersect with the subsea cable segments. The publicly available mapping layers used to evaluate the potential presence of MPA land use designations along the segments is non-exhaustive. Specifically, certain layers mapped had the geographic boundaries, but not the name of the associated MPA. As a result, Table 9 represents a portion of the MPAs that intersect with the segments. Figure 8 should be referenced for the geographic location of all MPAs (and NMSs).

The subsea cable segments cross SMRs, SMCAs, wildlife refuges, conservation zones and SMRMAs within California state waters. In these SMRs, it is "unlawful to injure, damage, take, or possess any living geological, or cultural marine resource, except under a permit or specific authorization from the managing agency for research, restoration, or monitoring purposes" (CDFW 2023). In SMCAs, "it is unlawful to injure, damage, take, or possess any living, geological, or cultural marine resource for commercial or recreational purposes, or a combination of commercial and recreational purposes, that the designating entity or managing agency determines would compromise protection of the species of interest, natural community, habitat, or geological features. The designating entity or managing agency may permit research, education, and recreational activities, and certain commercial and recreational harvest of marine resources" (CDFW 2023). Take of recreational and/or commercial marine resources may be allowed, but there are restrictions. In SMRMAs, "any activity that would compromise the recreational values for which the area may be designated" is unlawful and "recreational opportunities may be protected, enhanced, or restricted, while preserving basic resource values of the area" (CDFW 2023).

There are also certain Oregon state marine reserves and MPAs that intersect with subsea segments. In Oregon state reserves, and the removal of all marine life is prohibited. Ocean development is prohibited in their MPAs, although some fishing activities are allowed, and there are specific rules for each site (ODFW 2023). Since the publicly available mapping layers used to evaluate the potential presence of MPA land use designations along the segments did not include the names of each Oregon land use designation, Table 8 may only represent a portion of the MPAs that intersect with the segments.

The NMSs that intersect with the various subsea segments prohibit certain activities. There are specific regulations and a system of permits to allow certain activities to be conducted that would otherwise not be allowed (NOAA 2023). Activities including "the continued presence of commercial submarine cables or within the submerged lands of any national marine sanctuary," among others, may be eligible for special use permits (NOAA 2023b). The "lowering, laying, positioning, or raising any type of seabed cable or cable-laying device" is prohibited unless permitted (page 127 *in* NOAA 2023c).

Table 9. Land Use Designations Crossed by the Subsea Cable Segment Alternatives

Designation	Name
Marine Protected Area	
	Mattole Canyon State Marine Reserve
	Sea Lion Gulch State Marine Reserve
	Big Flat State Marine Conservation Area
	Russian River State Marine Recreational Management Area (state managed)
	Año Nuevo State Marine Reserve/Conservation Area
	Elkhorn Slough State Marine Reserve/Conservation Area
	Golden Gate National Recreation Area
	Bandon Marsh National Wildlife Refuge (Oregon)
	Klamath River Salmon Conservation Zone (Oregon)
National Marine Sanctuary	
	Cordell Bank NMS
	Greater Farallones NMS
	Monterey Bay NMS

Notes: Marine Protected Areas (MPAs) and National Marine Sanctuaries (NMS) that intersect with one of the subsea cable segments are listed in the second column. These land use designations are visualized in Figure 8. The publicly available mapping layers used to evaluate the potential presence of MPA land use designations along the segments are non-exhaustive: certain layers mapped had the geographical location, but not name of the associated MPA. As such, this table represents a portion of the MPAs that intersect with the segments.

Figure 8. Marine Protected Areas and National Marine Sanctuaries

Notes: This map visualized the various Marine Protected Areas and National Marine Sanctuaries in the project area. The Transmission Routes (in red, comprised of segments) are notional per the study, generally following existing Rights-of-Way Corridors, but may not represent final buildout and are subject to change. The white blocks offshore with diagonal lines represent the hypothetical, proposed, and established wind energy areas.

3.2.4 Marine Results Summary

A summary of all the evaluation topics reviewed in analyzing the feasibility of the subsea cable segments is provided in Table 10. This table is high-level, and further detail on the topics marked as intersecting with a given segment can be evaluated in greater detail by reviewing the previous subsections and Figures 3 through 8.

Table 10. Summary of Key Environmental Topics by Segment Focused on Subsea Cable Segments

Segment	Biologically Important Area	Species with Critical Habitat	EFH	MPA	National Marine Sanctuary	Notes
1	X	X	X	X		Primarily subsea
2	X	X	X			
3	X	X	X			
4		X	X			
5	X	X	X			Primarily subsea
6	X	X	X			
7	X	X	X	X		
8	X	X	X	X		Primarily subsea
9	X	X	X	X		Primarily subsea
10		X	X	X		Primarily subsea
11	X	X	X			Primarily subsea
12		X	X			
13		X	X			
14		X	X			
15	X	X	X	X		Primarily subsea
16		X	X			
17		X	X			
18		X	X			
19	X	X	X	X		
20	X	X	X	X	X	Primarily subsea
21	X	X	X	X	X	Primarily subsea
Coos Bay Call Area	X	X	X	X		
Brookings Call Area	X	X	X	X		
Hypothetical Del Norte Area	X	X	X	X		
Humboldt Wind Energy Area	X	X	X			
Hypothetical Cape Mendocino Area	X	X	X	X		

Notes: This table provides a high-level overview of the environmental topics that intersect with each of the 22 segments. Each segment is represented by a different row, and the numerical segment in the first column corresponds to the segments in Figure 1. Each column (besides the *Segment* column) represents a given environmental topic and spatial dataset that is important for evaluating the feasibility of the subsea specific segments. Cells highlighted in grey with an "X" in the cell indicate that the given environmental topic (representing a distinct spatial dataset) intersects with the segment. The Humboldt Wind Energy Area off California has already been leased via the Bureau of Ocean Energy Management (BOEM). The proposed wind energy areas (Coos Bay and Brookings Call Areas off Oregon) may be leased by BOEM in the future. The hypothetical areas (Del Norte and Mendocino Areas off California) are potential locations for wind energy.

3.3 Permitting

A variety of local, State, and federal permits may be required for each segment. Early and regular coordination with state and local agencies through a comprehensive strategy should address various needs, specifically related to early survey and data collection requirements, and where joint efforts may be more efficient. In particular, the terrestrial segments can cross numerous counties and federal lands, requiring determination of the lead agency, with additional responsible agencies that may include the counties. For all the offshore segments, BOEM or the U.S. Army Corps of Engineers would be the lead agency for NEPA, California State Lands Commission for state waters and CEQA, and Oregon Department of State Lands for Oregon territorial seas. Further, for the federal actions, under the Coastal Zone Management Act both the California Coastal Commission and the Oregon Coastal Management Program are responsible for reviewing consistency determinations, which are required for federal activities, Sequencing of federal, state and local permits, can certainly occur in parallel, and when completed in close coordination with all applicable agencies, efficiencies can be realized in the data collection phases and through the public review process under OAR, CEQA and/or NEPA, which will acknowledge coordinated efforts between agencies/stakeholders. Because all segments within California are subject to CEQA, these are not individually called out. Further, because NEPA will be dependent on whether a segment requires a federal action (e.g., segments that go through federal land or require a federal permit) these are also not called out individually; however, given the number of federal resources along the segments, it is likely many will require NEPA.

California Assembly Bill (AB) 525 requires the CEC, in consultation with other state, local and federal agencies, tribes and affected stakeholders, to develop and produce a permitting roadmap that describes timeframes and milestones for a permitting process for offshore wind energy facilities and associated electricity and transmission infrastructure off the coast of California. On April 28, 2023, the Energy Commission Report on AB 525 Offshore Wind Permitting Roadmap (Roadmap) (California Energy Commission [CEC] 2023) was released. The Roadmap outlines permitting options and frameworks for consideration in developing a final permitted roadmap, which would be included as part of the AB 525 offshore wind strategic plan. Although the Roadmap is primarily directed at the development of the offshore wind facilities, ancillary items, such as subsea cables within 3 miles of the shoreline, may also be able to use the Roadmap (CEC 2023). Another important aspect to consider is that the Roadmap is relevant only to California; however, the Roadmap may provide an integrated, coordinated approach that could be used in Oregon as well.

Table 11 provides a summary of potential permits by segment, based on the data collected for state and federal threatened or endangered species (and California fully protected species), sensitive habitats, and land use designations. Whether or a permit is needed will be based on impacts to the resources; some resources, such as wetlands and waters may be avoided through design and construction avoidance measures, and thus not require Sections 404 and 401 Clean Water Act permitting, a California Lake and Streambed Alteration Agreement, and/or an Oregon Removal-Fill permit. Other permits such as ESA, CESA, or coordination under the Oregon Endangered Species Act would also be determined based on impacts to threatened or endangered species, and similar to wetlands and waters, impacts may be avoided through design and construction avoidance measures. Other permits where the potential is based on the resource and potential impact are:

- Eagle Conservation Plan under the Bald and Golden Eagle Protection Act
- Essential Fish Habitat (EFH)

EFH is present within all segments. Within the marine environment there is more certainty of the need for EFH consultation. Within the terrestrial environment, depending on the final design of any alternative and Project design features to avoid and minimize impacts to water and wetlands, the need for EFH consultation is less certain. In either case, the EFH consultation would occur with any required ESA consultation and permitting.

Other permits are based on land use designations, such as Oregon Shore Alteration Permits, California Coastal Development Permits, California Submerged Lands leases, and National Forest Special Use permits. Because these permits are based on current land use designations, there is certainty in need for the permits. Two local development permits have been included in this analysis, those for the San Francisco Bay Conservation and Development Commission (BCDC) and the Humboldt Bay Harbor, Recreation and Conservation District. These would be limited to Segments 21 and 15, respectively. Of note, although the California Coastal Commission reviews consistency of federal actions under the Coastal Zone Management Act, within San Francisco Bay the BCDC is the reviewing state agency.

Table 11. Permits Required by Segment

Segment Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Federal																						
Section 401 of the Clean Water Act	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X
Applications for 401 Water Quality Certification	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X
Rivers and Harbors Act of 1899 Section 10 (33 USC 403) Individual Permit					X										X						X	
Section 404 of the Clean Water Act (33 USC 1344)	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X
Individual Permit	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X
Nationwide Permit	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X
Section 7 of Endangered Species Act (50 CFR 402)	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Biological Assessment/ Consultation (Section 7)	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Magnuson-Stevens Fisheries Conservation and Management Act (50 CFR 600)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Essential Fish Habitat Consultation, done in conjunction with Section 7 consultation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
National Marine Sanctuaries Act Special Use Permit																			X	X	X	
Incidental Harassment Authorization (annual)	X				X	X	X	X	X	X	X				X				X	X	X	

Segment Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Bald and Golden Eagle Protection Act (16 USC 668–668c) Eagle Conservation Plan												X	X	X		X		X	X			
Department of Defense (DOD) Mission Compatibility Evaluation (32 CFR 211) DOD Compatibility Approval																					X	
Section 307 of the Coastal Zone Management Act (15 CFR 930 Subpart C) Consistency Determination	X				X		X	X	X	X	X				X				X	X	X	
National Forest Management Act Special Use Permit		X	X	X								X	X	X				X				
Tribal Land Use Permit		X	X	X		X	X					X	X	X			X	X				
California State																						
California Endangered Species Act (14 CCR 783.0–787.9) Section 2081 Incidental Take Permit		X	X	X	X	X						X	X	X	X	X	X	X	X	X	X	
California Coastal Act Coastal Development Permit			X		X								X	X	X	X			X	X	X	
Section 1600 et seq. California Fish and Game Code Lake or Streambed Alteration Agreement			X									X	X	X	X	X	X	X	X	X	X	X
California Submerged Lands Act CPRC Section 6000 et seq. and 2 CCR 1900 et seq.)			X		X								X	X	X	X			X	X	X	

Segment Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Submerged Lands Lease																						
Oregon State																						
Oregon Removal-Fill Law (OAR 196.000-196.692 and ORS 196.800-196.990)	X	X	X	X	X	X	X	X				X										X
Territorial Sea Easement for Fiberoptic and Other Cables (OAR 141-083)	X				X	X	X															
Oregon Endangered Species Act For State owned or controlled lands		X	X	X	X	X	X															
Ocean Shores Permit (Oregon Administrative Rules [OAR] 736-020	X				X	X	X															
Joint Permit Application (OAR 141-85)	X	X	X	X	X	X	X	X				X										X
Local Agencies																						
Humboldt Bay Harbor District Development Permit													X	X	X							

Notes: This table outlines the different environmental permits that may be required to develop a particular segment (highlighted in grey with an "X" in the cell). Each row corresponds to a specific federal, State, or local permit. Each column corresponds to an individual segment (see Figure 1 for the location of each segment).

4 Discussion and Recommendations

The evaluation of the segments was separated between terrestrial and subsea sections; however the feasibility of the transmission alternatives has to consider that routes must connect from the sea to the land, and be continuous. Here, we synthesize the information presented for each environmental topic for each segment, rate each segment, and discuss whether there are high constraints to development. If a segment is identified as having very high barriers to development, we assess how that would impact any "downstream" interconnected segments, and propose alternative options, where appropriate.

Segments were screened based on the analysis of the environmental topic areas (i.e., number of special-status species and associated critical habitat, sensitive habitats, land use, and permitting challenges) along each segment. For each topic area, segments were rated low, medium, or high in terms of the challenges (Table 12, Figure 9); with low being relatively fewer challenges, medium being average for the segments, and high indicating many challenges for the topic area, including challenges that may make the segment impossible to permit. Finally, based on the rating of each topic area, an overall rating for each segment was compiled (Table 12). It should be noted, that even if only one topic area had a "high" rating, the overall rating may still be "high" based on the complexity of the challenge.

For example, for this analysis, if a segment has the redwood habitat type and northern spotted owl or marbled murrelet critical habitat, the segment was rated "high" for special-status species and sensitive habitats. This is a conservative approach to rating; both species require mature, old growth forests for nesting. As the extent of old growth forests, especially for redwood forests, is limited, any impact to these types of forest could potentially jeopardize northern spotted owl or marble murrelet, and be infeasible to mitigate for impacts. Segments in which critical habitat for either northern spotted owl or marbled murrelet are present were also conservatively rated "high" for the special-status species topic because of the sensitivity of the species and limited habitat. These challenges associated with the potential presence of northern spotted owl or marbled murrelet along a segment also correlate to a higher degree in permitting complexity, in particular with the ESA and CESA. Therefore, permitting challenges were also rated "high" for the segments with these species.

Similarly conservative, in the marine environment, segments with the known occurrences, or potential habitat for longfin smelt or delta smelt were rated as "high". The year-round occurrence of these species in some coastal areas, and difficulty in providing compensatory mitigation for impacts to the species, correlates to complexity for ESA and CESA consultations; however, permitting may be relatively straight forward for some of these species depending on the nature of the action and impact. For example, an overwater transmission line may have little or no impact, compared to trenching to bury a transmission cable. For the purposes of our assessment, we did not consider the type of impact and how it may differ between segments (particularly between overhead terrestrial cables and subsea cables, modifying existing terrestrial cables, etc.). These differences would need to be more fully described and the Project descriptions further developed in order to evaluate the feasibility of each alternative.

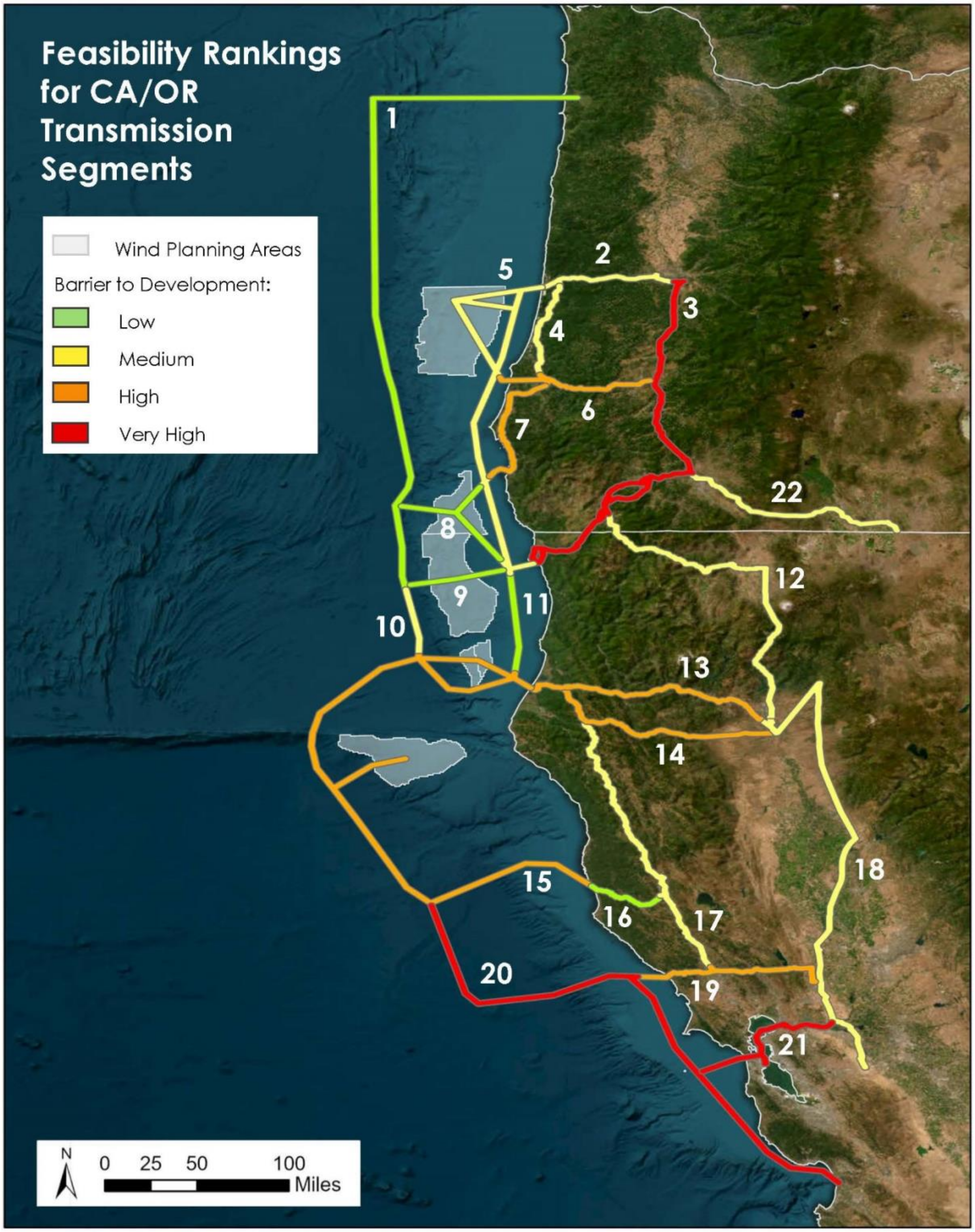

Figure 9. Feasibility Ratings for CA/OR Transmission Segments

Notes: Each of the potential transmission segments were rated based on their feasibility and with regards to the environmental topics used for evaluation. The segments in this map are colored based on their overall feasibility rating (corresponding to Table 12) and barrier to development. The color codes are provided in the legend. This transmission network, comprised of segments, are notional per the study and generally follow existing Rights-of-Way Corridors, but may not represent final buildout and are subject to change.

Table 12. Feasibility Ratings of Segments Based on Environmental Barriers

Segment	Special-status Species	Sensitive Habitats	Land Use	Permitting	Overall	Notes[1]
1	Medium	Low	Low	Medium	Low	Contains critical habitat for marbled murrelet, coho salmon, leatherback sea turtle, humpback whale, and killer whale, and Essential Fish Habitat (EFH) and a Biologically Important Area (BIA) for gray whale. Two habitats of particular concern are present: estuaries and rocky reefs. Intersect 3 Marine Protected Areas (MPAs) which allow uniform multiple uses; Three Arch Rocks National Wildlife Refuge (NWR), and Oregon Islands NWR.
2	High	Medium	Medium	High	Medium	Intersects northern spotted owl and marbled murrelet designated critical habitat, Joaquin Miller State Park (SP), tribal lands, Siuslaw National Forest, and Oregon Island NWR.
3	High	High	High	High	Very High	Intersects marbled murrelet and northern spotted owl designated critical habitat and the redwood sensitive habitat type. May impact Redwood National Park. Jedediah Smith Redwood State Park which also transects the segment contains a state wilderness area. Both the national park and state wilderness area may present a potential barrier to development, based on what needs to occur along the segment. These restrictions are primarily for the section of the segment running directly inland from the coast (east-west portion). Refer to Sectio 4.1.1 for further explanation of how the restrictions vary between portions of this segment. Contains a designated Section 368 energy corridor.
4	High	Medium	Low	Medium	Medium	Intersects northern spotted owl and marbled murrelet designated critical habitat, one state park, tribal lands, and the Elk Wild and Scenic River.
5	Medium	Medium	Medium	Medium	Medium	Contains critical habitat for leatherback sea turtle, humpback whale, and killer whale, and BIAs for gray and humpback whales. Rocky reefs, a habitat of particular concern, are present. The segment intersects the Oregon Islands NWR.
6	High	High	High	High	High	This is primarily a terrestrial segment, with a subsea component. The terrestrial and subsea aspects require a variety of permits. Intersects marbled murrelet, northern spotted owl, killer whale, humpback whale, and coho salmon critical habitat, BIAs for gray whale, rocky reef habitat of particular concern, tribal lands, and the Oregon Islands NWR. Because of the number of permits required this segment was rated "high."
7	Low	Medium	High	High	High	This is primarily a terrestrial segment, with a subsea component. The terrestrial and subsea aspects require a variety of permits. Intersects Coho salmon critical habitat, and BIAs for gray whale, and killer whale, humpback whale, contains the habitat of particular concern; kelp canopy. Intersects one state park and one state heritage site, tribal lands, Brandon Marsh NWR, federal MPAs that allow uniform multiple uses, and the Oregon Islands NWR. Because of the number of permits required this segment was rated "high."
8	Medium	Low	Low	Low	Low	Intersects humpback whale and killer whale critical habitat and BIAs for humpback and gray whale. Contains rocky reef habitat of particular concern, and intersects MPAs that allow uniform multiple uses.
9	Medium	Low	Low	Low	Low	Intersects humpback whale and killer whale critical habitat and BIAs for humpback and gray whale. Intersects EFH and federal MPAs.
10	Low	Low	Low	Low	Low	Intersects EFH and federal MPAs.
11	Low	Low	Medium	Low	Low	Intersects humpback whale and killer whale critical habitat, and BIAs for humpback and gray whale. Intersects the Klamath River Salmon Conservation Zone, an MPA.
12	High	Medium	High	High	Medium	Potential impacts to many potential State and federal threatened or endangered listed species, including northern spotted owl and its critical habitat. Intersects 3 national forests, castle Crags State Park, tribal lands, and the CA designated Klamath Wild and Scenic River. This segment would also likely require a take permit via the Bald and Golden Eagle Protection Act (BGEPA). It is a designated Section 368 energy corridor.
13	High	High	High	High	High	Potential impacts to many potential State and federal threatened or endangered listed species, including northern spotted owl and marbled murrelet, their critical habitat, and the redwood sensitive habitat type. Intersects 2 national forests, and the CA designated Trinity Wild and Scenic River. This segment would also likely require a BGEPA take permit.
14	High	High	High	High	High	Potential impacts to many potential State and federal threatened or endangered listed species, including northern spotted owl and marbled murrelet, their critical habitat, and the redwood sensitive habitat type. Intersects 2 national forests, Grizzly Creek Redwood State Park, tribal lands, and the CA designated Trinity Wild and Scenic River. This segment would also likely require a BGEPA take permit. A portion of this segment is a designated Section 368 energy corridor.
15	High	High	Medium	High	High	Potential impacts to longfin smelt, and its associated habitat within Humboldt Bay, and snowy plover. Intersects humpback whale, killer whale, steelhead, coho salmon, and western snowy plover critical habitat, and BIAs for gray, blue, and humpback whale. Intersects EFH, and the Eel River Canyon Essential Fish Habitat Conservation Area, an MPA.

Segment	Special-status Species	Sensitive Habitats	Land Use	Permitting	Overall	Notes[1]
16	Low	Low	Low	Low	Low	Would require a BGEPA take permit.
17	High	High	Low	High	Medium	Potential impacts to State and federal threatened or endangered listed species, including northern spotted owl and marbled murrelet, their critical habitat, and the redwood sensitive habitat type, in the northern portion of the segment. Intersects tribal land.
18	High	High	High	High	Medium	Potential impacts to many State and federal threatened or endangered listed species including delta smelt and longfin smelt (in the upper Delta). Intersects 3 national forests, Bethany Reservoir State Recreation Area, and tribal land. This segment would also likely require a BGEPA take permit.
19	High	High	High	High	High	This is primarily a terrestrial segment, with some subsea component. The terrestrial and subsea aspects require a variety of permits. Potential impacts to State and federal threatened or endangered listed species, including longfin smelt and the Sonoma County DPS of California tiger salamander, and humpback whale, killer whale, and leatherback sea turtle, steelhead, and Coho and Chinook salmon critical habitat. Intersects BIAs for gray, humpback, and blue whales, two state parks, the Russian River State Marine Recreation Management Area, one no take MPA, and the Sacramento NWR. This segment would also likely require a BGEPA take permit.
20	High	High	High	High	Very High	Potential impacts to State and federal threatened or endangered listed species including longfin smelt. Tidewater goby, and western snowy plover. Intersects humpback whale, killer whale, leatherback sea turtle, steelhead, Coho salmon, western snowy plover, and tidewater goby critical habitat, and intersects BIAs for gray, humpback, and blue whales, and for harbor porpoise. Intersects EFH, MPAs, including one state no take MPA, Monterey Bay National Marine Sanctuary (NMS), Cordell Banks NMS, and Gulf of the Farallones NMS.
21	High	High	High	High	Very High	Potential impacts to many State and federal threatened or endangered listed species, including longfin and delta smelt, including the territory for the federally listed longfin smelt distinct population segment, and humpback whale, killer whale, leatherback sea turtle, and green sturgeon critical habitat. Intersects Monterey Bay and Gulf of Farallones NMSs, and Golden Gate National Recreation Area, and several state MPAs that allow multiple uses, and one federal no access MPA.
22	High	Medium	Low	High	Medium	Intersects designated northern spotted owl critical habitat and the Jenny Creek Wild and Scenic River.

Notes: This table provides feasibility ratings for different environmental topics. The ratings for individual topics contribute to the overall rating of the Segment. 'Low' indicates that a segment (or aspect of a segment) is more feasible and has fewer challenges, barriers or restrictions to development, whereas 'high' and 'very high' indicate challenges associated with development that more ramifications for permitting that could make a segment impossible or very difficult to permit. The environmental topics reviewed that contribute to the Overall rating include:

Special-status Species: Special-status Species in this review (and table) include those threatened or endangered by the Federal Endangered Species Act, or by California or Oregon State. It also includes fully protected species but excludes those that may be candidates or proposed for listing.

Sensitive Habitats: Sensitive habitats are unique, provide specific living conditions, and are thus important for conservation. Those covered include Essential Fish Habitat, biologically important areas for cetaceans, wetlands and waters, and habitats such as old growth redwoods.

Land Use: Land use (i.e., ownership/designations) are similar to sensitive habitats in that they are intended to enhance conservation; however, they are less focused on habitat type, and have fixed, often linear boundaries.

Permitting: This column relates to the federal and state permits, approvals or authorizations, agency consultations, and regulatory requirements. The permitting feasibility is often dependent on the special-status species and sensitive habitats present.

[1]The *Notes* column contains a summary of information that was used to determine the feasibility rating but does not include all the information evaluated. More detailed information on permitting constraints for a specific segment can be reviewed in other figures and tables. Segments (or portion of segments) that have been designated as a Section 368 energy corridor are noted. Section 368 corridors are designated for energy transmission and considered to be preferable pathways for interstate energy transport, but do not necessarily contribute to permitting feasibility or remove permitting challenges.

It should also be noted that segments with "high" or "very high" final ratings for potential barriers to development should not be disregarded as possibilities. Rather, their constraints are complex, suggesting that permits will be more time intensive, and require added minimization and mitigation efforts compared to those with "low" and "medium" barriers to development.

4.1 Segments with a High Barrier to Development

Segments with a "high" or "very high" barrier to development are discussed below. These are segment where the majority of environmental topics have individually been rated "high." Based on this analysis, and the complexity of natural resources, land uses, and permitting required, it is anticipated development of these segments would take considerably longer than those segments with an overall rating of "medium" or "low." Instances where a land use incompatible with development of the segment may be present is noted, and a discussion of "downstream" interconnection impacts presented.

4.1.1 Segment 3

Segment 3 has an overall screening of "very high". But this rating generally only applies to the east-west portion of Segment 3 (the portion located in Northern California). This portion has many challenges including potentially impacting Redwood National Park, a state wilderness area, redwood forests, and marbled murrelet and northern spotted owl critical habitat. These land use and natural resources permitting challenges may make the east-west portion of Segment 3 impossible to permit. The more north-south portion of the segment does not contain these challenges and would likely be easier to permit.

The constraints to development along the east-west portion of Segment 3 would also preclude "downstream" interconnections, such as to Segment 12 (Segment 12 could still interconnect to the south to Segments 13/18); however, because the constraints along Segment 3 are restricted to the east-west portion, Segment 6 could be used as an interconnection to reach the north-south portion of Segment 3, bringing power to the Medford, OR and Malin, OR areas via Segment 22. Thus, Segment 3 should not be disregarded as part of an alternative route. Rather, secondary routes avoiding the east-west section of the segment that is difficult to permit could be explored.

4.1.2 Segments 6, 7 and 19

Segments 6, 7 and 19 have all been rated with a "high" barrier to development because of the number of special-status species, habitats, land use, and permits that would be required for each segment. These segments are all primarily terrestrial, with some subsea component. The fact that these segments have both terrestrial and subsea components increases the complexity of all environmental topic areas assessed because of the permitting needs associated along both habitat types. If only the terrestrial, or subsea portions of each segment were considered, each of the segments would be rated "medium." Therefore, although rated "high" because of the number of constraints to development (number of permits, species, etc.), these could be considered "medium" in terms of complexity if viewed from only a terrestrial or subsea perspective.

Each of these segments has slightly different areas of concern. If only the terrestrial portions were assessed, the segments would be rated "medium" with least to most complex being Segments 7, 6, and 19, in that order. If only the subsea portions were assessed, the segments would be rated "medium" with least to most complex being Segments 6, 7 and 19, in that order.

4.1.3 Segment 13

There are high constraints to development of Segment 13. Northern spotted owl and marbled murrelet, their associated critical habitat, and the redwood sensitive habitat type exist along the segment. Blue Oak and Valley Oak woodlands are also present along the segment. These resources would make permitting difficult. Tribal lands, two national forests, the Humboldt Bay National Wildlife Refuge, and the Trinity Wild and Scenic River also intersect with the segment, increasing permitting complexity, and present high constraints to development. Segment 13 (and 14) run roughly parallel to existing highways, including Highway 299 to the north and Highway 36 to the south.

4.1.4 Segment 14

There are high constraints to development of Segment 14. Northern spotted owl and marbled murrelet, their associated critical habitat, and the redwood sensitive habitat type exist along the segment. Blue Oak and Valley Oak woodlands are also present along the segment. These resources would make permitting difficult. One state park (Grizzly Creek Redwoods SP), tribal lands, two national forests, the Humboldt Bay National Wildlife Refuge, and the Trinity Wild and Scenic River also intersect with the segment, increasing permitting complexity, and present high constraints to development.

Segments 13 and 14 are geographically close together, and likely one of the segments should be prioritized for further analysis. Taking into consideration the constraints of both segments, Segment 13 has one less constraint than Segment 14 (which intersects the Grizzly Creek Redwoods SP), and therefore would likely be more permittable, but only slightly. If only one of the two was being moved forward for further analysis, we would recommend that one be Segment 13. That said, both have similar levels of feasibility and can be further analyzed.

Both segments interconnect to the same downstream segments and if one is moved forward, there would be no downstream constraints as they both connect to Segments 12 and 18; however, if neither segment is moved forward, this could constrain Segments 12 and 18, and would likely also eliminate the northern portion of Segment 17, which would transfer power to the San Francisco Bay Area load center.

4.1.5 Segment 15

Segment 15 is rated as having "high" constraint to development. Segment 15 has potential impacts to longfin smelt, and its associated habitat within Humboldt Bay, and snowy plover. The segment intersects humpback whale, killer whale, steelhead, coho salmon, and western snowy plover critical habitat, and BIAs for gray, blue, and humpback whales. The segment also intersects EFH, and the Eel River Canyon Essential Fish Habitat Conservation Area, an MPA. Although this is a subsea segment, and the offshore agencies and permits described in the Results section would be relevant, this segment would also require a development permit from the Humboldt Bay Harbor, Recreation and Conservation District, as it enters the Humboldt Bay. This adds another layer of review and compliance with marine resources plans within the Bay. Given this complexity, this segment is more complex than others in the "high" rated group; but there are no highly problematic barriers to development.

4.1.6 Segments 20 and 21

Segments 20 and 21 have "very high" constraints to development. Segment 20 has potential impacts to State and federal threatened or endangered listed species including longfin smelt, tidewater goby, and western snowy plover. The segment intersects humpback whale, killer whale, leatherback sea turtle, steelhead, coho salmon, western snowy plover, and tidewater goby critical habitat, and intersects BIAs for gray, humpback, and blue whales, and for harbor porpoise. Of particular interest along this segment, is it intersects MPAs, including one state no take MPA, and the Monterey Bay NMS, Cordell Banks NMS, and Gulf of the Farallones NMS. The number of agencies and NMS involved would make this a complex segment to permit. These constraints are most pronounced after the segment turns east toward the coast because of the intersection with the Cordell Banks and Gulf of the Farallones NMS. Under existing legislation, the construction of subsea cables is not allowed. An alternative that may lessen, but not totally remove, these constraints would be for Segment 20 to continue further south (and potentially further west) prior to turning east toward the California coast. Any such change would need to be evaluated by design and other subject areas for feasibility, and there may be additional logistical challenges associated with routing cables through submarine canyons

Segment 21 goes through the Golden Gate into San Francisco Bay, through the Bay and Delta, to interconnect with Segment 18. Many marine species use these areas as part of their life history, including green sturgeon, delta smelt, and anadromous salmonids. The segment also intersects Monterey Bay and Gulf of Farallones NMS, Golden Gate National Recreation Area, several state MPAs that allow multiple uses, and one federal no access MPA. Because the segment enters San Francisco Bay, California Coastal Act permitting via the CCC would be required, and San Francisco Bay Conservation and Development Commission permitting. The number of agencies involved would make this a complex segment to permit.

An alternative to concerns associated with Segments 20 and 21 would be to further study Segment 16 connecting to Segment 17, and then to the terrestrial portion of Segment 19. Further analysis would be required to assess how to access the load centers of the San Francisco Bay Area, but this alternative would address the potential development barriers of Segments 20 and 21. An additional alternative for each segment would be to route them around the Cordell Banks and Gulf of Farallones NMS, as indicated above.

4.2 Segments with a Medium Barrier to Development

Segments with a medium barrier to development (2, 4, 5, 12, 17, 18, and 22) have a variety of natural resources, land uses, and potential required permits. The exact nature of the potential impacts and required permitting may be lower than what is identified herein. It is expected that through transmission structure design and best management practices that would be incorporated into the Project, many of these resources could be avoided, with many potential impacts minimized. Those segments for which the overall rating is "medium" but have several "high" rated environmental topics are discussed below to describe the "medium" rating. We recommend all segments rated "medium" be moved forward for further evaluation and further analysis of how the segments can support interconnection.

4.2.1 Segment 2

Segment 2 has the potential to impact many potential State and federal threatened or endangered listed species, including northern spotted owl and marbled murrelet and their critical habitat. The segment also intersects tribal lands, Joaquin Miller State Park, Siuslaw National Forest, and Oregon Island National Wetlands Refuge. It is expected that through transmission structure design and best management practices that would be incorporated into the Project, many of these sensitive natural resources could be avoided, with many potential impacts minimized. The presence of northern spotted owl and its critical habitat, and the sensitive habitats contribute to the permitting complexity of this segment, which may be offset by the more moderate number of identified land uses designations along the segment.

4.2.2 Segment 4

Segment 4 has the potential to impact many State and federal threatened or endangered species, including northern spotted owl and its critical habitat. Segment 4 also intersects with one state park, tribal lands, and the Elk Wild and Scenic River. It is expected that through transmission structure design and best management practices that would be incorporated into the Project, potential impacts can be minimized, but permits would be necessary. The presence of northern spotted owl and its critical habitat contribute to a complex permitting strategy for this segment, which may be offset by the low number of identified land uses designations along the segment.

4.2.3 Segment 5

Segment 5 is a subsea segment that contains critical habitat for leatherback sea turtles, killer and humpback whales, and BIAs for gray and humpback whales. It also contains critical habitat for green sturgeon. The segment intersects with Oregon Islands NWR. It is expected that through transmission structure design and best management practices that would be incorporated into the Project, potential impacts can be minimized, but permits would be necessary.

4.2.4 Segment 12

Segment 12 has the potential to impact many State and federal threatened or endangered species, including northern spotted owl and its critical habitat. The segment also intersects Blue Oak and Valley Oak woodland sensitive habitats. It is expected that through transmission structure design and best management practices that would be incorporated into the Project, many of these sensitive natural resources could be avoided, with many of the potential impacts minimized. The segment also intersects three national forests, Castle Crags State Park, tribal lands, the CA designated Klamath Wild and Scenic River, and would likely require a Bald and Golden

Eagle Protection Act take permit for bald eagles. The presence of northern spotted owl and its critical habitat, and the many land uses all contribute to a complex permitting strategy for this segment.

4.2.5 Segment 17

Segment 17 has the potential to impact many potential State and federal threatened or endangered listed species, including northern spotted owl and marbled murrelet and their critical habitat. The segment also intersects Blue Oak and Valley Oak woodland, and redwood sensitive habitats. It is expected that through transmission structure design and best management practices that would be incorporated into the Project, many of these sensitive natural resources could be avoided, with many potential impacts minimized. Land use challenges analyzed for this segment are limited to tribal coordination and permits. The presence of northern spotted owl and its critical habitat, and the sensitive habitats contribute to the permitting complexity of this segment, which may be offset by the more limited number of identified land uses designations along the segment.

4.2.6 Segment 18

Although each environmental topic area of Segment 18 is rated high, this segment should not be screened out. Many of the State and federal listed species are freshwater fish, and the sensitive habitats are potential waters/wetlands. It is expected that through transmission structure design and best management practices that would be incorporated into the Project, many of these sensitive natural resources could be avoided, with many potential impacts minimized. Permitting based on land use would require special use permits from three National Forests, and early coordination and permits from tribes. None of these would present a constraint to development, and therefore Segment 18 has an overall rating of "medium."

4.2.7 Segment 22

Segment 22 contains northern spotted owl critical habitat which could be a challenge to permit under ESA. Sensitive habitats along the segment consist primarily of wetland and waters, and potentially vernal pools and vernal pool fairy shrimp; however, as described, it is likely these water-based resources could be avoided, or potential impacts to them minimized. Jenny Creek, a Wild and Scenic River intersects the segment, and any transmission line development would need to conform to the permitting requirements of the Wild and Scenic Rivers Act. In considering the foregoing, it is likely that although permitting for northern spotted owl may be difficult, it would not likely present a constraint to development, and therefore Segment 22 has an overall rating of "medium."

4.3 Segments with a Low Barrier to Development

Segments with a low barrier to development (1, 8, 9, 10, 11, and 16) have a limited number of natural resources, land uses, and potential required permitting challenges. Many of the permits required are standard for all similar segments. We recommend these segments be moved forward for further evaluation and further analysis of how the segments can support interconnection.

4.4 Future Analysis

The next phase of environmental review should conduct an in-depth analysis to further identify which alternatives could move toward development. The next phase of analysis should include any segments rated "low" or "medium" (Table 12). We also recommend segments 6, 7, 13, 14, 15, and 19 be considered because although rated "high," design considerations and potential avoidance and minimization measures could be incorporated into any design and may allow development of these segments.

Further analyses for these segments could involve:

- Creating more detailed maps to identify potential constraints at a finer scale. This might be useful for adjusting sections of certain segments to avoid locally restrictive sections;
- Ground truthing from site-specific surveys to create more detailed maps, and obtaining up to date habitat characteristics and information on the potential presence of listed species; and
- A more detailed analysis of current infrastructure design and development standards.

These analyses would look different for the terrestrial and subsea segments. For example, any future analysis for subsea cables would likely involve the use of existing geophysical information on the seabed and data on the abundance or presence of species and habitats. Ground truthing surveys for terrestrial segments could confirm potential habitat characteristics and presence of listed species. Design development for terrestrial segments must also identify where new parallel transmission lines would be placed. The specific design parameters would therefore be an important part of the terrestrial analysis, as some of those segments rated "high" may be easily developed provided best management practices are implemented. The locations and footprints of upgraded or new substations, and the location of interconnection of the subsea and terrestrial segments would need to be closely analyzed.

Segments 3, 20 and 21 were deemed as having "very high" barriers to development (Figure 9, Table 12). As detailed in Section 4.1, these segments should not be eliminated as possible alternatives. Our recommendations for next steps differ from those segments with "low" and "medium" constraints. Follow up analyses for Segment 3, 20, and 21 should:

- Explore potential detours around sections of a given segment that have more constraints, and identify whether sections of a segment could be avoided to improve feasibility;
- Conduct a more detailed evaluation of the permits needed;
- A more detailed analysis of current infrastructure design and development standards; and
- Identify potential minimization and mitigation measures to be incorporated into design, and conduct a cost-benefit analysis weighing the options.

5 References

Calambokidis, J., G. H. Steiger, C. Curtice, J. Harrison, M. C. Ferguson, E. Becker, M. DeAngelis, and S. Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1):39-53.

[CDFW] California Department of Fish and Wildlife. 2023. MPA Definitions and Acronyms - Legal Definitions, Commonly Used Acronyms, and Abbreviated Terms. Monterey, California <https://wildlife.ca.gov/Conservation/Marine/MPAs/Definitions#smca>.

[CNDDB] California Natural Diversity Database. 2023. State and Federally Listed Endangered and Threatened Animals of California. April. Sacramento, California. Prepared by the California Department of Fish and Wildlife

[CEC] Jones, M., K. Chew, E. Harland, and J. Bartridge. 2023. Assembly Bill 525 Offshore Wind Energy Permitting Roadmap. Commission Report. April 2023. CEC-700-2023-004.

[NMFS] National Marine Fisheries Service. 2012. Endangered and Threatened Species: Final Rule To Revise the Critical Habitat Designation for the Endangered Leatherback Sea Turtle. Federal Register 77(17):4147-4200.

[NMFS] National Marine Fisheries Service. 2021. Endangered and threatened wildlife and plants: Revision of critical habitat for the southern resident killer whale distinct population segment. Federal Register 86(145):41668–41698.

[NMFS] National Marine Fisheries Service. 2021b. Endangered and Threatened Wildlife and Plants: Designating Critical Habitat for the Central America, Mexico, and Western North Pacific Distinct Population Segments of Humpback Whales. Federal Register 86(75):21082.

[NOAA] National Marine Fisheries Service. 2020. Definitions and Classification System for U.S. Marine Protected Areas. June 2020. Factsheet. <https://nmsmarineprotectedareas.blob.core.windows.net/ marineprotectedareas-prod/media/docs/20200715-mpa-classification.pdf>. Accessed April, 2023.

[NOAA] National Oceanographic and Atmospheric Administration. 2021a. Habitat Conservation – Habitat Areas of Particular Concern on the West Coast. <https://www.fisheries.noaa.gov/west-coast/habitat-conservation/habitat-areas-particular-concern-west-coast>. Accessed April 2023.

[NOAA] National Oceanic and Atmospheric Administration. 2021b. Marine Protected Areas: Tools for a Healthy Ocean January 7, 2021. Factsheet. <https://nmsmarineprotectedareas.blob.core. windows.net / marineprotectedareas-prod/media/docs/20210107-mpa-fact-sheet-update-v3.pdf>. Accessed April 2023.

[NOAA] National Oceanographic and Atmospheric Administration. 2022. Endangered Species Conservation-Critical Habitat. <https://www.fisheries.noaa.gov/national/endangered-species-conservation/critical-habitat/>. Accessed April 2023.

[NOAA] National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries. 2023. National Marine Sanctuaries - West Coast Region. Monterey, California. <https://sanctuaries.noaa.gov/about/westcoast.html#documents>. Accessed April, 2023.

[NOAA] National Oceanic and Atmospheric Administration. 2023b. National Marine Sanctuaries - National Marine Sanctuary Permits. <https://sanctuaries.noaa.gov/management/permits/welcome.html>. Accessed May 16, 2023.

[NOAA] National Oceanic and Atmospheric Administration. 2023c. Part 922 - National Marine Sanctuary Program Federal Register 88(958).

[NWI] National Wetlands Inventory. 2023. U.S. Fish and Wildlife Service. Wetlands Seamless Wetlands Data. <https://www.fws.gov/program/national-wetlands-inventory/data-download>. Accessed April 2023.

[ODFW] Oregon Department of Fish and Wildlife. 2023. The Reserves - Overview. Newport, Oregon. <https://oregonmarinereserves.com/reserves/>. Accessed May 16, 2023.

[PFMC] Pacific Fishery Management Council. 1998. Description and Identification of Essential Fish Habitat for the Coastal Pelagic Species Fisheries Management Plan. Appendix D. December. [PFMC] Pacific Fishery Management Council. 2014. Pacific Coast Salmon Fishery Management Plan. Appendix A. September 2014. Portland, Oregon.

[PFMC] Pacific Fishery Management Council. 2020. Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery. August. Pacific Fishery Management Council, Portland, Oregon.

[PFMC] Pacific Fishery Management Council. 2021. Coastal Pelagic Species Fishery Management Plan as Amended through Amendment 18. Fisheries Management Plan. January. Portland, Oregon.

[USFWS] U.S. Fish and Wildlife Service. 2023. Information for Planning and Conservation Online Database. Environmental Conservation Online System. <https://ecos.fws.gov/ipac/>. Accessed April 2023.

[USFS] USDA Forest Service. 2000 and 2007. CALVEG—Existing Vegetation [ESRI personal geodatabase]. USDA, Forest Service, Pacific Southwest Region, Remote Sensing Lab, McClellan, California.

[USGS] U. S. Geological Survey. 2023. National Hydrology Dataset. <https://www.usgs.gov/national-hydrography/national-hydrography-dataset>. Accessed April 2023.

Appendix G: Power flow analysis reliability standards and criteria

(prepared by Quanta Technology)

Reliability Standards and Criteria

The Steady-State Power Flow Reliability Analysis was conducted to ensure the CAISO controlled grid complies with the North American Electric Reliability Corporation (NERC) reliability standards, Western Electricity Coordinating Council (WECC) regional criteria, and the CAISO planning standards.

NERC Reliability Standards

Quanta Technology conducted an analysis of the necessity for transmission network upgrades on the Northern California coast and Southern Oregon coast, adhering to the guidelines established by the North American Electric Reliability Corporation (NERC) for ensuring system reliability. These NERC reliability standards impose specific criteria to be met under diverse operating conditions. It is essential to note that these NERC reliability standards apply to both the California Independent System Operator (CAISO), operating as a registered NERC planning authority, and the Public Transmission Operators (PTOs), serving as transmission planners. Moreover, these standards represent the principal guidelines governing the interconnection of new facilities and the overall system performance:

- FAC-001: Facility Connection Requirements
- FAC-002: Coordination of Plans for New Facilities
- TPL-001-4: Transmission System Planning Performance Requirements

WECC Regional Criteria

WECC's System Performance TPL-001-WECC-CRT-2.2 Regional Criteria apply to CAISO as a planning authority and set forth additional requirements that must be met under a varied but specific set of operating conditions.

California ISO Planning Standards

California ISO's standards specify the grid planning criteria to be used when planning CAISO transmission facilities.[1] These standards cover the following:

- Specifics not covered in the NERC reliability standards and WECC regional criteria
- Interpretations of the NERC reliability standards and WECC regional criteria specific to the CAISO controlled grid
- If specific criteria that are more stringent than the NERC standards or WECC regional criteria should be adopted

Contingencies

The system's performance with the addition of the OSW development was evaluated under normal conditions (Category P0) and following the loss of single or multiple bulk electric system (BES) elements as defined by the applicable reliability standards and criteria.

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[1] http://www.caiso.com/Documents/FinalISOPlanningStandards-April12015_v2.pdf

Single Contingency (Category P1)

The assessment considered all possible Category P1 contingencies based on the following:

- 3-phase fault with loss of one generator (P1-1)[2]
- 3-phase fault with loss of one transmission circuit (P1-2)
- 3-phase fault with loss of one transformer (P1-3)
- 3-phase fault with loss of one shunt device (P1-4)
- Single line-to-ground (SLG) fault with loss of a single pole of a DC line (P1-5)

Single Contingency (Category P2)

The assessment considered selected possible Category P2 contingencies based on the following:

- Opening a line section without a fault (P2-1)
- SLG fault with loss of one bus section (P2-2)
- SLG fault with loss of one breaker (internal fault) (non-Bus-tie Breaker) (P2-3)
- SLG fault with loss of one breaker (internal fault) (Bus-tie Breaker) (P2-4)

Multiple Contingencies (Category P4)

The assessment considered some Category P4 contingencies with the loss of multiple elements caused by a stuck breaker (non-bus-tie breaker for P4-1 through P4-5 and bus-tie breaker for P4-6) attempting to clear an SLG fault on one of the following:

- Generator (P4-1)
- Transmission circuit (P4-2)
- Transformer (P4-3)
- Shunt device (P4-4)
- Bus section (P4-5)
- Bus(es) associated with bus-tie breaker (P4-6)

Multiple Contingencies (Category P5)

The assessment considered selected possible Category P5 contingencies of delayed fault clearing due to the failure of a non-redundant relay protecting the faulted element to operate as designed:

- SLG fault with loss of one generator (P5-1)
- SLG fault with loss of one transmission circuit (P5-2)
- SLG fault with loss of one transformer (P5-3)
- SLG fault with loss of one shunt device (P5-4)
- SLG fault with loss of one bus section (P5-5)

Multiple Contingencies (Category P7)

The assessment considered all possible Category P7 contingencies for an SLG fault with the loss of a common structure. They are as follows:

[2] Includes per CAISO Planning Standards, Loss of Combined Cycle Power Plant Module as a Single Generator Outage Standard.

- Any two adjacent circuits on a common structure (P7-1)[3]
- Loss of a bipolar DC line (P7-2)

Steady State Study Criteria

Normal Overloads

Normal overloads exceed 100% of the normal facility rating under Category P0 conditions (no contingency). Normal overloads are identified in reliability study power flow analyses using Reliability Standard TPL-001-4. The loading of all transmission system facilities must be within their normal ratings for Category P0 conditions.

Emergency Overloads

Emergency overloads are those that exceed 100% of emergency ratings under Categories P1 through P7 conditions. Emergency overloads are identified in the reliability study power flow analyses using Reliability Standard TPL-001-4. The loading of all transmission system facilities must be within their emergency ratings for Categories P1 through P7 conditions.

Power Flow Study Assumptions

Reliability Analysis

The analysis entails a steady-state power flow reliability analysis following the guidelines of the California Independent System Operator (CAISO) annual transmission planning process. CAISO TPP power flow cases for the year 2032 were used as the baseline power flow models. These cases reflect peak loading conditions for the years studied and were updated to reflect study assumptions. To support the evaluation of all OSW transmission alternatives, “2032 Summer Peak” long-term planning models (through the year 2032) are used in the study.

A reliability study was performed using TARA Software to evaluate the OSW development’s local impacts using steady-state power flow analysis (the studies do not consider short circuit analysis). The contingency analysis was performed using the applicable NERC category contingencies, and CAISO’s recommended performance criteria were used for the study.

From the perspective of transmission planning studies, it is needed to ensure that the constraints can be mitigated by “congestion management” or system redispatch. If not, they could potentially trigger network upgrades.

[3] Excludes circuits that share a common structure or common right-of-way for 1 mile or less.

Appendix H: Power flow analysis thermal overload violations

(prepared by Quanta Technology)

Table H-1. Thermal Violation Summary of "Low" OSW Development Scenarios

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	7.2a Loading %	7.2b Loading %
PITSBG D - PITSBG E 230 kV	P1-1: DEC STG1 18.00KV & DEC CTG1 18.00KV & DEC CTG2 18.00KV & DEC CTG3 18.00KV GEN UNITS	97.4	104.1	122.3
Collinsville - PITSBG F 230 kV	P1-2: COLLNSVL-PITSBG E #1 230KV [0]	85.6	Less than 60 %	138.4
PITSBG F - PITSBG E 230 kV	P1-2: COLLNSVL-PITSBG E #1 230KV [0]	88.4	Less than 60 %	131.5
Collinsville - PITSBG E 230 kV	P1-2: COLLNSVL-PITSBG F #1 230KV [0]	86.3	Less than 60 %	139.3
LAKEWOOD-MEADOW LANE-CLAYTON 115kV [2080]	P1-2: LAKEWOOD-CLAYTON 115KV [2082]	97.6	Less than 60 %	105.7
MORAGA-OAKLAND J 115kV [2760]	P2-1: SAN LEANDRO-OAKLND J #1 115KV [3520] (STATIN J-EDESJCT1)	100.7	Less than 60 %	113
EASTSHORE 230/115 kV TRANSFORMER #1	P2-3: E. SHORE 230KV - MIDDLE BREAKER BAY 3	90.7	Less than 60 %	104.5
PITTSBURG-EASTSHORE 230kV [5462]	P2-3: NEWARK E - 2E 230KV & NEWARK E-TASSAJAR-RESEARCH LINE	82.3	Less than 60 %	103.2
PITTSBURG-SAN MATEO 230kV [5463]	P2-3: NEWARK E - 2E 230KV & NEWARK E-TASSAJAR-RESEARCH LINE	91.2	Less than 60 %	107.6
TESLA C - NEWARK E 230 kV	P2-3: TESLA 500KV - MIDDLE BREAKER BAY 3	94.7	105.9	Less than 60 %
VACA-VACAVILLE 230 kV	P2-4: LAKEVILE 230KV - SECTION 2E & 2D	99.5	103.8	Less than 60 %
LOS ESTEROS-METCALF 230kV Section	P2-4: NEWARK D SECTION 1D & NEWARK E SECTION 1E 230KV	97.2	Less than 60 %	105.4
LOS ESTEROS-METCALF 230kV Section	P2-4: NEWARK D SECTION 1D & NEWARK E SECTION 1E 230KV	97.2	Less than 60 %	105.4
LOS ESTEROS-METCALF 230kV Section	P2-4: NEWARK D SECTION 1D & NEWARK E SECTION 1E 230KV	97.1	Less than 60 %	105.4
LOS ESTEROS-METCALF 230kV	P2-4: NEWARK D SECTION 1D & NEWARK E SECTION 1E 230KV	96.4	Less than 60 %	104.9
NEWARK-NORTHERN RECEIVING STATION #1 115kV [3100]	P2-4: NEWARK E 230KV - SECTION 1E & 2E	107.8	Less than 60 %	124
TESLA C - NEWARK E 230 kV	P2-4: PITSBG E 230KV - SECTION 1E & 2E	90.2	Less than 60 %	112.2

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	7.2a Loading %	7.2b Loading %
SAN LEANDRO-OAKLND J #1 115kV [3520]	P2-4: PITSBG E 230KV - SECTION 1E & 2E	95.3	Less than 60 %	111.6
SAN LEANDRO-OAKLND J #1 115kV [3520]	P2-4: PITSBG E 230KV - SECTION 1E & 2E	95.3	Less than 60 %	111.6
SOBRANTE-MORAGA 115kV [3742]	P2-4: PITSBG E 230KV - SECTION 1E & 2E	82.7	Less than 60 %	111.2
SAN LEANDRO-OAKLND J #1 115kV [3520]	P2-4: PITSBG E 230KV - SECTION 1E & 2E	96.2	Less than 60 %	112.6
PITTSBURG-KIRKER-COLUMBIA STEEL 115kV [3310]	P2-4: PITSBURG 115KV - SECTION 2E & 2D	103.4	Less than 60 %	122.7
PITTSBURG-KIRKER-COLUMBIA STEEL 115kV [3310]	P2-4: PITSBURG 115KV - SECTION 2E & 2D	103.5	119.5	Less than 60 %
LAWRENCE LIVERMORE LAB #1 TAP 115kV [4250]	P2-4: TESLA D 230KV - SECTION 1D & 2D	94.1	111.5	Less than 60 %
LAWRENCE LIVERMORE LAB 230/115 kV Transformer	P2-4: TESLA D 230KV - SECTION 1D & 2D	155.1	173.3	Less than 60 %
LAWRENCE LIVERMORE LAB #1 115kV [4250]	P2-4: TESLA D 230KV - SECTION 1D & 2D	188.7	213.7	Less than 60 %
LAWRENCE LIVERMORE LAB #1 TAP 115kV [4250]	P2-4: TESLA D 230KV - SECTION 1D & 2D	188.1	216.2	Less than 60 %
METCALF-MORGAN HILL 115kV [2570]	P7-1: Moss Landing - Green Valley #1 and #2 115 kV Lines	99.6	103	Less than 60 %
METCALF-PIERCY 115kV	P7-1: Newark-Dixon Landing 115 kV and Newark-Milpitas No. 1 115 kV lines	99.6	Less than 60 %	103.2
LOS ESTEROS-NORTECH 115kV [4032]	P7-1: Newark-Northern Nos. 1 & 2 115 kV lines	116	Less than 60 %	126.5
NORTECH-NORTHERN RECEIVING STATION 115kV [1551]	P7-1: Newark-Northern Nos. 1 & 2 115 kV lines	103.5	Less than 60 %	113.6
LOS ESTEROS-NORTECH 115kV [4032]	P7-1: Newark-Northern Nos. 1 & 2 115 kV lines	116.1	Less than 60 %	126.6
NORTHERN RECEIVING STATION-KIFER 115 kV	P7-1: Northern - Scott #1 and #2 115 kV Lines	137.2	Less than 60 %	147.3
SAN LEANDRO-OAKLND J #1 115kV [3520]	P7-1: Pittsburg-San Mateo 230 kV and Pittsburg-East Shore 230 kV lines	99.5	103.2	Less than 60 %
VIERRA - MANTECA 115 kV	P7-1: SCHULTE SW STA-KASSON-MANTECA 115KV [7472] & TESLA-SALADO-MANTECA 115KV [4000]	155.7	169.4	Less than 60 %
KIFER-FMC 115kV [2020]	P7-1: Swift - Metcalf & Piercy - Metcalf 115 kV Lines	99.9	Less than 60 %	112.3
AHSAHKA - OROFINO 115 kV	P1-3: DWORSHAK 100/13.8 kV TRANSFORMER	147.71	125.62	142.15
BENTON_CITY - RED MTN 115 kV	P1-2: COLD_CRK - MIDWAY B 115 kV	210.26	212.46	210.88

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	7.2a Loading %	7.2b Loading %
BIG EDDY - CELILO 500 kV #1	P1-2: BIG EDDY - CELILO 500 kV #2	Less than 90 %	Less than 90 %	159.93
BIG EDDY - CELILO 500 kV #2	P1-2: BIG EDDY - CELILO 500 kV #1	Less than 90 %	Less than 90 %	160.13
BIG EDDY 500/230 kV TRANSFORMER #3	P1-3: BIG EDDY 500/230 kV TRANSFORMER #2	121.27	98.24	Less than 90 %
CHEMAWA 230/115 kV TRANSFORMER	P1-3: SALEM 230/115 kV TRANSFORMER	94.63	Less than 90 %	Less than 90 %
CHEMAWA 230/115 kV TRANSFORMER	P0: Base Case	Less than 90 %	101.19	Less than 90 %
FAIRVIEW - NORWAY 115 kV	P2-4: FAIRVIEW 230 kV - SECTION BS	Less than 90 %	Less than 90 %	91.23
FAIRVIEW - SUMNER 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	115.1	Less than 90 %
FAIRVIEW - SUMNER 115 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	Less than 90 %	119.37
FAIRVIEW - RESTON #1 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	95.2	Less than 90 %
FAIRVIEW - RESTON #1 230 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	Less than 90 %	91.95
FAIRVIEW - RESTON #2 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	148.3	Less than 90 %
FAIRVIEW - RESTON #2 230 kV	P1-2: FAIRVIEW - DIXONVLE 500 kV	Less than 90 %	Less than 90 %	137.89
FAIRVEW2 - ROGUE 230 kV	P1-3: FAIRVIEW 500/230 kV TRANSFORMER	Less than 90 %	Less than 90 %	111.26
GLASGOW - HAUSER 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	112.66	Less than 90 %
GLASGOW - HAUSER 115 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	Less than 90 %	116.69
GLASGOW - SUMNER 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	114.47	Less than 90 %
GLASGOW - SUMNER 115 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	Less than 90 %	118.71
GRN_VALLEY - MARTIN 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	125.83	Less than 90 %
GRN_VALLEY - MARTIN 230 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	Less than 90 %	121
HAUSER - LAKE_SID 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	110.78	Less than 90 %
HAUSER - LAKE_SID 115 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	Less than 90 %	114.4
LAKE_SID - REEDSPRT 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	108.93	Less than 90 %
LAKE_SID - REEDSPRT 115 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	Less than 90 %	112.07

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	7.2a Loading %	7.2b Loading %
LANE - WENDSON 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	165.25	Less than 90 %
LONGVIEW - CHEMICAL 230 kV Section	P1-2: LONGVANX - NDP 230 kV	97.94	102.27	99.53
PEARL E - PEA_PEA_CIO 230 kV	P1-2: SHERWOOD - PEA_SHE_CIO 230 kV	Less than 90 %	91.5	90
ACORD - CHANDLER 115 kV	P1-2: COLD_CRK - MIDWAY B 115 kV	176.15	178.45	176.79
REEDSPRT - TAHKNICH 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	105.52	Less than 90 %
REEDSPRT - TAHKNICH 115 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	Less than 90 %	102.37
RESTON - DIXONVLE 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	158.59	Less than 90 %
RESTON - DIXONVLE 230 kV	P1-2: FAIRVIEW - DIXONVLE 500 kV	Less than 90 %	Less than 90 %	147.17
ROGUE 230/115 kV TRANSFORMER	P2-4: FAIRVIEW 230 kV - SECTION BS	Less than 90 %	96.57	Less than 90 %
TOLEDO - WENDSON 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	179.1	Less than 90 %
TOLEDO - WENDSON 230 kV	P1-2: MARION - SANTIAM 500 kV	Less than 90 %	Less than 90 %	95.37
BETHEL - BET_SAN_CIO 230 kV	P1-2: MARION - PEARL 500 kV	Less than 90 %	94.95	Less than 90 %
DAYTON - MCMINVIL 115 kV Section	P1-2: CASCADE - SHERWOOD 230 kV	Less than 90 %	93.27	Less than 90 %
PEARL - SHERWOOD 230 kV	P1-2: SHERWOOD - PEA_SHE_CIO 230 kV	Less than 90 %	99.46	92.93
SAMS VLY - WHTSTNE 230 kV	P1-2: SAMS VLY - MERIDINP 500 kV Section	Less than 90 %	122.28	148.44
CANYVLLE - RIDDLE 115 kV	P1-2: HANNATAP - DIXONVLE 230 kV	Less than 90 %	Less than 90 %	110.76
CANYVLLE - DAYSCREK 115 kV	P1-2: HANNATAP - DIXONVLE 230 kV	Less than 90 %	Less than 90 %	122.36
PARKDALE - GRANT PS 115 kV	P1-2: APPLEGAT - GRANT PS 115 kV	Less than 90 %	Less than 90 %	237.42
PARKDALE - JEROME P 115 kV	P1-2: APPLEGAT - GRANT PS 115 kV	Less than 90 %	Less than 90 %	237.37
HANNATAP - DIXONVLE 230 kV	P1-2: SAMS VLY - DIXONVLE 500 kV	Less than 90 %	Less than 90 %	117.56
HANNATAP - GLENDL 230 kV	P1-2: SAMS VLY - DIXONVLE 500 kV	Less than 90 %	Less than 90 %	124.87
APPLEGAT - CAVE JCT 115 kV	P1-2: PARKDALE - JEROME P 115 kV	Less than 90 %	Less than 90 %	217.82
APPLEGAT - GRANT PS 115 kV	P1-2: PARKDALE - JEROME P 115 kV	Less than 90 %	Less than 90 %	233.63

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	7.2a Loading %	7.2b Loading %
CAVE JCT - DELNORTE 115 kV	P1-2: CAVE JCT - OBRIEN P 115 kV	Less than 90 %	Less than 90 %	162.87
CAVE JCT - DELNORTE 115 kV	P1-2: DELNORTE - GASQUET 115 kV	Less than 90 %	94.59	Less than 90 %
CAVE JCT - OBRIEN P 115 kV	P1-2: CAVE JCT - DELNORTE 115 kV	Less than 90 %	95.8	156.53
CAVE JCT - SELMA 115 kV	P1-2: APPLEGAT - GRANT PS 115 kV	Less than 90 %	Less than 90 %	219.3
COPCO - LONEPINE 230 kV	P1-2: SNOGOOSE - KFALLS 500 kV	Less than 90 %	Less than 90 %	95.84
DELNORTE - GASQUET 115 kV	P1-2: CAVE JCT - DELNORTE 115 kV	Less than 90 %	96.71	154.08
GLENDL - GRANT PS 230 kV	P1-2: SAMS VLY - DIXONVLE 500 kV	Less than 90 %	Less than 90 %	122.25
JEROME P - SELMA 115 kV	P1-2: APPLEGAT - GRANT PS 115 kV	Less than 90 %	Less than 90 %	224.84
GASQUET - PATRICK 115 kV	P1-2: CAVE JCT - DELNORTE 115 kV	Less than 90 %	96.24	155.03
OBRIEN P - PATRICK 115 kV	P1-2: CAVE JCT - DELNORTE 115 kV	Less than 90 %	96.63	155.42
T_DALLES - 3MILE 115 kV Section	P1-2: CHENOWTH - DISCV_NW 115 kV	98.26	101.69	94.95
MORISON - NORWAY 115 kV	P2-4: FAIRVIEW 230 kV - SECTION BS	Less than 90 %	Less than 90 %	95.93

Table H-2. Thermal Violation Summary of "Mid" OSW Development Scenarios

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
LOS ESTEROS-NORTECH 115kV [4032]	P0: Base Case	99.7	103.8	Less than 60 %	103.3	Less than 60 %	Less than 60 %	Less than 60 %
LOS ESTEROS-NORTECH 115kV [4032]	P0: Base Case	99.8	103.8	Less than 60 %	103.3	Less than 60 %	Less than 60 %	Less than 60 %
PITSBG D - PITSBG E 230 kV	P1-1: DEC STG1 18.00KV & DEC CTG1 18.00KV & DEC CTG2 18.00KV & DEC CTG3 18.00KV GEN UNITS	97.4	124.8	118.9	120	115.1	124.3	122.5
PITTSBURG-EASTSHORE 230kV [5462]	P1-1: RUSCTYECST1 18.00KV & RUSCTYECCT2 15.00KV & RUSCTYECCT1 15.00KV GEN UNITS	101.1	115.8	Less than 60 %	Less than 60 %	Less than 60 %	112.5	112.4
Collinsville - PITSBG F 230 kV	P1-2: COLLNSVL-PITSBG E #1 230KV [0]	85.6	147.1	125.5	131.6	113	145.8	140.8
PITSBG F - PITSBG E 230 kV	P1-2: COLLNSVL-PITSBG E #1 230KV [0]	88.4	141.8	113.6	127	Less than 60 %	137.6	134.3
Collinsville - PITSBG E 230 kV	P1-2: COLLNSVL-PITSBG F #1 230KV [0]	86.3	148.1	126.3	132.5	113.7	146.7	141.7
LAKEWOOD-MEADOW LANE-CLAYTON 115kV [2080]	P1-2: LAKEWOOD-CLAYTON 115KV [2082]	97.6	105.8	Less than 60 %	Less than 60 %	Less than 60 %	106	104.9
NEWARK-NORTHERN RECEIVING STATION #1 115kV [3100]	P1-2: NEWARK E-F BUS TIE 230KV [4640]	108.6	120.6	123.8	Less than 60 %	124.1	Less than 60 %	Less than 60 %
MARTIN C 230/115 kV Transfromer 7	P1-2: SAN MATEO-MARTIN 230KV [9980]	Less than 60 %	Less than 60 %	153.4	Less than 60 %	201.6	Less than 60 %	Less than 60 %

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
MARTIN C 230/115 kV Transfromer 8	P1-2: SAN MATEO-MARTIN 230KV [9980]	Less than 60 %	Less than 60 %	178	Less than 60 %	234.1	Less than 60 %	Less than 60 %
EASTSHORE 230/115 kV TRANSFORMER #2	P1-3: E. SHORE 230/115KV TB 1	91.1	Less than 60 %	Less than 60 %	Less than 60 %	103.3	Less than 60 %	Less than 60 %
EASTSHORE 230/115 kV TRANSFORMER #1	P1-3: E. SHORE 230/115KV TB 2	90.9	Less than 60 %	Less than 60 %	Less than 60 %	103.1	Less than 60 %	Less than 60 %
NEWARK-NORTHERN RECEIVING STATION #2 115kV [3110]	P1-3: SSS 230/230KV TB 1	90.5	Less than 60 %	103.5	Less than 60 %	104.3	Less than 60 %	Less than 60 %
FMC-SAN JOSE B 115kV [2021]	P1-3: SSS 230/230KV TB 1	92.4	Less than 60 %	Less than 60 %	104.6	Less than 60 %	103.6	103.6
KIFER-FMC 115kV [2020]	P1-3: SSS 230/230KV TB 1	112	Less than 60 %	Less than 60 %	131.7	Less than 60 %	130.1	130.1
MARTIN C - EGBERT 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-EMBRCDRD)	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	170.4	Less than 60 %	Less than 60 %
EMBARCADERO - EGBERT S1 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	60.7	Less than 60 %	Less than 60 %	Less than 60 %	112.8	Less than 60 %	Less than 60 %
EGBERT Switching Station - EGBERT S3 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	Less than 60 %	Less than 60 %	138.8	Less than 60 %	171.2	Less than 60 %	Less than 60 %
EGBERT S1 - EGBERT Switching Station 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	64	Less than 60 %	104.7	Less than 60 %	115.2	Less than 60 %	Less than 60 %
EGBERT S3 - MARTIN 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	Less than 60 %	Less than 60 %	138.8	Less than 60 %	171.2	Less than 60 %	Less than 60 %
MARTIN C - EGBERT 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	Less than 60 %	Less than 60 %	136.8	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %
METCALF 230/115 kV TRANSFORMER #1	P2-2: MTCALF D 115KV SECTION 1X	93.3	104.3	103.7	Less than 60 %	103.8	Less than 60 %	Less than 60 %
EMBARCADERO - POTRERO 230 kV	P2-3: MARTIN C 115KV - MIDDLE BREAKER BAY 8	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	113	Less than 60 %	Less than 60 %

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
EMBARCADERO - POTRERO 230 kV	P2-3: MARTIN C 115KV - MIDDLE BREAKER BAY 8	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	113.9	Less than 60 %	Less than 60 %
EMBARCADERO - POTRERO 230 kV	P2-3: MARTIN C 115KV - MIDDLE BREAKER BAY 8	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	114	Less than 60 %	Less than 60 %
MARTIN-EMBARCADERO #2 230kV	P2-3: MARTIN C 230KV - MIDDLE BREAKER BAY 1	Less than 60 %	Less than 60 %	135.3	Less than 60 %	166.4	Less than 60 %	Less than 60 %
MARTIN-EMBARCADERO #2 230kV	P2-3: MARTIN C 230KV - MIDDLE BREAKER BAY 1	Less than 60 %	Less than 60 %	136.4	Less than 60 %	167.2	Less than 60 %	Less than 60 %
MONTA VISTA-WHISMAN 115kV	P2-3: MNTA VSA 115KV - MIDDLE BREAKER BAY 2	85	Less than 60 %	Less than 60 %	104.7	Less than 60 %	103.6	Less than 60 %
MORAGA-CASTRO VALLEY 230kV [5250]	P2-3: NEWARK E - 2E 230KV & NEWARK E-TASSAJAR-RESEARCH LINE	100.6	111.1	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %
NEWARK E - CASTRO VALLEY 230 kV	P2-3: NEWARK E - 2E 230KV & NEWARK E-TASSAJAR-RESEARCH LINE	93.1	105.2	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %
TRIMBLE-SAN JOSE B 115kV [4030]	P2-3: SANJOSEB 115KV - MIDDLE BREAKER BAY 2	81.8	Less than 60 %	Less than 60 %	103.6	Less than 60 %	Less than 60 %	Less than 60 %
TRIMBLE-SAN JOSE B 115kV [4030]	P2-3: SANJOSEB 115KV - MIDDLE BREAKER BAY 2	81.8	Less than 60 %	Less than 60 %	103.6	Less than 60 %	Less than 60 %	Less than 60 %
MONTA VISTA-HICKS 230kV Section	P2-4: METCALF 230KV - SECTION 1D & 1E	102.4	Less than 60 %	Less than 60 %	117.8	Less than 60 %	116.2	116.6
MONTA VISTA-HICKS 230kV [5210]	P2-4: METCALF 230KV - SECTION 1D & 1E	102.4	Less than 60 %	Less than 60 %	117.8	Less than 60 %	116.2	116.6
HICKS-METCALF 230kV [4910]	P2-4: METCALF 230KV - SECTION 1D & 1E	101.2	Less than 60 %	Less than 60 %	113.3	Less than 60 %	112	112.6

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
METCALF 230/115 kV TRANSFORMER #4	P2-4: METCALF 230KV - SECTION 1D & 1E	115.2	Less than 60 %	Less than 60 %	126.3	Less than 60 %	126	Less than 60 %
METCALF 230/115 kV TRANSFORMER #2	P2-4: METCALF 230KV - SECTION 1D & 1E	114.6	Less than 60 %	Less than 60 %	125.5	Less than 60 %	125.3	Less than 60 %
METCALF 230/115 kV TRANSFORMER #1	P2-4: METCALF 230KV - SECTION 2D & 2E	110.7	Less than 60 %	Less than 60 %	121.8	Less than 60 %	121.8	Less than 60 %
METCALF 230/115 kV TRANSFORMER #3	P2-4: METCALF 230KV - SECTION 2D & 2E	110	Less than 60 %	Less than 60 %	120.9	Less than 60 %	120.9	Less than 60 %
MCKEE-PIERCY 115kV [2379]	P2-4: MTCALF D SECTION 1D & MTCALF E SECTION 1E 115KV	92	Less than 60 %	Less than 60 %	103	Less than 60 %	Less than 60 %	Less than 60 %
METCALF-EL PATIO #1 115kV [2500]	P2-4: MTCALF D SECTION 2D & MTCALF E SECTION 2E 115KV	104.5	Less than 60 %	Less than 60 %	119.3	Less than 60 %	118.2	117.6
NEWARK E 230/115 kV Transfromer 11	P2-4: NEWARK D 230KV - SECTION 2D & 1D	111	123.6	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %
NEWARK F 230/115 kV Transfromer	P2-4: NEWARK D 230KV - SECTION 2D & 1D	107.9	120.1	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %
NORTECH-NORTHERN RECEIVING STATION 115kV [1551]	P2-4: NEWARK D SECTION 1D & NEWARK E SECTION 1E 115KV	98.8	104.2	103.3	Less than 60 %	103.2	Less than 60 %	Less than 60 %
LOS ESTEROS-NORTECH 115kV [4032]	P2-4: NEWARK D SECTION 2D & NEWARK E SECTION 2E 230KV	110.9	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	121.1	Less than 60 %
NORTECH-NORTHERN RECEIVING STATION 115kV [1551]	P2-4: NEWARK D SECTION 2D & NEWARK E SECTION 2E 230KV	97.6	Less than 60 %	Less than 60 %	106.2	Less than 60 %	107.1	Less than 60 %

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
LOS ESTEROS-NORTECH 115kV [4032]	P2-4: NEWARK D SECTION 2D & NEWARK E SECTION 2E 230KV	111	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	121.1	Less than 60 %
PITTSBURG-SAN MATEO 230kV [5463]	P2-4: NEWARK E 230KV - SECTION 1E & 2E	93.7	114.4	Less than 60 %	104.6	Less than 60 %	109.2	109
LOS ESTEROS-METCALF 230kV Section	P2-4: NEWARK E 230KV - SECTION 1E & 2E	102.7	Less than 60 %	Less than 60 %	118.1	Less than 60 %	117.5	117
LOS ESTEROS-METCALF 230kV Section	P2-4: NEWARK E 230KV - SECTION 1E & 2E	102.7	Less than 60 %	Less than 60 %	118.1	Less than 60 %	117.5	117
LOS ESTEROS-METCALF 230kV Section	P2-4: NEWARK E 230KV - SECTION 1E & 2E	102.6	Less than 60 %	Less than 60 %	118.1	Less than 60 %	117.5	117
LOS ESTEROS-METCALF 230kV	P2-4: NEWARK E 230KV - SECTION 1E & 2E	101.9	Less than 60 %	Less than 60 %	117.7	Less than 60 %	117.1	116.5
NEWARK-NORTHERN RECEIVING STATION #1 115kV [3100]	P2-4: NEWARK E 230KV - SECTION 1E & 2E	107.8	Less than 60 %	Less than 60 %	119.4	Less than 60 %	119.6	123.8
KIFER-FMC 115kV [2020]	P2-4: NEWARK E 230KV - SECTION 1E & 2E	95.7	104.8	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %
MORAGA-LAKEWOOD 115kV [3741]	P2-4: PITSBG D 230KV - SECTION 2D & 1D	59.6	105	106.7	107.7	107.1	107.3	106.8
MORAGA-LAKEWOOD 115kV [3741]	P2-4: PITSBG D 230KV - SECTION 2D & 1D	63.1	111.2	112.9	114	113.4	113.5	113.1
TESLA C - NEWARK E 230 kV	P2-4: PITSBG E 230KV - SECTION 1E & 2E	90.2	115.8	Less than 60 %	110.2	Less than 60 %	111	111.5
SAN LEANDRO-OAKLND J #1 115kV [3520]	P2-4: PITSBG E 230KV - SECTION 1E & 2E	95.3	110.6	Less than 60 %	Less than 60 %	Less than 60 %	106	105.9

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
SAN LEANDRO-OAKLND J #1 115kV [3520]	P2-4: PITSBG E 230KV - SECTION 1E & 2E	95.3	110.6	Less than 60 %	Less than 60 %	Less than 60 %	106.1	106
SOBRANTE-MORAGA 115kV [3742]	P2-4: PITSBG E 230KV - SECTION 1E & 2E	82.7	116.6	Less than 60 %	Less than 60 %	Less than 60 %	113.6	110
SAN LEANDRO-OAKLND J #1 115kV [3520]	P2-4: PITSBG E 230KV - SECTION 1E & 2E	96.2	111.6	Less than 60 %	103.9	Less than 60 %	107	106.9
PITTSBURG-KIRKER-COLUMBIA STEEL 115kV [3310]	P2-4: PITSBURG 115KV - SECTION 2E & 2D	103.4	120.4	119	119.9	117.5	121.5	120.7
SOBRANTE-GRIZZLY-CLAREMONT #2 115kV [3750]	P2-4: SOBRANTE 115KV - SECTION 1D & 1E	91.9	106.5	Less than 60 %	Less than 60 %	Less than 60 %	104.6	Less than 60 %
MTN VIEW-MONTA VISTA 115kV [2920]	P7-1: Britton-Monta Vista & Lawrence-Monta Vista 115 kV Lines	93.1	Less than 60 %	Less than 60 %	109.5	Less than 60 %	108.4	105
TLCYVACARCTR - VACA DIXON 230 kV	P7-1: GEYSERS #12-FULTON & GEYSERS #9-LAKEVILLE LINES	97.1	105.5	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	106.4
WARNERVILLE - WILSONRCTR 230 kV	P7-1: HENTAP1-MUSTANGSS #1 230KV [0] & TRANQLTYSS-MCMULLN1 #1 230KV [0]	72.9	110.9	110.8	103.2	111.2	104.4	104.5
TLCYVACARCTR - VACA DIXON 230 kV	P7-1: Ignacio-Sobrante 230kV and Lakeville-Sobrante #2 230kV	80	Less than 60 %	105	105.3	104.2	106.3	Less than 60 %
MORAGA-OAKLAND J 115kV [2760]	P7-1: Moraga-Oakland J 115 kV and San Leandro-Oakland J #1 115 kV lines	100.7	113	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
METCALF-PIERCY 115kV	P7-1: Newark-Dixon Landing 115 kV and Newark-Milpitas No. 1 115 kV lines	99.6	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	104
NEWARK-KIFER 115kV [3040]	P7-1: Newark-Northern Nos. 1 & 2 115 kV lines	86.8	Less than 60 %	Less than 60 %	Less than 60 %	103.5	Less than 60 %	Less than 60 %
LOS ESTEROS-NORTECH 115kV [4032]	P7-1: Newark-Northern Nos. 1 & 2 115 kV lines	116	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	126.5
NORTECH-NORTHERN RECEIVING STATION 115kV [1551]	P7-1: Newark-Northern Nos. 1 & 2 115 kV lines	103.5	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	113.7
LOS ESTEROS-NORTECH 115kV [4032]	P7-1: Newark-Northern Nos. 1 & 2 115 kV lines	116.1	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	Less than 60 %	126.5
SAN MATEO-BELMONT 115kV [3570]	P7-1: Ravenswood-San Mateo Nos. 1 & 2 230 kV lines	Less than 60 %	Less than 60 %	135.6	Less than 60 %	244.4	Less than 60 %	Less than 60 %
AHSAHKA - OROFINO 115 kV	P1-3: DWORSHAK 100/13.8 kV TRANSFORMER	147.71	133.79	133.62	133.64	133.48	133.6	133.45
ALVEY 230/115 kV TRANSFORMER	P0: Base Case	Less than 90 %	144.64	135.75	148.49	138.72	144.95	140.24
ALVEY - MCKENZEW 230 kV	P1-2: SANTIAM WEST - SANTIAM 230 kV	Less than 90 %	90.47	Less than 90 %	Less than 90 %	92.78	Less than 90 %	Less than 90 %
BANDON - FAIRVIEW 115 kV	P1-2: ROGUE - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	105.43	Less than 90 %
BANDON - MORISON 115 kV	P1-2: ROGUE - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	97.31	Less than 90 %	Less than 90 %	159.51	Less than 90 %
BENTON_CITY - RED MTN 115 kV	P1-2: COLD_CRK - MIDWAY B 115 kV	210.26	211.64	211.69	211.74	211.69	211.61	211.67
BIG EDDY - JOHN DAY 500 kV	P1-2: BIG EDDY - JOHN DAY 500 kV	Less than 90 %	Less than 90 %	104.48	Less than 90 %	102.45	Less than 90 %	Less than 90 %
BIG EDDY - CELILO 500 kV #1	P1-2: BIG EDDY - CELILO 500 kV #2	Less than 90 %	167.44	166.79	166.15	167.26	168.57	167.4

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BIG EDDY - CELILO 500 kV #2	P1-2: BIG EDDY - CELILO 500 kV #1	Less than 90 %	167.65	166.99	166.35	167.47	168.78	167.61
BIG EDDY 500/230 kV TRANSFORMER #3	P1-3: BIG EDDY 500/230 kV TRANSFORMER #2	121.27	138.01	138.08	139.46	140.38	138.31	138.15
CHEMAWA 230/115 kV TRANSFORMER	P1-3: SALEM 230/115 kV TRANSFORMER	94.63	96.69	97.37	98.49	Less than 90 %	98.14	98.46
CHEMAWA 230/115 kV TRANSFORMER	P0: Base Case	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	98.92	Less than 90 %	Less than 90 %
FAIRVIEW - NORWAY 115 kV	P1-2: ROGUE - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	112.83	Less than 90 %	Less than 90 %	192.64	Less than 90 %
FAIRVIEW - SUMNER 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	112.36	Less than 90 %	Less than 90 %	Less than 90 %
FAIRVIEW - SUMNER 115 kV	P1-2: ALVEY - DIXNVILE 500 kV Section	Less than 90 %	118.17	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %
FAIRVIEW - RESTON #1 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	97	Less than 90 %	Less than 90 %	Less than 90 %
FAIRVIEW - RESTON #2 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	Less than 90 %	94.06	146.12	113.21	96.8	117.41
FAIRVEW2 - ROGUE 230 kV	P1-2: ROGUE - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	174.9	Less than 90 %	Less than 90 %	240.33	Less than 90 %
GEISEL_M - PORT_ORFORD 115 kV	P1-2: ROGUE - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	103.47	Less than 90 %
GEISEL_M - ROGUE 115 kV	P1-2: ROGUE - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	103.19	Less than 90 %
GLASGOW - HAUSER 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	109.75	Less than 90 %	Less than 90 %	Less than 90 %
GLASGOW - HAUSER 115 kV	P1-2: ALVEY - DIXNVILE 500 kV Section	Less than 90 %	115.5	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %
GLASGOW - SUMNER 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	111.69	Less than 90 %	Less than 90 %	Less than 90 %
GLASGOW - SUMNER 115 kV	P1-2: ALVEY - DIXNVILE 500 kV Section	Less than 90 %	117.5	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
GRN_VALLEY - MARTIN 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	127.87	105.43	Less than 90 %	101.41
GRN_VALLEY - MARTIN 230 kV	P1-2: ALVEY - DIXNVILE 500 kV Section	Less than 90 %	104.08	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %
HAUSER - LAKE_SID 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	107.64	Less than 90 %	Less than 90 %	Less than 90 %
HAUSER - LAKE_SID 115 kV	P1-2: ALVEY - DIXNVILE 500 kV Section	Less than 90 %	113.25	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %
LAKE_SID - REEDSPRT 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	105.56	Less than 90 %	Less than 90 %	Less than 90 %
LAKE_SID - REEDSPRT 115 kV	P1-2: ALVEY - DIXNVILE 500 kV Section	Less than 90 %	110.98	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %
LANE - WENDSON 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	Less than 90 %	120.25	170.7	144.09	114.25	140.93
LONGVIEW - CHEMICAL 230 kV Section	P1-2: LONGVANX - NDP 230 kV	97.94	100.5	100.6	100.6	100.56	100.63	100.74
PEARL E - PEA_PEA_CIO 230 kV	P1-2: PEARL W - PEA_PEA_JMP 230 kV	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	93.82	Less than 90 %
PEARL E - PEA_PEA_CIO 230 kV	P1-2: SHERWOOD - PEA_SHE_CIO 230 kV	Less than 90 %	93.39	93.64	93.7	94.21	Less than 90 %	93.77
ACORD - CHANDLER 115 kV	P1-2: COLD_CRK - MIDWAY B 115 kV	176.15	177.57	177.62	177.66	177.62	177.56	177.61
REEDSPRT - TAHKNICH 115 kV	P1-2: WENDSON - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	101.77	Less than 90 %	Less than 90 %	Less than 90 %
REEDSPRT - TAHKNICH 115 kV	P1-2: ALVEY - DIXNVILE 500 kV Section	Less than 90 %	101.16	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %
RESTON - DIXONVLE 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	Less than 90 %	99.53	156.19	120.34	102.53	125.01
ROGUE 230/115 kV TRANSFORMER	P1-2: ROGUE - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	197.24	Less than 90 %

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
TOLEDO - WENDSON 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	Less than 90 %	141.53	185.02	166.92	137.67	158.44
BETHEL - BET_SAN_CIO 230 kV	P1-2: MARION - PEARL 500 kV	Less than 90 %	90.38	92.36	97.31	100.37	92.77	93.11
DAYTON - MCMINVIL 115 kV Section	P1-2: CASCADE - SHERWOOD 230 kV	Less than 90 %	Less than 90 %	90.35	90.54	90.44	90.03	90.54
SHERWOOD - PEA_SHE_CIO 230 kV	P1-2: PEARL E - PEA_PEA_CIO 230 kV	Less than 90 %	Less than 90 %	90.59	90.72	91.23	Less than 90 %	90.29
SHERWOOD - PEA_SHE_CIO 230 kV	P1-2: PEARL - PEA_PEA_CIO 230 kV	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	90.09	Less than 90 %
PEARL - SHERWOOD 230 kV	P1-2: PEARL W - PEA_PEA_JMP 230 kV	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	98.61	Less than 90 %
PEARL - SHERWOOD 230 kV	P1-2: SHERWOOD - PEA_SHE_CIO 230 kV	Less than 90 %	98.2	98.51	98.92	99.52	Less than 90 %	98.79
MERIDINP - SAMS VLY 500 kV Section	P0: Base Case	Less than 90 %	105.79	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %
SAMS VLY - WHTSTNE 230 kV	P1-2: SAMS VLY - MERIDINP 500 kV Section	Less than 90 %	Less than 90 %	136.71	127.2	227.61	100.8	100.15
SAMS VLY - WHTSTNE 230 kV	P1-2: MERIDINP - SAMS VLY 500 kV Section	Less than 90 %	236.87	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %
SNOGOOSE 500/230 kV TRANSFORMER	P1-2: SNOGOOSE - CAPTJACK 500 kV	Less than 90 %	119.38	Less than 90 %	Less than 90 %	112.46	Less than 90 %	Less than 90 %
SNOGOOSE - MALIN 230 kV	P1-2: SNOGOOSE - CAPTJACK 500 kV	Less than 90 %	129.29	Less than 90 %	Less than 90 %	120.81	Less than 90 %	Less than 90 %
WHTSTNE - MERIDINP 230 kV	P1-2: SAMS VLY - MERIDINP 500 kV Section	Less than 90 %	121.99	Less than 90 %	Less than 90 %	117.5	Less than 90 %	Less than 90 %
PARKDALE - GRANT PS 115 kV	P1-2: APPLEGAT - CAVE JCT 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	103.78	Less than 90 %	Less than 90 %	Less than 90 %
PARKDALE - JEROME P 115 kV	P1-2: APPLEGAT - CAVE JCT 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	104.03	Less than 90 %	Less than 90 %	Less than 90 %

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
APPLEGAT - CAVE JCT 115 kV	P1-2: CAVE JCT - SELMA 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	118.65	Less than 90 %	Less than 90 %	Less than 90 %
APPLEGAT - GRANT PS 115 kV	P1-2: CAVE JCT - SELMA 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	108.29	Less than 90 %	Less than 90 %	Less than 90 %
BOYLE - COPCO 230 kV	P1-2: SNOGOOSE - KFALLS 500 kV	Less than 90 %	104.63	Less than 90 %	Less than 90 %	99.2	Less than 90 %	Less than 90 %
BOYLE - KLAFALLS 230 kV	P1-2: SNOGOOSE - KFALLS 500 kV	Less than 90 %	112.32	Less than 90 %	Less than 90 %	106.86	Less than 90 %	Less than 90 %
CAVE JCT - DELNORTE 115 kV	P1-2: DELNORTE - GASQUET 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	127.18	Less than 90 %	95.79	Less than 90 %
CAVE JCT - OBRIEN P 115 kV	P1-2: CAVE JCT - DELNORTE 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	128.31	Less than 90 %	95.94	90.06
CAVE JCT - SELMA 115 kV	P1-2: APPLEGAT - CAVE JCT 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	118.18	Less than 90 %	Less than 90 %	Less than 90 %
COPCO - LONEPINE 230 kV	P1-2: SNOGOOSE - KFALLS 500 kV	Less than 90 %	139.15	Less than 90 %	Less than 90 %	133.05	Less than 90 %	Less than 90 %
DELNORTE - GASQUET 115 kV	P1-2: CAVE JCT - DELNORTE 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	130.63	Less than 90 %	98.35	92.46
JEROME P - SELMA 115 kV	P1-2: APPLEGAT - CAVE JCT 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	113.51	Less than 90 %	Less than 90 %	Less than 90 %
LONEPINE - MERIDINP 230 kV #1	P1-2: LONEPINE - MERIDINP 230 kV #2	Less than 90 %	117.36	Less than 90 %	Less than 90 %	102.39	Less than 90 %	Less than 90 %
LONEPINE - MERIDINP 230 kV #2	P1-2: LONEPINE - MERIDINP 230 kV #1	Less than 90 %	111.55	Less than 90 %	Less than 90 %	97.33	Less than 90 %	Less than 90 %
MERIDINP - SAMS VLY 500 kV Section	P0: Base Case	Less than 90 %	187.9	Less than 90 %	Less than 90 %	153.12	Less than 90 %	Less than 90 %
KFALLS - MERIDINP 500 kV	P1-2: ALVEY - DIXNVILE 500 kV Section	Less than 90 %	112.58	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %	Less than 90 %
GASQUET - PATRICK 115 kV	P1-2: CAVE JCT - DELNORTE 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	129.67	Less than 90 %	97.36	91.47
OBRIEN P - PATRICK 115 kV	P1-2: CAVE JCT - DELNORTE 115 kV	Less than 90 %	Less than 90 %	Less than 90 %	129.5	Less than 90 %	97.15	91.27

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	12.4a Loading %	12.4b Loading %	12.4c Loading %	12.4d Loading %	12.4e Loading %	12.4f Loading %
T_DALLES - 3MILE 115 kV Section	P1-2: CHENOWTH - DISCV_NW 115 kV	98.26	97.81	97.8	97.19	96.72	97.55	97.77
MORISON - NORWAY 115 kV	P1-2: ROGUE - FAIRVIEW 500 kV	Less than 90 %	Less than 90 %	117.79	Less than 90 %	Less than 90 %	197.18	Less than 90 %

Table H-3. Thermal Violation Summary of “High” OSW Development Scenarios

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	25.8a Loading %	25.8b Loading %
PITSBG D - PITSBG E 230 kV	P1-1: DEC STG1 18.00KV & DEC CTG1 18.00KV & DEC CTG2 18.00KV & DEC CTG3 18.00KV GEN UNITS	97.4	131.2	132.3
Collinsville - PITSBG F 230 kV	P1-2: COLLNSVL-PITSBG E #1 230KV [0]	85.6	152.9	154.3
PITSBG F - PITSBG E 230 kV	P1-2: COLLNSVL-PITSBG E #1 230KV [0]	88.4	136	137
Collinsville - PITSBG E 230 kV	P1-2: COLLNSVL-PITSBG F #1 230KV [0]	86.3	153.8	155.2
MARTIN-EMBARCADERO #2 230kV	P1-2: EGBERTSWSTA-MARTIN C 230KV [0]	Less than 60 %	154.6	155.8
MARTIN-EMBARCADERO #2 230kV	P1-2: EGBERTSWSTA-MARTIN C 230KV [0]	Less than 60 %	155.7	156.8
LAKEWOOD-MEADOW LANE-CLAYTON 115kV [2080]	P1-2: LAKEWOOD-CLAYTON 115KV [2082]	97.6	106.5	106.9
NEWARK-NORTHERN RECEIVING STATION #1 115kV [3100]	P1-2: NEWARK E-F BUS TIE 230KV [4640]	108.6	126.9	127.4
Collinsville 230/500 kV Transformer 2	P1-3: COLLNSVL 500/230KV TB 1	58.7	104.9	104.9
Collinsville 230/500 kV Transformer 1	P1-3: COLLNSVL 500/230KV TB 2	58.7	104.9	104.9
NEWARK-NORTHERN RECEIVING STATION #2 115kV [3110]	P1-3: SSS 230/230KV TB 1	90.5	107.4	107.1
MARTIN C - EGBERT 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-EMBRCDRD)	Less than 60 %	157.6	Less than 60 %
EMBARCADERO - EGBERT S1 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	60.7	110	110.8
EGBERT Switching Station - EGBERT S3 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	Less than 60 %	159	159.8
EGBERT S1 - EGBERT Switching Station 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	64	113	113.6
EGBERT S3 - MARTIN 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	Less than 60 %	159	159.8
MARTIN C - EGBERT 230 kV	P2-1: H-Z #2 230KV [9982] (MARTIN S5-MARTIN C)	Less than 60 %	Less than 60 %	158
EASTSHORE 230/115 kV TRANSFORMER #2	P2-2: EASTSHRE 115KV SECTION 1D	91.1	103.1	105.5
EASTSHORE 230/115 kV TRANSFORMER #1	P2-2: EASTSHRE 115KV SECTION 1E	90.9	103.1	105.9
METCALF 230/115 kV TRANSFORMER #1	P2-2: MTCALF D 115KV SECTION 1X	93.3	108.5	108.1

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	25.8a Loading %	25.8b Loading %
METCALF 230/115 kV TRANSFORMER #4	P2-2: MTCALF D 115KV SECTION 2Y	91.3	106.3	105.8
EMBARCADERO - POTRERO 230 kV	P2-3: MARTIN C 115KV - MIDDLE BREAKER BAY 8	Less than 60 %	108.3	109.1
EMBARCADERO - POTRERO 230 kV	P2-3: MARTIN C 115KV - MIDDLE BREAKER BAY 8	Less than 60 %	109.6	110.3
EMBARCADERO - POTRERO 230 kV	P2-3: MARTIN C 115KV - MIDDLE BREAKER BAY 8	Less than 60 %	109.7	110.3
MARTIN C 230/115 kV Transfromer 7	P2-3: MARTIN S1 230KV - MIDDLE BREAKER BAY 2	Less than 60 %	182.5	182.5
MARTIN C 230/115 kV Transfromer 8	P2-3: MARTIN S1 230KV - MIDDLE BREAKER BAY 2	Less than 60 %	211.8	211.8
NORTECH-NORTHERN RECEIVING STATION 115kV [1551]	P2-4: NEWARK D SECTION 1D & NEWARK E SECTION 1E 115KV	98.8	105.2	105.1
OLEUM-NORTH TOWER-CHRISTIE 115kV [3180]	P2-4: PITSBG D 230KV - SECTION 2D & 1D	51.5	117.8	119
NORTH TOWER - SOBRANTE 115 kV	P2-4: PITSBG D 230KV - SECTION 2D & 1D	51.6	118	119.2
MORAGA-LAKEWOOD 115kV [3741]	P2-4: PITSBG D 230KV - SECTION 2D & 1D	59.6	126.1	126.7
OLEUM-MARTINEZ 115kV [3170]	P2-4: PITSBG D 230KV - SECTION 2D & 1D	Less than 60 %	115.3	116.5
OLEUM-MARTINEZ 115kV [3170]	P2-4: PITSBG D 230KV - SECTION 2D & 1D	Less than 60 %	115.5	116.6
MORAGA-LAKEWOOD 115kV [3741]	P2-4: PITSBG D 230KV - SECTION 2D & 1D	63.1	133.5	134.1
SOBRANTE-MORAGA 115kV [3742]	P2-4: PITSBG E 230KV - SECTION 1E & 2E	82.7	106.1	107.5
PITTSBURG-KIRKER-COLUMBIA STEEL 115kV [3310]	P2-4: PITSBURG 115KV - SECTION 2E & 2D	103.4	119.4	119.9
PALERMO - E.MRY J2 115 kV	P7-1: Colgate - Rio Oso 230kV and Table Mountain(D)-Rio Oso 230 kV Line	67.2	105.9	105.3
WARNERVILLE - WILSONRCTR 230 kV	P7-1: HENTAP1-MUSTANGSS #1 230KV [0] & TRANQLTYSS-MCMULLN1 #1 230KV [0]	72.9	154.6	154
TULUCAY - TLCYVACARCTR 230 kV	P7-1: Ignacio-Sobrante 230kV and Lakeville-Sobrante #2 230kV	76.8	110.1	110.6
TLCYVACARCTR - VACA DIXON 230 kV	P7-1: Ignacio-Sobrante 230kV and Lakeville-Sobrante #2 230kV	80	115	115.6
NEWARK-KIFER 115kV [3040]	P7-1: Newark-Northern Nos. 1 & 2 115 kV lines	86.8	107.5	107.3

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	25.8a Loading %	25.8b Loading %
NEWARK-KIFER 115kV [3040]	P7-1: Newark-Northern Nos. 1 & 2 115 kV lines	87	106	105.8
NORTHERN RECEIVING STATION-KIFER 115 kV	P7-1: Northern - Scott #1 and #2 115 kV Lines	137.2	Less than 60 %	147.2
COTTONWOOD - ROUND MOUNTAIN 230 kV	P7-1: Pit No.1-Cottonwood(F) 230 kV Line and Round Mountain-Cottonwood(E) No.2 230 kV Line	45.2	110	Less than 60 %
MARTINEZ-SOBRANTE 115kV [2270]	P7-1: Pittsburg-Tidewater 230 kV and Pittsburg-Tesoro SW STA 230 kV lines	82.1	Less than 60 %	103.1
SAN MATEO-BELMONT 115kV [3570]	P7-1: Ravenswood-San Mateo Nos. 1 & 2 230 kV lines	Less than 60 %	236.3	236.5
HUMBOLDT - BRDGVLLE 115 kV	P7-1: Round Mountain-Cottonwood(E) No.2 230 kV Line and Round Mountain-Cottonwood(E) No.3 230 kV Line	Less than 60 %	Less than 60 %	110.9
WEBER - TESLA E 230 kV	P7-1: Table Mountain(D)-Rio Oso 230 kV Line and Table Mountain(D)-Palermo 230 kV Line	Less than 60 %	118.5	118.7
TESLA E 500/230 kV Transformer	P7-1: Table Mountain(D)-Rio Oso 230 kV Line and Table Mountain(D)-Palermo 230 kV Line	54	112.5	112
VIERRA - MANTECA 115 kV	P7-1: Table Mountain(D)-Rio Oso 230 kV Line and Table Mountain(D)-Palermo 230 kV Line	64.8	114.5	114.9
AHSAHKA - DWORSHAK 115 kV	P1-3: DWORSHAK 500/100 kV TRANSFORMER	Less than 90 %	156.73	156.62
AHSAHKA - OROFINO 115 kV	P1-3: DWORSHAK 500/100 kV TRANSFORMER	Less than 90 %	269.21	269.04
AHSAHKA - OROFINO 115 kV	P1-3: DWORSHAK 100/13.8 kV TRANSFORMER	147.71	Less than 90 %	Less than 90 %
ALVEY 230/115 kV TRANSFORMER	P0: Base Case	Less than 90 %	110.54	103.57
ALVEY - LANE 230 kV	P1-2: LANE - ALVEY 500 kV	Less than 90 %	145.78	Less than 90 %
ALVEY - MCKENZEW 230 kV	P1-2: ALVEY - MARION 500 kV Section	Less than 90 %	115.24	138.49
ALVEY - MARION 500 kV Section	P0: Base Case	Less than 90 %	Less than 90 %	110.54
ALVEY - MARION 500 kV Section	P1-2: LANE - MARION 500 kV	Less than 90 %	Less than 90 %	103.28
BANDON - MORISON 115 kV	P2-4: FAIRVIEW 230 kV - SECTION BS	Less than 90 %	108.57	Less than 90 %
BENTON_CITY - RED MTN 115 kV	P1-2: COLD_CRK - MIDWAY B 115 kV	210.26	216.73	216.76

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	25.8a Loading %	25.8b Loading %
BIG EDDY 500/230 kV TRANSFORMER #3	P1-3: BIG EDDY 500/230 kV TRANSFORMER #2	121.27	Less than 90 %	Less than 90 %
CARLTON - WINDSHAR 115 kV	P1-2: CARLTON - CARLTON 115 kV	Less than 90 %	110.48	Less than 90 %
CHEMAWA 230/115 kV TRANSFORMER	P1-3: SALEM 230/115 kV TRANSFORMER	94.63	Less than 90 %	Less than 90 %
CHEMAWA 230/115 kV TRANSFORMER	P0: Base Case	Less than 90 %	106.67	116.36
CHEMAWA - SANTIAM EAST 230 kV	P1-2: MARION - PEARL 500 kV	Less than 90 %	101.4	121.26
FAIRVIEW - NORWAY 115 kV	P2-4: FAIRVIEW 230 kV - SECTION BS	Less than 90 %	128.38	101.19
FAIRVIEW - SUMNER 115 kV	P1-3: WENDSON 500/230 kV TRANSFORMER	Less than 90 %	150.32	120.79
FAIRVIEW - RESTON #1 230 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	116.37	Less than 90 %
FAIRVIEW - RESTON #2 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	Less than 90 %	126.72
FAIRVIEW - RESTON #2 230 kV	P1-2: LANE - ALVEY 500 kV	Less than 90 %	170.32	Less than 90 %
FAIRVEW2 - ROGUE 230 kV	P1-3: FAIRVIEW 500/230 kV TRANSFORMER	Less than 90 %	148.74	120.76
GLASGOW - HAUSER 115 kV	P1-3: WENDSON 500/230 kV TRANSFORMER	Less than 90 %	147.67	118.14
GLASGOW - SUMNER 115 kV	P1-3: WENDSON 500/230 kV TRANSFORMER	Less than 90 %	149.64	120.11
GRN_VALLEY - MARTIN 230 kV	P1-2: FAIRVIEW - RESTON 230 kV	Less than 90 %	154.23	116.3
HAUSER - LAKE_SID 115 kV	P1-3: WENDSON 500/230 kV TRANSFORMER	Less than 90 %	145.54	115.99
LAKE_SID - REEDSPRT 115 kV	P1-3: WENDSON 500/230 kV TRANSFORMER	Less than 90 %	143.44	113.86
LANE - WILLOW C 115 kV	P1-2: EUGENE - LANE 115 kV	Less than 90 %	Less than 90 %	104.08
LANE - WILLOW C 115 kV	P1-2: LANE - ALVEY 500 kV	Less than 90 %	116.29	Less than 90 %
LANE - DAN_LANE_CIO 115 kV	P1-2: ALVEY - MCKENZEW 230 kV	Less than 90 %	Less than 90 %	109.18
LANE - DAN_LANE_CIO 115 kV	P1-2: LANE - ALVEY 500 kV	Less than 90 %	109.41	Less than 90 %
LANE - WENDSON 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	Less than 90 %	99.58
LANE - WENDSON 230 kV	P1-2: TOLEDO - WENDSON 230 kV	Less than 90 %	98.53	Less than 90 %
LANE - MARION 500 kV	P1-2: ALVEY - MARION 500 kV Section	Less than 90 %	Less than 90 %	156.1
LANE - MARION 500 kV	P1-2: LANE - ALVEY 500 kV	Less than 90 %	129.26	Less than 90 %

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	25.8a Loading %	25.8b Loading %
LONGVIEW - CHEMICAL 230 kV Section	P1-2: LONGVANX - NDP 230 kV	97.94	107.95	107.86
MARION - PEARL 500 kV	P1-2: SAMS VLY - DIXONVLE 500 kV	Less than 90 %	94.75	116.75
PEARL E - PEA_PEA_CIO 230 kV	P1-2: SHERWOOD - PEA_SHE_CIO 230 kV	Less than 90 %	93.5	106.25
ACORD - CHANDLER 115 kV	P1-2: COLD_CRK - MIDWAY B 115 kV	176.15	182.56	182.58
REEDSPRT - TAHKNICH 115 kV	P1-3: WENDSON 500/230 kV TRANSFORMER	Less than 90 %	133.3	103.8
RESTON - DIXONVLE 230 kV	P1-2: WENDSON - LANE 500 kV	Less than 90 %	Less than 90 %	134.92
RESTON - DIXONVLE 230 kV	P1-2: LANE - ALVEY 500 kV	Less than 90 %	182.56	Less than 90 %
TILLAMOK 230/115 kV TRANSFORMER	P1-2: CARLTON - TILLAMOK 230 kV	Less than 90 %	Less than 90 %	134.45
TILLAMOK 230/115 kV TRANSFORMER	P0: Base Case	Less than 90 %	93.59	Less than 90 %
TOLEDO - WENDSON 230 kV	P1-2: ALVEY - MARION 500 kV Section	Less than 90 %	Less than 90 %	189.12
TOLEDO - WENDSON 230 kV	P1-2: LANE - ALVEY 500 kV	Less than 90 %	184.68	Less than 90 %
BETHEL - BET_SAN_CIO 230 kV	P1-2: MARION - PEARL 500 kV	Less than 90 %	128.95	151.94
DAYTON - MCMINVIL 115 kV Section	P1-2: CASCADE - SHERWOOD 230 kV	Less than 90 %	Less than 90 %	112.86
MURRAY H - MURRAY 115 kV #1	P1-2: MURRAY H - ST MARYS 230 kV	Less than 90 %	105.36	103.53
MURRAY H - SHERWOOD 230 kV #1	P1-2: MURRAY H - SHERWOOD 230 #2	Less than 90 %	108.7	106.26
MURRAY H - SHERWOOD 230 kV #2	P1-2: MURRAY H - SHERWOOD 230 #2	Less than 90 %	108.7	106.26
SHERWOOD - PEA_SHE_CIO 230 kV	P1-2: PEARL - SHERWOOD 230 kV	Less than 90 %	90.35	108.73
PEARL - SHERWOOD 230 kV	P1-2: SHERWOOD - PEA_SHE_CIO 230 kV	Less than 90 %	103.22	121.7
SAMS VLY - WHTSTNE 230 kV	P1-2: SAMS VLY - MERIDINP 500 kV Section	Less than 90 %	123.69	191.48
SNOGOOSE 500/230 kV TRANSFORMER	P1-2: SNOGOOSE - CAPTJACK 500 kV	Less than 90 %	Less than 90 %	93.07
WHTSTNE - MERIDINP 230 kV	P1-2: SAMS VLY - MERIDINP 500 kV Section	Less than 90 %	Less than 90 %	92.85
CANYVLLE - DAYSCREK 115 kV	P1-2: HANNATAP - DIXONVLE 230 kV	Less than 90 %	100.34	97.39
HANNATAP - GLENDL 230 kV	P1-2: SAMS VLY - DIXONVLE 500 kV	Less than 90 %	91.66	92.33
CALAPOYA - DIA HILL 230 kV	P1-2: ALVEY - MARION 500 kV Section	Less than 90 %	Less than 90 %	106.55

Overloaded Facility	Contingency (Worst)	2032 Summer Peak Loading %	25.8a Loading %	25.8b Loading %
CALAPOYA - FRY 230 kV	P1-2: ALVEY - MARION 500 kV Section	Less than 90 %	Less than 90 %	103.69
COPCO - LONEPINE 230 kV	P1-2: SNOGOOSE - KFALLS 500 kV	Less than 90 %	Less than 90 %	100.72
DIA HILL - MCKENZEW 230 kV	P1-2: ALVEY - MARION 500 kV Section	Less than 90 %	96.85	120.21
LONEPINE - MERIDINP 230 kV #1	P1-2: LONEPINE - MERIDINP 230 kV #2	Less than 90 %	Less than 90 %	102.01
LONEPINE - MERIDINP 230 kV #2	P1-2: LONEPINE - MERIDINP 230 kV #1	Less than 90 %	Less than 90 %	96.97
MERIDINP - SAMS VLY 500 kV Section	P0: Base Case	Less than 90 %	Less than 90 %	138.08
MCKENZEW - WILAKENZ 115 kV	P1-2: ALVEY - MCKENZEW 230 kV	Less than 90 %	100.47	115.04
T_DALLES - 3MILE 115 kV Section	P1-2: CHENOWTH - DISCV_NW 115 kV	98.26	105.31	105.97
MORISON - NORWAY 115 kV	P2-4: FAIRVIEW 230 kV - SECTION BS	Less than 90 %	132.8	105.91
JULIAETT - MOSCOW 115 kV	P1-3: DWORSHAK 500/100 kV TRANSFORMER	Less than 90 %	127.62	127.15
JULIAETT - OROFINO 115 kV	P1-3: DWORSHAK 500/100 kV TRANSFORMER	Less than 90 %	133.55	133.09
NEZPERCE - OROFINO 115 kV	P1-3: DWORSHAK 500/100 kV TRANSFORMER	Less than 90 %	130.86	131.12
GRNDROND - BOYER 115 kV Section	P1-2: CARLTON - TILLAMOK 230 kV	Less than 90 %	Less than 90 %	158.29

Appendix I: Onshore transmission unit cost parameters

(prepared by Quanta Technology)

Data Source	Transmission Infrastructure	Cost / mile or unit ($M)
PacifiCorp 2023	Construct New 500 kV POI Substation	34.3
PacifiCorp 2023	Install New 500-230 kV Auto Transformer	39.7
PacifiCorp 2023	Construct New 500 kV Double-Circuit Line	6.21
PacifiCorp 2023	Construct New 500 kV Single-Circuit Line	3.88
PG&E 2022	Install New 500-230 kV Auto Transformer	37
PG&E 2022	Construct New 500 kV POI Substation	60
PG&E 2022	Construct New 115 kV Single-Circuit Line*	3.07
PG&E 2022	Construct New 500 kV Single-Circuit Line*	4.15
PG&E 2022	Construct New 500 kV Double-Circuit Line*	6.64
PG&E 2022	Install New 500-115 kV Auto Transformer	11
Quanta Technology 2023	Install New 500-230 kV Phase Shifting Transformer	74
Quanta Technology 2023	Install New 500-115 kV Phase Shifting Transformer	22
ICF 2018	Construct New HVDC Line	5.19
ICF 2018	Construct Land-based HVDC Conversion Station	478.88
PG&E 2022	Add Line Position	15.5

*Includes applied factors for terrain, population density and line length

Data Sources:

ICF International, Inc. “Assessment of the Potential for High-Voltage Direct Current Transmission to Mitigate Impacts of Non-Dispatchable Generation Technologies,” Final Report, Submitted to United States Energy Information Administration, March 2018.

PacifiCorp, “Oregon Public Utility Commission Request for Offshore Wind Integration - Economic Study Request,” March 16, 2023.

Pacific Gas and Electric Company, 2022 PG&E Generator Interconnection Unit Cost Guide, Revised 1/12/2022, http://www.caiso.com/Documents/PGE2022FinalPerUnitCostGuide.xlsx.

Appendix J: ORBIT cost model inputs and learning curve assumptions

(prepared by NREL)

Table J-1 provides a list of the key inputs to ORBIT for each offshore wind site. The locations of the Port of Humboldt and the Port of Coos Bay were used to calculate representative distances from each site to the closest port for staging and integration of wind plant components. Water depth and port distance inputs are a single average value for each location. The plant capacity and point of interconnection vary by transmission alternative.

Table J-1. Site Parameters Used in ORBIT

Site	Capacity (GW)	Water Depth (m)	Distance to Port (km)	Distance to Cable Landfall (km)	Point of Interconnection
Coos Bay	1.3 – 3.9	620	66	58 90 346	Wendson Fairview Portland
Brookings	1.8 – 5.9	740	150	54 71	Rogue Del Norte
Del Norte	2.1 – 7.0	810	131	54	Del Norte
Humboldt	2.0 – 2.7	755	45	44 452 670 769	Humboldt Elk SF Bay Area Moss Landing
Cape Mendocino	2.1 – 6.3	1200	110	307 526 624	Elk SF Bay Area Moss Landing

We used the following set of technology assumptions for wind plant components. Each offshore wind power plant used 15-MW wind turbines with dimensions based on the IEA 15-MW Reference Wind Turbine (Gaertner et al. 2020). While this turbine rating may be somewhat conservative for the early 2030s, as turbine manufacturers have already announced plans to develop 18-MW platforms, data presented in Musial et al. (2023) shows that it has historically taken 6 to 8 years from the installation of working prototypes for that platform rating to reach significant market penetration. We assume a turbine capital cost of $1,500/kW or $22.5 million per turbine. This represents an increase of $200/kW (15.4%) over other recent analyses (Beiter et al. 2020, Cooperman et al. 2022, Duffy et al. 2022) and reflects some cost increases from inflation, labor, and supply chain pressures (Lloyd-Williams 2023).

Because the water depths in the study region are too deep for fixed-bottom designs, we modeled only floating wind turbines and substations. There are many different designs that could be adopted for floating platforms and mooring systems; we developed cost estimates based on semi-submersible platforms with semi-taut mooring lines and drag embedment anchors. These assumptions are consistent with other recent studies (Beiter et al. 2020b; Shields et al. 2021; Musial et al. 2019). Although we would expect to see some variation in cost for alternative design choices, they are not the focus of this study. The wind turbines and floating platforms are integrated at port and towed out to the installation sites. We used a wind and wave time series (Hersbach et al. 2020) from the Humboldt wind energy area[1] to simulate weather delays affecting the tow-out process and other vessel operations during installation. The intra-array power collection system consisted of dynamic AC cables with a voltage of 132 kV (Carbon Trust 2022), organized into strings of no more than 9 turbines. Intra-array cable lengths were calculated for each segment based on 4-rotor-diameter (D) by 10D turbine spacing, with cables suspended horizontally in the water column at a depth of 300 m below the water surface between turbines.

The offshore export system includes floating offshore substations, export cables, and subsea "backbone" cables that directly connect two wind plants or coastal substations. We broadly categorize the components as substations or cables, which are either High Voltage Alternating Current (HVAC) or High Voltage Direct Current (HVDC).

HVAC substations: Floating platforms serve as collection points for the strings of intra-array cables up to a maximum of 1 GW per platform, which is comparable to current fixed-bottom HVAC substation capacities. Each platform holds a transformer to step up from the array system voltage of 132 kV to the export cable voltage of 400 kV. The offshore substation also has switchgear to protect the equipment against electrical faults. HVAC export systems require reactive power compensation to maintain the cable voltage at the specified level. The size and cost of reactive compensation systems depend on the export cable length. The total cost of an HVAC substation (approximately $160 million) includes major electrical components, a floating platform scaled to the weight of those components, a mooring system sized for the water depth, installation at sea, and project management costs.

HVDC substations: Floating platforms serve as collection points for the strings of intra-array cables up to a maximum of 2 GW per platform, which is comparable to fixed-bottom HVDC substations that are planned to be in service by 2030 (TenneT 2023). Each platform holds a transformer to step up from the array system voltage of 132 kV to

[1] To investigate the sensitivity of our modeling to the choice of weather time series, we also ran ORBIT for all of the wind plants in the 25.8 GW scenario using two additional weather profiles from the Coos Bay and Brookings Call Areas. Mean significant wave heights: 2.39 m (Humboldt), 2.44 m (Brookings), 2.35 m (Coos Bay). Mean wind speeds at 150 m: 9.3 m/s (Humboldt), 10.5 m/s (Brookings), 9.2 m/s (Coos Bay). Relative to the Humboldt weather profile, installation costs were 0.9% lower with Coos Bay weather and 6.0% higher with Brookings weather. Total CapEx was 0.1% lower with Coos Bay weather and 0.7% higher with Brookings weather. We considered the range of less than 1% in total CapEx to be small enough to use Humboldt weather conditions for all ORBIT results reported in this study.

the export cable voltage of 525 kV. HVDC export systems require an AC/DC converter between the collection system and the export cable. The offshore platform also holds DC circuit breakers to protect the equipment from electrical faults. The total cost of an HVDC substation (approximately $700 million) includes major electrical components, a floating platform scaled to the weight of those components, a mooring system appropriate to the water depth, installation at sea, and project management costs.

HVAC export cables: Subsea export cables extend from an offshore substation to a coastal landfall point where there is a transition joint between the subsea and overland cables. Floating offshore wind plants require “dynamic” cables that are designed to withstand motion while in operation. Export cables can use a relatively short segment of dynamic cable between the floating substation and the seabed, then transition to static cable for the remaining distance to the cable landfall. For this study, we assume the availability of dynamic HVAC power export cables with a capacity of 1 GW, which is approximately twice the capacity of current HVAC export cables. The total cost of each cable (approximately $2.4 million per kilometer) is calculated using the straight-line distance—plus 5% to allow for minor route deviations—between the wind plant and the cable landfall and includes cable procurement, installation, and project management.

HVDC export cables: HVDC export cables are used for all segments of the offshore backbone between individual offshore wind plants in certain scenarios, as well as for some export cable segments between an offshore substation and a coastal landfall. Floating offshore wind plants require dynamic cables that are designed to withstand motion while in operation. Static cables can be used for segments that are not suspended above the seabed, but dynamic cables are needed to connect to a floating substation. For this study, we assume the availability of dynamic HVDC power cables with a capacity of 2 GW, which is comparable to currently available static HVDC cables. We model a 525 kV bipole configuration with metallic return, bundled for installation in a single trench. The total cost of each cable (approximately $4.3 million per kilometer) is calculated using 105% of the straight-line distance between the cable endpoints and includes procurement, installation, and project management.

Table J-2 summarizes the total costs (including installation) of offshore cables and substations used in this study and provides a comparison with costs for similar equipment used in two other recent studies. Guidehouse (Huang, Busse, and Baker 2023) surveyed transmission technologies relevant to floating offshore wind that are currently available or under development. As part of the Atlantic Offshore Wind Transmission Study (NREL, forthcoming), DNV assessed capital costs for HVAC and HVDC technologies suitable for fixed-bottom offshore wind sites along the U.S. Atlantic Coast.

Table J-2. Comparison of Offshore Transmission System Component Costs

Component	Cost this study	Cost – DNV*	Cost – Guidehouse**
HVAC cable cost (& capacity)	$2.4 million per km (1000 MW)	$2.0-2.1 million per km (400 MW)	$1.2-1.8 million per km (300-500 MW)
HVAC offshore substation (& capacity)	$160 million (1000 MW)	$155 million (1200 MW)	$120-190 million (800-1000 MW)
HVDC cable (& capacity)	$4.3 million per km (2 GW)	$4.4 million per km (2 GW)	$1.8-3.3 million per km (800-1300 MW)
HVDC offshore substation (& capacity)	$720 million (2 GW)	$690 million (2GW)	$296-616 million (800-1200 MW)

Sources: *DNV = NREL (forthcoming); **Guidehouse = Huang, Busse, and Baker (2023)

To estimate how offshore wind plant CapEx is likely to change over time, we apply a learning rate. The process for projecting future floating offshore wind costs is taken from Shields et al. (2022) and includes the following steps (summarized in Figure J-1):

1. Calculate hypothetical present-day costs for commercial-scale floating offshore wind projects using ORBIT (Nunemaker et al. 2020).
2. Scale up ORBIT outputs by a factor of 2.5 to represent costs of pilot-scale projects (Shields et al. 2022; Musial et al. 2020; Musial et al. 2019). This step corrects for the fact that ORBIT models commercial-scale project costs.
3. Determine the global floating offshore wind deployment trajectory and learning rate to calculate the learning curve and associated CapEx cost reductions.
4. Apply cost reductions from learning to the present-day costs (step 2) to estimate future costs.

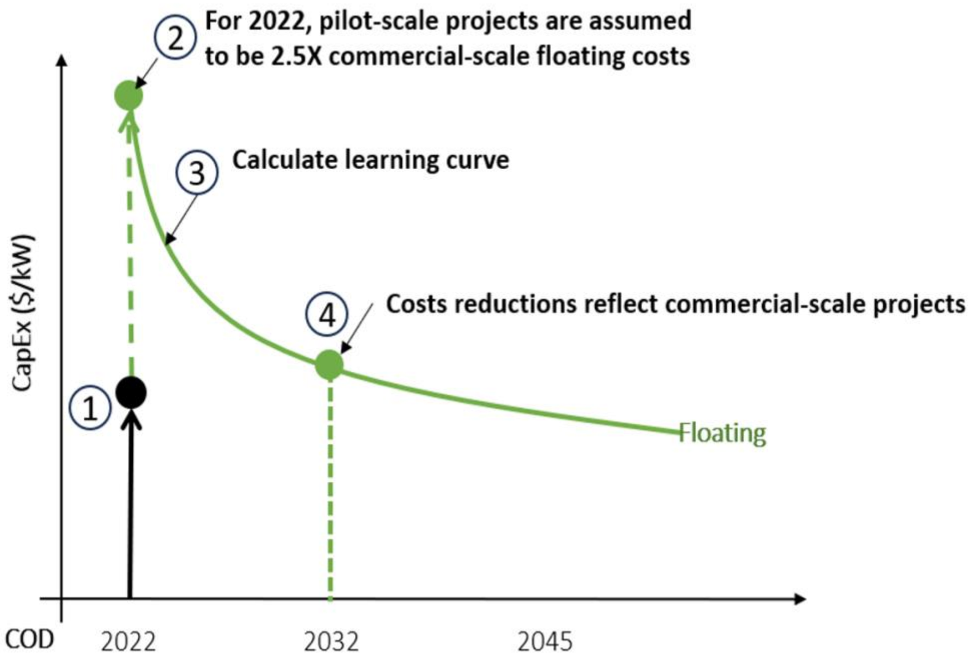

Figure J-1. Summary of cost projection methodology. Steps from cost projection process identified in bubbles on chart.

We average projections of floating offshore wind deployment to obtain the deployment trajectory presented in Table J-3 through 2050.

Table J-3. Cumulative Global Floating Offshore Wind Energy Deployment Projection

Cumulative capacity	Year 2023	Year 2025	Year 2030	Year 2035	Year 2040	Year 2045	Year 2050
Global Deployment (MW)	123	975	9,709	45,510	110,155	195,194	275,207

Sources: 2023 deployment obtained from Musial et al. (2023); other years represent an average of GWEC (2022), Wood Mackenzie (2020), Hannon et al. (2019), DNV (2022), ORE Catapult (2022), AEGIR Insights (2022), and 4C Offshore (2023).

We calculate the CapEx cost reductions from learning presented in Figure J-2 using a floating offshore wind learning rate of 11.5% (Shields et al. 2022). This learning rate is equivalent to a reduction of 11.5% in CapEx for every doubling of floating offshore wind deployment. Note in Figure J-2 that the cost reductions are more rapid between 2022 and 2030 due to the rapid growth of offshore wind deployment.

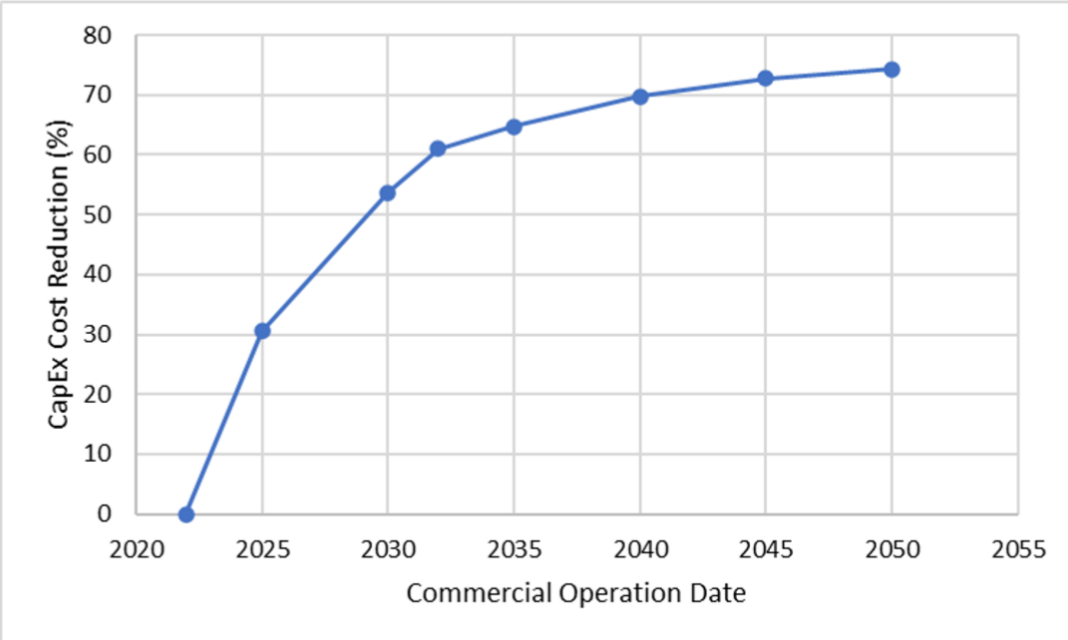

Figure J-2. CapEx learning curve expressed in terms of percent cost reduction. Note that initial costs are scaled to represent pilot-scale projects.

References

4C Offshore. 2023. "Floating offshore wind report: H1 2023." https://www.4coffshore.com/. Accessed through subscription.

AEGIR Insights. 2022. "Aegir Insights' Floating Market Forecast." Presented in webinar.

Beiter, Philipp, Walter Musial, Patrick Duffy, Aubryn Cooperman, Matthew Shields, Donna Heimiller, and Michael Optis. 2020. "The Cost of Floating Offshore Wind Energy in California Between 2019 and 2032." NREL/TP-5000-77384. https://doi.org/10.2172/1710181.

Carbon Trust. 2022. "Unlocking the Next Generation of Offshore Wind: Step Change to 132kV Array Systems." https://www.carbontrust.com/our-work-and-impact/guides-reports-and-tools/unlocking-the-next-generation-of-offshore-wind-step-change-to-132kv-array-systems.

Cooperman, Aubryn, Patrick Duffy, and Walt Musial. 2022. "Transmission Alternatives for California North Coast Offshore Wind Volume 4: Cost-Benefit Analysis Report." OCS Study BOEM 2022-016. http://schatzcenter.org/pubs/2022-OSW-R4.pdf.

DNV. 2022. "Energy Transition Outlook 2022." https://www.dnv.com/energy-transition-outlook/index.html.

Duffy, Patrick, Gabriel R. Zuckerman, Travis Williams, Alicia Key, Luis A. Martínez-Tossas, Owen Roberts, Nina Choquette, Jaemo Yang, Haiku Sky, and Nate Blair. 2022. "Wind Energy Costs in Puerto Rico Through 2035." Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-83434. https://www.nrel.gov/docs/fy22osti/83434.pdf.

Gaertner, Evan, Jennifer Rinker, Latha Sethuraman, Frederik Zahle, Benjamin Anderson, Garrett Barter, Nikhar Abbas, et al. 2020. “Definition of the IEA Wind 15-Megawatt Offshore Reference Wind Turbine.” NREL/TP-5000-75698. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy20osti/75698.pdf.

Global Wind Energy Council (GWEC). 2022. “Floating Offshore Wind – A Global Opportunity.” https://gwec.net/wp-content/uploads/2022/03/GWEC-Report-Floating-Offshore-Wind-A-Global-Opportunity.pdf

Hannon, M., E. Topham, D. MacMillan, J. Dixon, M. Collu. 2019. “Offshore wind, ready to float? Global and UK trends in the floating offshore wind market.” University of Strathclyde, Glasgow, https://doi.org/10.17868/69501.

Hersbach, Hans, Bill Bell, Paul Berrisford, Shoji Hirahara, András Horányi, Joaquín Muñoz-Sabater, Julien Nicolas, et al. 2020. “The ERA5 Global Reanalysis.” *Quarterly Journal of the Royal Meteorological Society* 146 (730): 1999–2049. https://doi.org/10.1002/qj.3803.

Huang, Claire, Lily Busse, and Robert Baker. 2023. “Offshore Wind Transmission Technologies Assessment.” Guidehouse. https://efiling.energy.ca.gov/GetDocument.aspx?tn=250520&DocumentContentId=85289

Lloyd-Williams, Peter. 2023. “Tackling the Cost Inflation Challenge in Offshore Wind.” Westwood Global Energy Group.

Musial, Walter D, Philipp C Beiter, Jacob Nunemaker, Donna M Heimiller, Josh Ahmann, and Jason Busch. 2019. “Oregon Offshore Wind Site Feasibility and Cost Study.” NREL/TP-5000-74597. https://doi.org/10.2172/1570430.

Musial, Walter, Philipp Beiter, and Jake Nunemaker. 2020. *Cost of Floating Offshore Wind Energy Using New England Aqua Ventus Concrete Semisubmersible Technology*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-75618. https://www.nrel.gov/docs/fy20osti/75618.pdf.

Musial, Walt, Paul Spitsen, Patrick Duffy, Philipp Beiter, Matt Shields, Daniel Mulas Hernando, Rob Hammond, Melinda Marquis, Jennifer King, and Sathish Sriharan. 2023. “Offshore Wind Market Report: 2023 Edition.” U.S. Department of Energy. https://www.energy.gov/sites/default/files/2023-08/offshore-wind-market-report-2023-edition_0.pdf.

NREL. Forthcoming. “Atlantic Offshore Wind Transmission Study.” https://www.nrel.gov/wind/atlantic-offshore-wind-transmission-study.html

Nunemaker, Jake, Matt Shields, Hammond Robert, and Patrick Duffy. 2020. “ORBIT: Offshore Renewables Balance-of-System and Installation Tool.” NREL/TP-5000-77081. Golden, CO: National Renewable Energy Laboratory (NREL). https://www.nrel.gov/docs/fy20osti/77081.pdf.

Offshore Renewable Energy (ORE) Catapult. 2022. “Floating Offshore Wind Centre of Excellence. International Market Opportunities, Summary Report.” https://ore.catapult.org.uk/wp-content/uploads/2022/06/FOW-PR12-Int-Market-Projections-Report-May-22-AW.pdf

Shields, Matt, Patrick Duffy, Walt Musial, Michael Laurienti, Donna Heimiller, Rob Spencer, and Mike Optis. 2021. "The Cost and Feasibility of Floating Offshore Wind Energy in the O'ahu Region." National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy22osti/80808.pdf.

Shields, Matt, Philipp Beiter, and Jake Nunemaker. 2022. A Systematic Framework for Projecting the Future Cost of Offshore Wind Energy. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-81819. https://www.nrel.gov/docs/fy23osti/81819.pdf.

TenneT. 2023. "The 2GW Program." https://www.tennet.eu/about-tennet/innovations/2gw-program.

Wood Mackenzie. 2020. "Foresight 20/20: Wind, Onshore and Offshore." https://www.woodmac.com/our-expertise/focus/Power--Renewables/wind-foresight-2020/?utm_source=gtm&utm_medium=article&utm_campaign=wmpr_fs2020wind. Accessed through subscription.

Appendix K. Transmission infrastructure cost results

(prepared by Quanta Technology, NREL and the Schatz Energy Research Center)

Table K-1. New Land-based Transmission Infrastructure Costs by Transmission Alternative ($ Millions)

State	New Transmission Infrastructure	Alt. 7.2a	Alt. 7.2b	Alt. 12.4a	Alt. 12.4b	Alt. 12.4c	Alt. 12.4d	Alt. 12.4e	Alt. 12.4f	Alt. 25.8a	Alt. 25.8b
OR	Construct New Wendson 500 kV POI Substation	49.8	49.8		49.8	49.8	49.8	49.8	49.8	34.3	49.8
OR	Install New 500-230 kV AutoTransformer at Wendson	39.7	39.7		39.7	39.7	39.7	39.7	39.7	39.7	39.7
OR	Construct Onshore Landing-Wendson 500 kV Single-Circuit Line	35.308	35.308		35.308	35.308	35.308	35.308	35.308	35.308	35.308
OR	Construct New Fairview 500 kV POI Substation	34.3	34.3	49.8	34.3	34.3	34.3	34.3	34.3	34.3	49.8
OR	Install New 500-230 kV AutoTransformer at Fairview	39.7	39.7	39.7	39.7	39.7	39.7	39.7	39.7	39.7	39.7
OR	Construct Onshore Landing-Fairview 500 kV Single-Circuit Line			80.704							
OR	Construct New Rogue 500 kV POI Substation	34.3	34.3		34.3	34.3	34.3	34.3	34.3	34.3	34.3
OR	Install New 500-230 kV AutoTransformer at Rogue	39.7	39.7		39.7	39.7	39.7	39.7	39.7	39.7	39.7
OR	Construct Onshore Landing-Rogue 500 kV Single-Circuit Line	5.82	5.82		5.82	5.82	5.82	5.82	5.82	5.82	5.82
OR	Construct Wendson-Fairview 500 kV Single-Circuit Line	50.44			50.44	50.44	50.44	50.44	50.44	50.44	50.44
OR	Construct Rogue-Fairview 500 kV Single-Circuit Line	248.32	248.32		248.32	248.32	248.32	248.32	248.32	248.32	248.32

State	New Transmission Infrastructure	Alt. 7.2a	Alt. 7.2b	Alt. 12.4a	Alt. 12.4b	Alt. 12.4c	Alt. 12.4d	Alt. 12.4e	Alt. 12.4f	Alt. 25.8a	Alt. 25.8b
OR	Construct Wendson-Lane 500 kV Single-Circuit Line	159.08			159.08	159.08	159.08	159.08	159.08	159.08	
OR	Construct Alvey-Lane 500 kV Single-Circuit Line	50.44	50.44		50.44	50.44	50.44	50.44	50.44	50.44	
OR	Construct Dixonville-Fairview 500 kV Single-Circuit Line	178.48			178.48	178.48	178.48	178.48	178.48	178.48	
OR	Construct Wendson-Lane 500 kV Double-Circuit Line		254.61								254.61
OR	Construct Dixonville-Fairview 500 kV Double-Circuit Line		285.66	285.66							285.66
OR	Construct New Del Norte-Sams Valley 500 kV Single-Circuit Line			349.2			349.2				349.2
OR	Construct New Del Norte-Sams Valley 500 kV Double-Circuit Line				558.9						
OR	Construct Alvey-Lane 500 kV Double-Circuit Line										80.73
OR	Construct Alvey-Dixonville 500 kV Single-Circuit Line										225.04
OR	Construct Land-based HVDC Conversion Stations									1436.64	957.76
OR	Construct Portland-Tillamook HVDC Line									72.141	
CA	Construct New Del Norte 500 kV POI Substation	91.00	60.00	199.50	168.50	153.00	91.00	60.00	60.00	60.00	60.00
CA	Construct Onshore Landing (Brk)-New Del Norte 500 kV Single-Circuit Line			59.73	59.73						

State	New Transmission Infrastructure	Alt. 7.2a	Alt. 7.2b	Alt. 12.4a	Alt. 12.4b	Alt. 12.4c	Alt. 12.4d	Alt. 12.4e	Alt. 12.4f	Alt. 25.8a	Alt. 25.8b
CA	Construct Onshore Landing-New Del Norte 500 kV Single-Circuit Line	44.38	44.38	44.38	44.38	44.38	44.38	44.38	44.38	44.38	44.38
CA	Construct New Humboldt 500 kV POI Substation	75.50	60.00	75.50	91.00	75.50	75.50	60.00	60.00	60.00	60.00
CA	Construct Onshore Landing-New Humboldt 500 kV Single-Circuit Line	13.69	13.69	13.69	13.69	13.69	13.69	13.69	13.69	13.69	13.69
CA	Install New 500-115 kV Phase Shifting Transformer at Humboldt	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
CA	Install New 500-115 kV Phase Shifting Transformer at Del Norte	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
CA	Construct New Humboldt-Humboldt 115 kV Single-Circuit Line	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40
CA	Construct New Del Norte-Fern Road 500 kV Double-Circuit Line	1527.64		1527.64		1527.64			1527.64	1527.64	
CA	Construct New Humboldt-Fern Road 500 kV Double-Circuit Line	929.87			929.87					929.87	929.87
CA	Construct Round mountain-Tesla 500 kV Single-Circuit Line	954.04	954.04	954.04	954.04	954.04	954.04	954.04	954.04	954.04	954.04
CA	Construct New Humboldt-Fern Road 500 kV Single-Circuit Line		580.72	580.72		580.72	580.72	580.72	580.72		
CA	Construct New Del Norte-Fern Road 500 kV Single-Circuit Line						954.04	954.04			954.04
CA	Construct New Humboldt-collinsville 500 kV Single-Circuit Line									1078.48	1078.48

State	New Transmission Infrastructure	Alt. 7.2a	Alt. 7.2b	Alt. 12.4a	Alt. 12.4b	Alt. 12.4c	Alt. 12.4d	Alt. 12.4e	Alt. 12.4f	Alt. 25.8a	Alt. 25.8b
CA	Construct Land-based HVDC Conversion Station		1436.64	1436.64	1915.52	478.88	957.76	2394.40	1915.52	2394.40	2394.40
CA	Construct New Humboldt-Collinsville HVDC Line		1349.40	1349.40	1349.40			1349.40		1349.40	1349.40
CA	Construct Elk-Collinsville HVDC Line						855.31		855.31		
CA	Construct New Del Norte-Fern Road HVDC Line							1193.70			

Table K-2. Total New Land-based Substation Costs by Transmission Alternative ($ Millions)

Region	Alt. 7.2a	Alt. 7.2b	Alt. 12.4a	Alt. 12.4b	Alt. 12.4c	Alt. 12.4d	Alt. 12.4e	Alt. 12.4f	Alt. 25.8a	Alt. 25.8b
Central Valley Area	0	0	0	0	0	0	479	0	0	0
Humboldt Area	98	561	576	592	98	98	561	561	561	561
SF Bay Area	0	479	479	958	0	958	479	958	958	958
Central Coast Area	0	0	0	0	479	0	479	0	479	479
BPAT	238	238	90	238	238	238	238	238	1,659	1,211
PacifiCorp	113	561	700	669	175	113	561	561	561	561
Total	448	1,838	1,845	2,457	989	1,406	2,796	2,317	4,217	3,769

Table K-3. Total New Land-based Transmission Line Costs by Transmission Alternative ($ Millions)

Region	Alt. 7.2a	Alt. 7.2b	Alt. 12.4a	Alt. 12.4b	Alt. 12.4c	Alt. 12.4d	Alt. 12.4e	Alt. 12.4f	Alt. 25.8a	Alt. 25.8b
Central Valley Area	2,183	1,244	2,008	1,419	2,008	1,721	2,318	2,008	2,183	1,896
Humboldt Area	497	997	997	1,172	322	322	997	322	2,250	2,250
SF Bay Area	0	675	675	675	0	855	675	855	675	675
Central Coast Area	0	0	0	0	0	0	0	0	0	0
BPAT	639	737	224	639	639	639	639	639	711	931
PacifiCorp	897	187	1,360	752	897	960	1,207	897	897	1,126
Total	4,216	3,841	5,264	4,656	3,867	4,498	5,836	4,722	6,716	6,877

Table K-4. Total Network Upgrade Costs by Transmission Alternative ($ Millions)

Region	Alt. 7.2a	Alt. 7.2b	Alt. 12.4a	Alt. 12.4b	Alt. 12.4c	Alt. 12.4d	Alt. 12.4e	Alt. 12.4f	Alt. 25.8a	Alt. 25.8b
Central Valley Area	33.7	0.0	53.1	53.1	53.1	53.1	53.1	53.1	161.2	96.6
Humboldt Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.6
SF Bay Area	49.5	61.8	140.2	115.9	165.6	142.4	153.6	109.4	307.3	317.6
Central Coast Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BPAT	333.4	283.9	159.5	369.0	377.8	319.2	446.7	269.4	718.7	832.4
PacifiCorp	40.3	395.3	459.3	8.7	268.8	259.3	0.0	31.6	46.1	118.3
Avista Corp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.2	96.2
Portland General	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.8	123.5
LA Area	4.1	70.0	79.7	19.3	23.5	31.7	34.7	34.7	33.2	33.2
Total	461	811	892	566	889	806	688	498	1,391	1,681

Table K-5. Total Cost of Land-based Transmission Infrastructure by Transmission Alternative ($ Millions)

Region	Alt. 7.2a	Alt. 7.2b	Alt. 12.4a	Alt. 12.4b	Alt. 12.4c	Alt. 12.4d	Alt. 12.4e	Alt. 12.4f	Alt. 25.8a	Alt. 25.8b
Central Valley Area	2,216	1,244	2,061	1,472	2,061	1,774	2,850	2,061	2,344	1,993
Humboldt Area	595	1,558	1,574	1,764	420	420	1,558	883	2,811	2,875
SF Bay Area	50	1,215	1,294	1,748	166	1,955	1,307	1,922	1,940	1,950
Central Coast Area	0	0	0	0	479	0	479	0	479	479
BPAT	1,210	1,259	473	1,245	1,254	1,195	1,323	1,146	3,088	2,974
PacifiCorp	1,051	1,143	2,520	1,430	1,341	1,332	1,768	1,490	1,504	1,805
Avista Corp	0	0	0	0	0	0	0	0	96	96
Portland General	0	0	0	0	0	0	0	0	29	124
LA Area	4.1	70	80	19	24	32	35	35	33	33
Total	5,125	6,490	8,000	7,679	5,744	6,709	9,320	7,537	12,324	12,328

Table K-6. Offshore Infrastructure Costs and Characteristics by Transmission Alternative

Characteristic	Alt. 7.2a	Alt. 7.2b	Alt. 12.4a	Alt. 12.4b	Alt. 12.4c	Alt. 12.4d	Alt. 12.4e	Alt. 12.4f	Alt. 25.8a	Alt. 25.8b
Cable Distance (km)	474	771	1,130	2,077	1,779	2,008	1,557	1,868	4,412	3,007
# HVAC Floating Platforms	9	9	14	14	14	9	3	3	0	0
# HVDC Floating Platforms	0	0	0	0	5	8	7	8	15	15
# WTs	480	480	827	827	827	827	827	827	1,720	1,720
Capacity (MW)	7,200	7,200	12,405	12,405	12,405	12,405	12,405	12,405	25,800	25,800
Export CapEx ($M)*	$2,378	$3,641	$5,410	$9,619	$12,048	$14,884	$11,570	$13,409	$29,015	$23,011
Total CapEx ($M)**	$28,526	$29,789	$51,407	$55,617	$58,073	$60,961	$57,589	$59,610	$126,985	$120,907

*The Export CapEx includes the cost of the offshore transmission infrastructure (floating substations and undersea cables)

**The Total CapEx includes the cost of the floating offshore wind farms, as well as the cost of the offshore transmission infrastructure

Appendix L: Regional Cost Maps

(prepared by Schatz Energy Research Center)

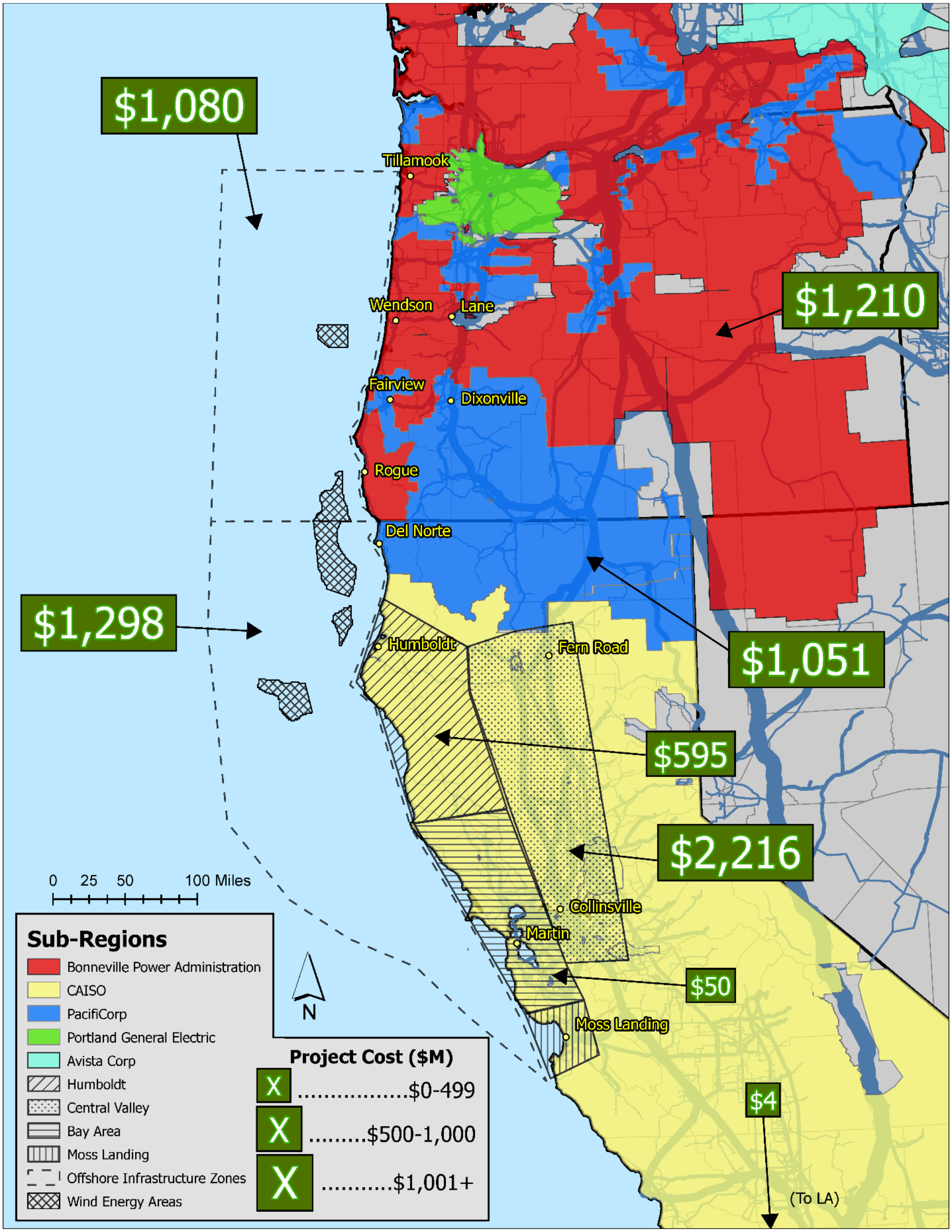

Figure L1 – Regional Cost Figure for Transmission Alternative 7.2a

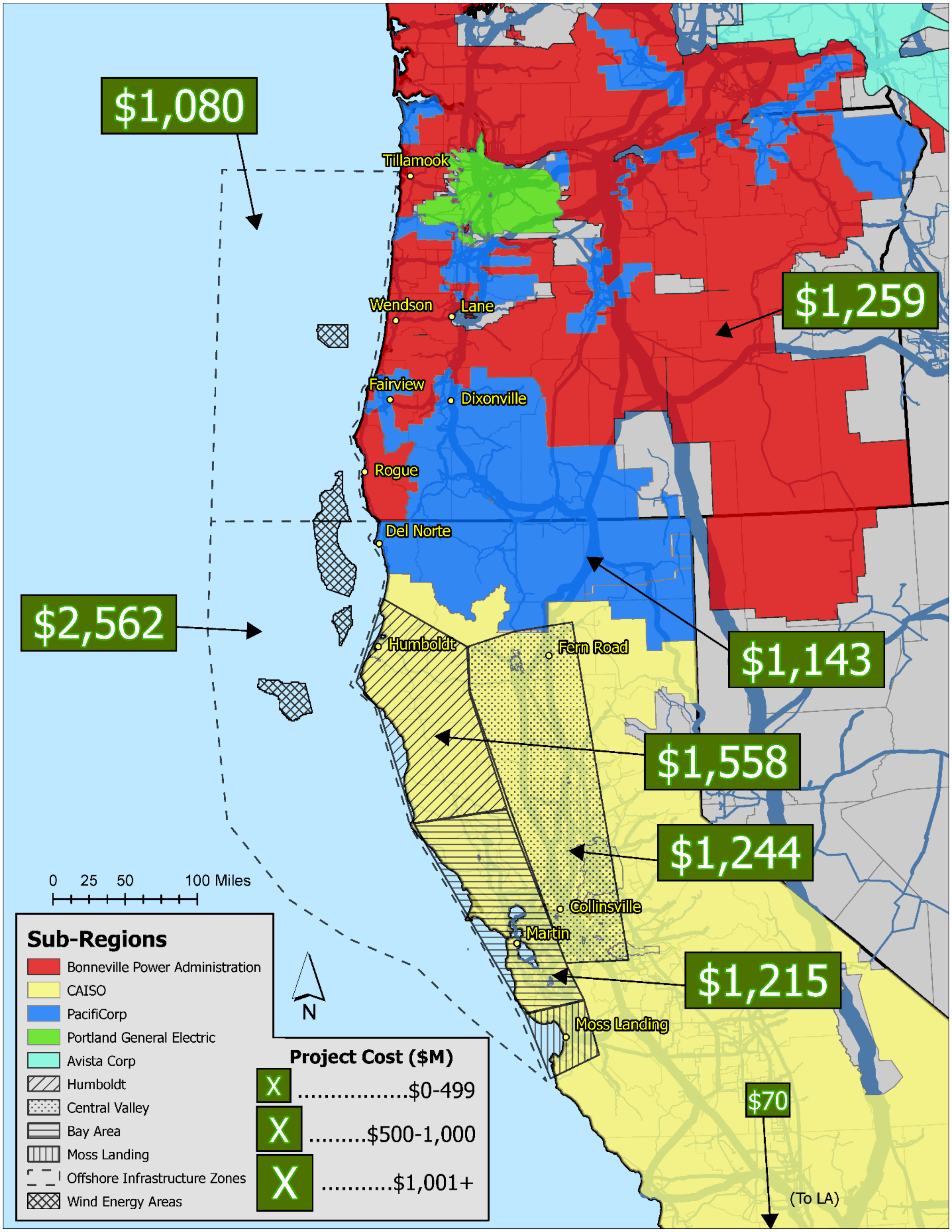

Figure L2 – Regional Cost Figure for Transmission Alternative 7.2b

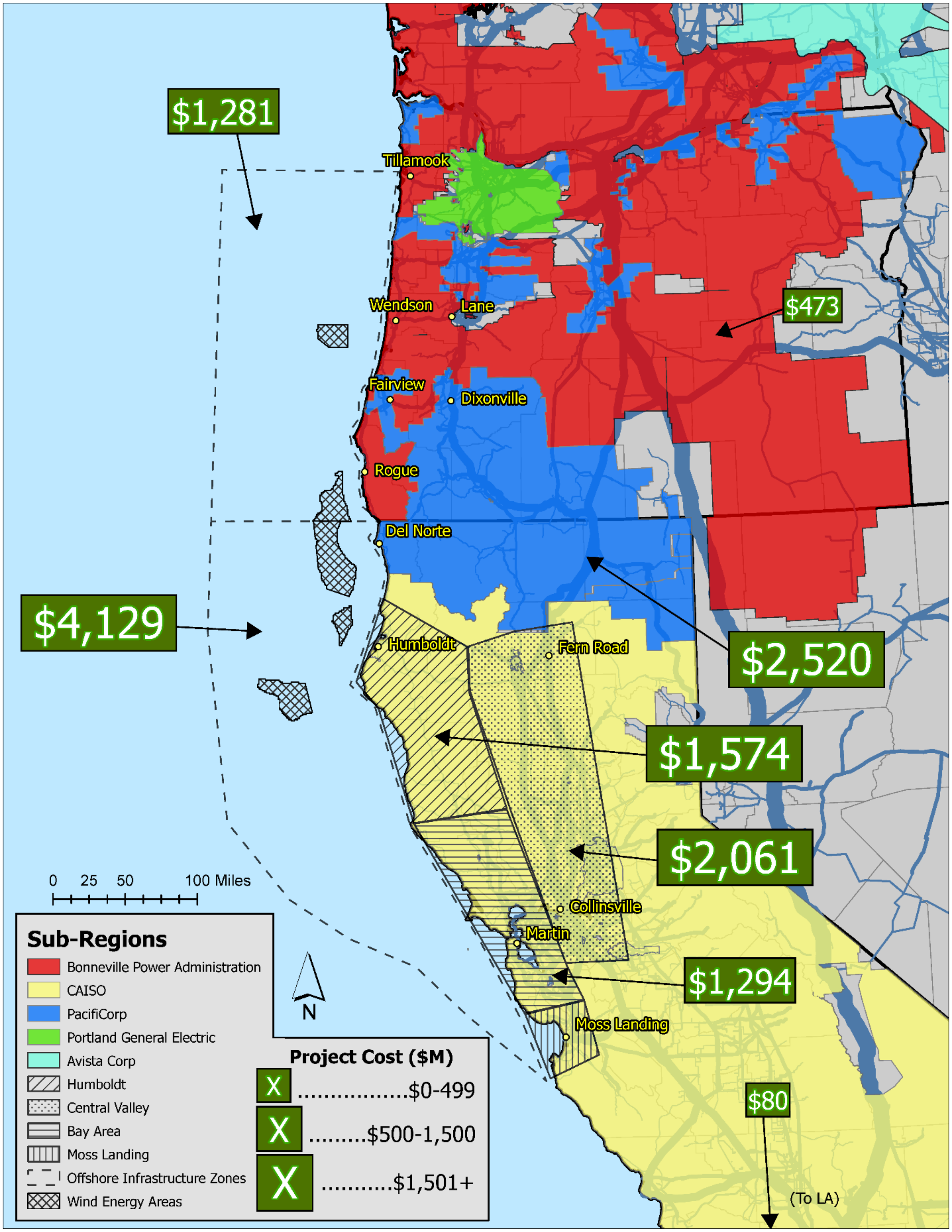

Figure L3 - Regional Cost Figure for Transmission Alternative 12.4a

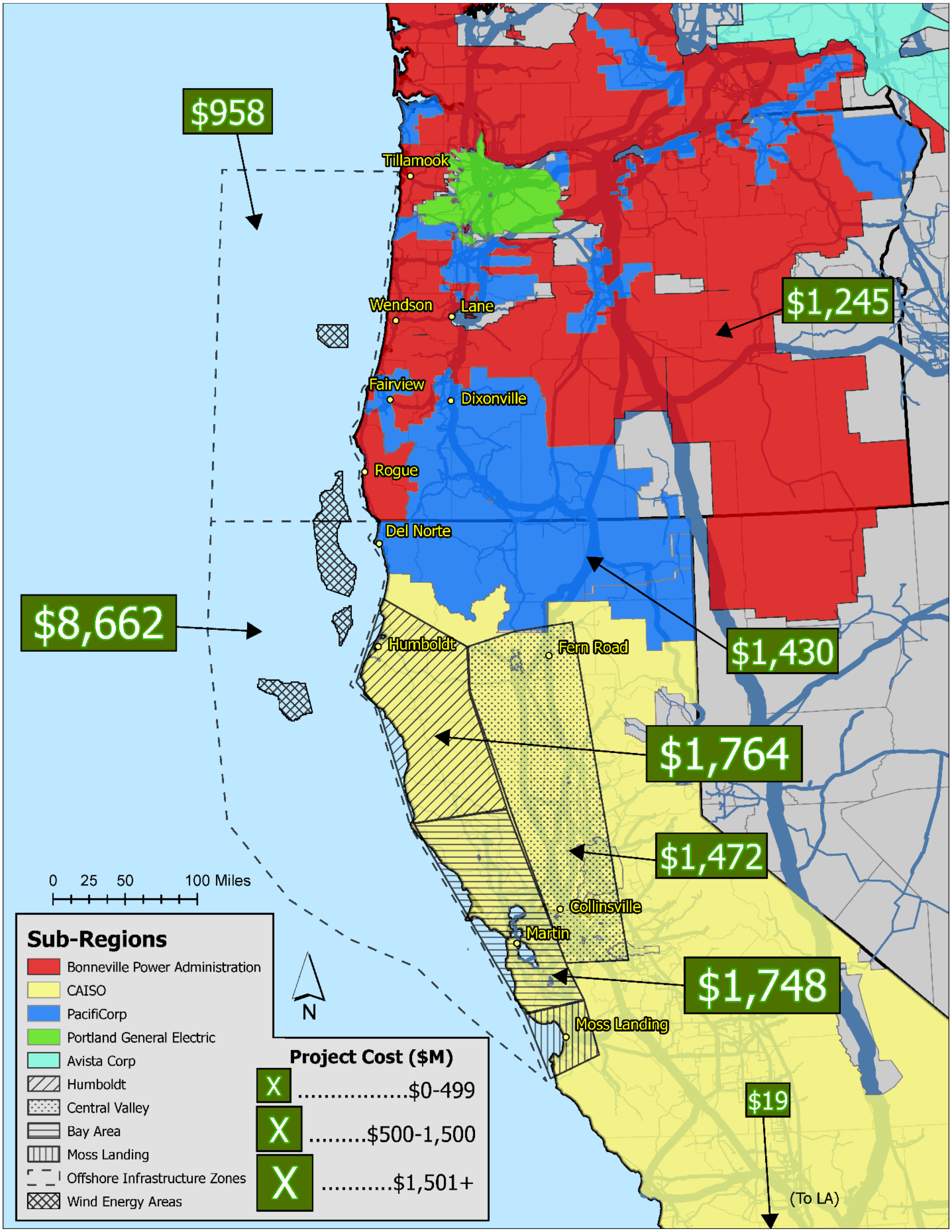

Figure L4 - Regional Cost Figure for Transmission Alternative 12.4b

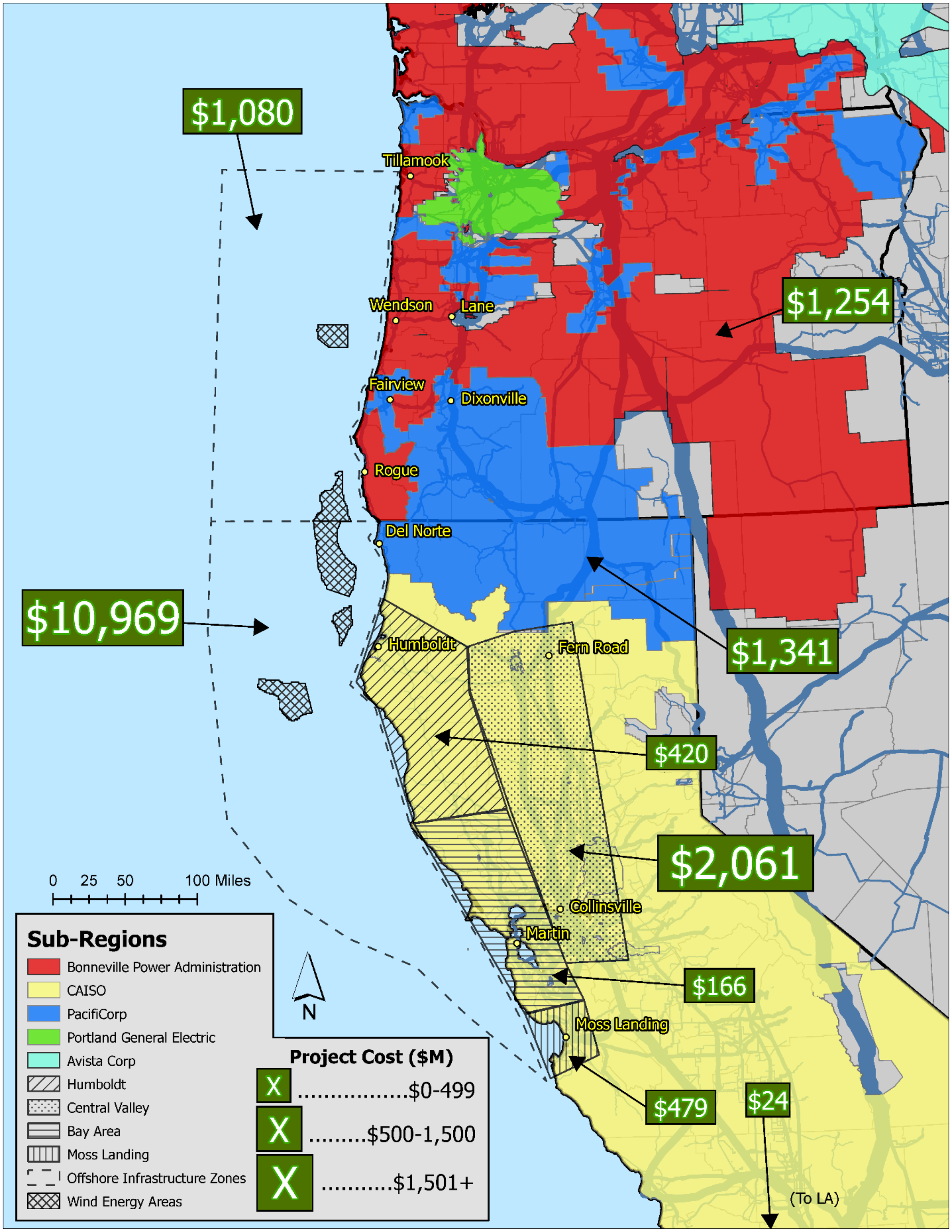

Figure L5 - Regional Cost Figure for Transmission Alternative 12.4c

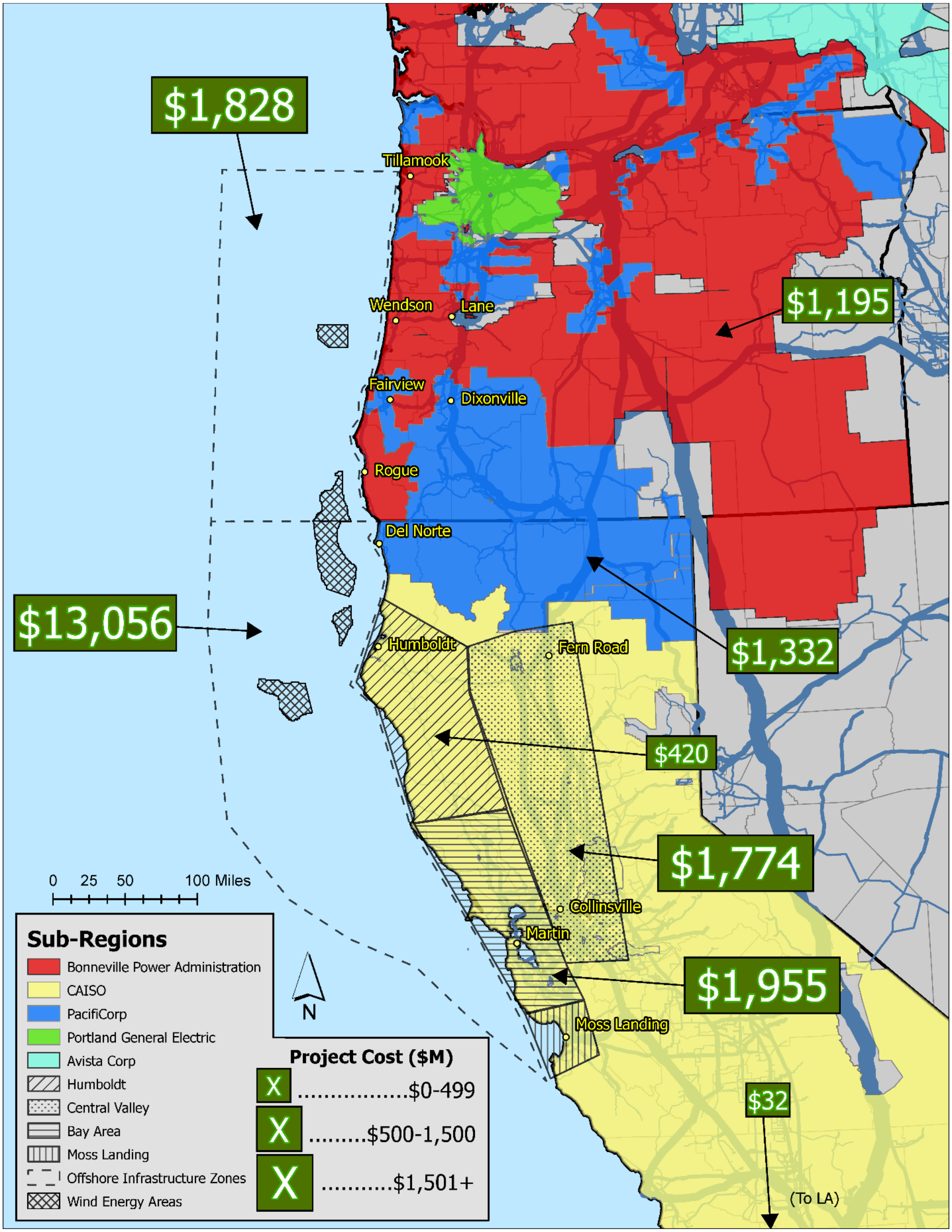

Figure L6 - Regional Cost Figure for Transmission Alternative 12.4d

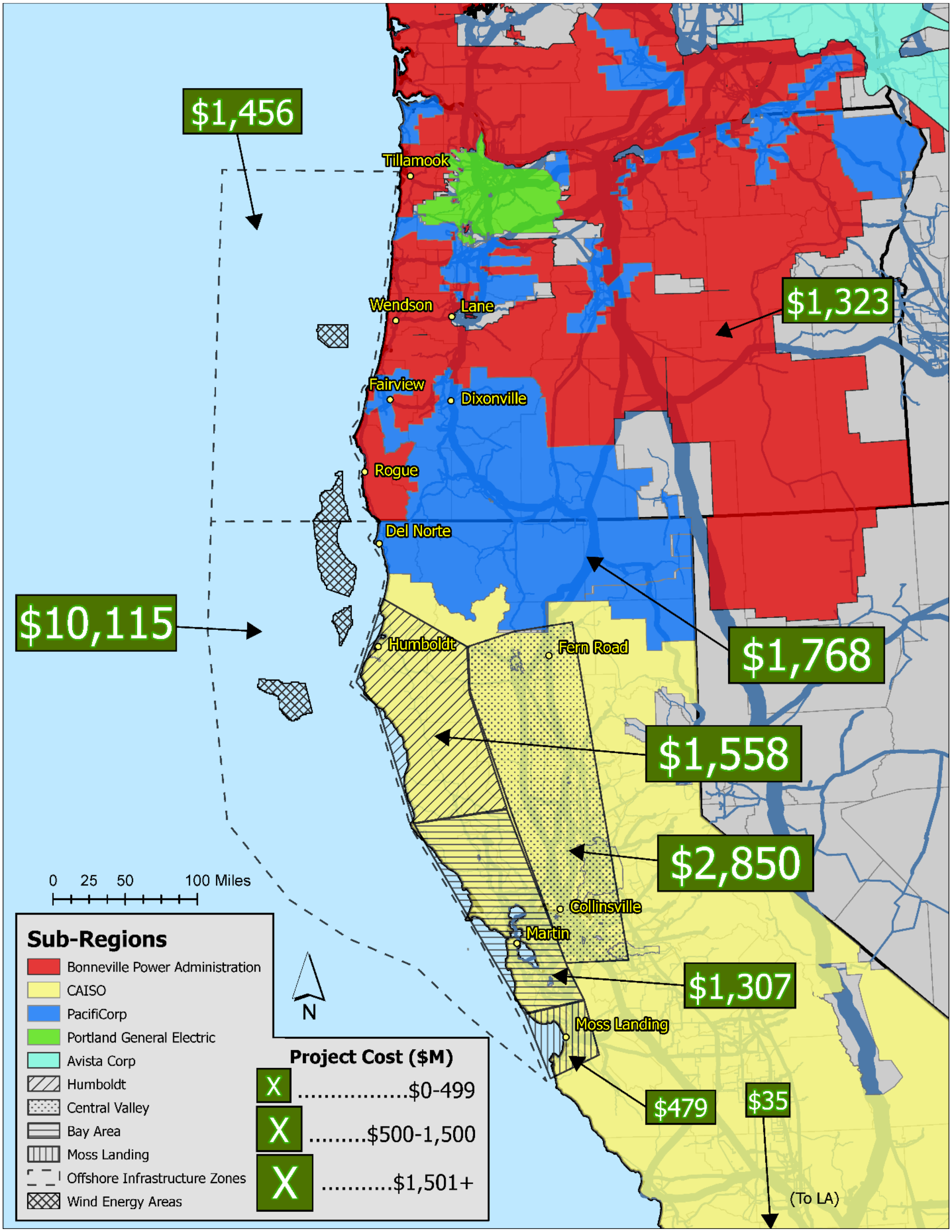

Figure L7 - Regional Cost Figure for Transmission Alternative 12.4e

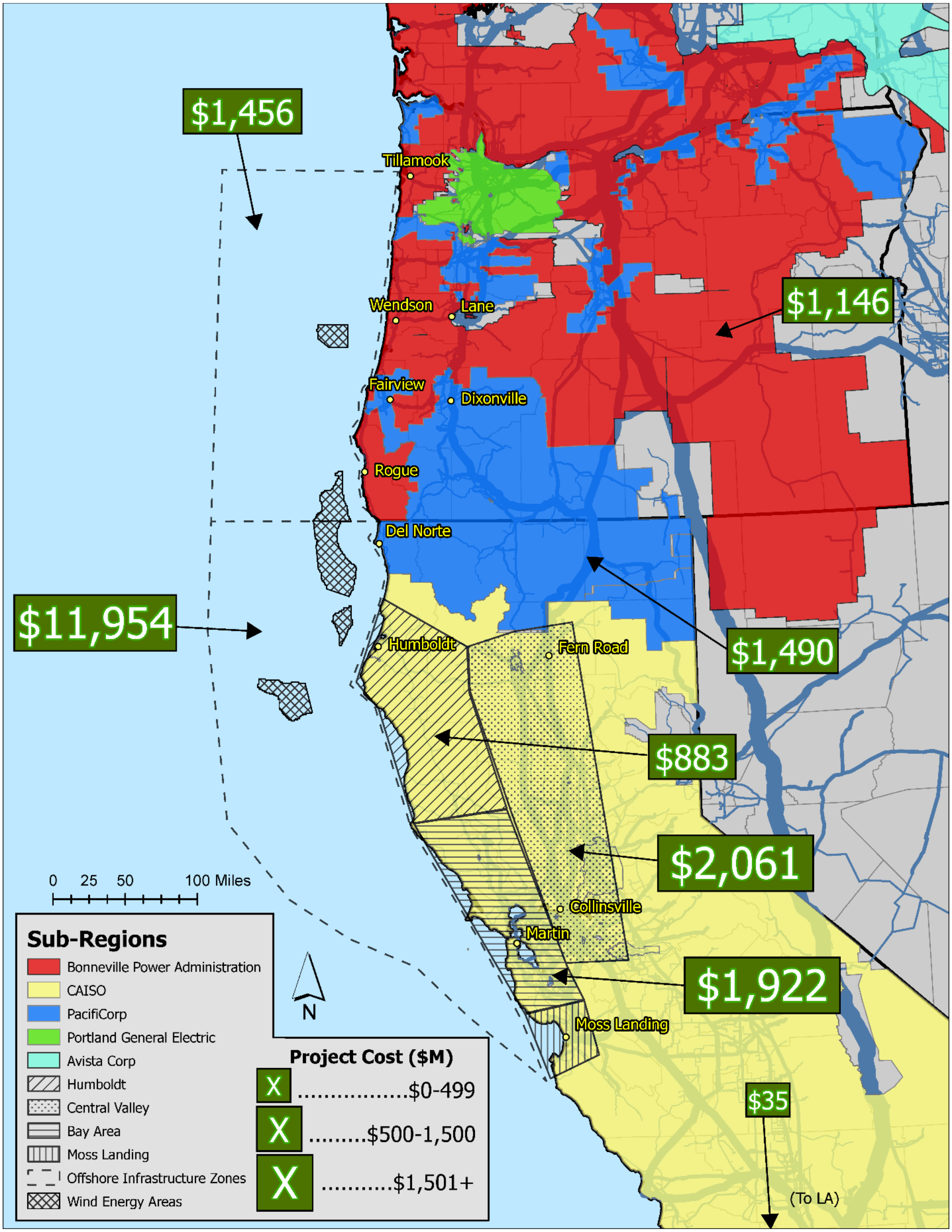

Figure L8 - Regional Cost Figure for Transmission Alternative 12.4f

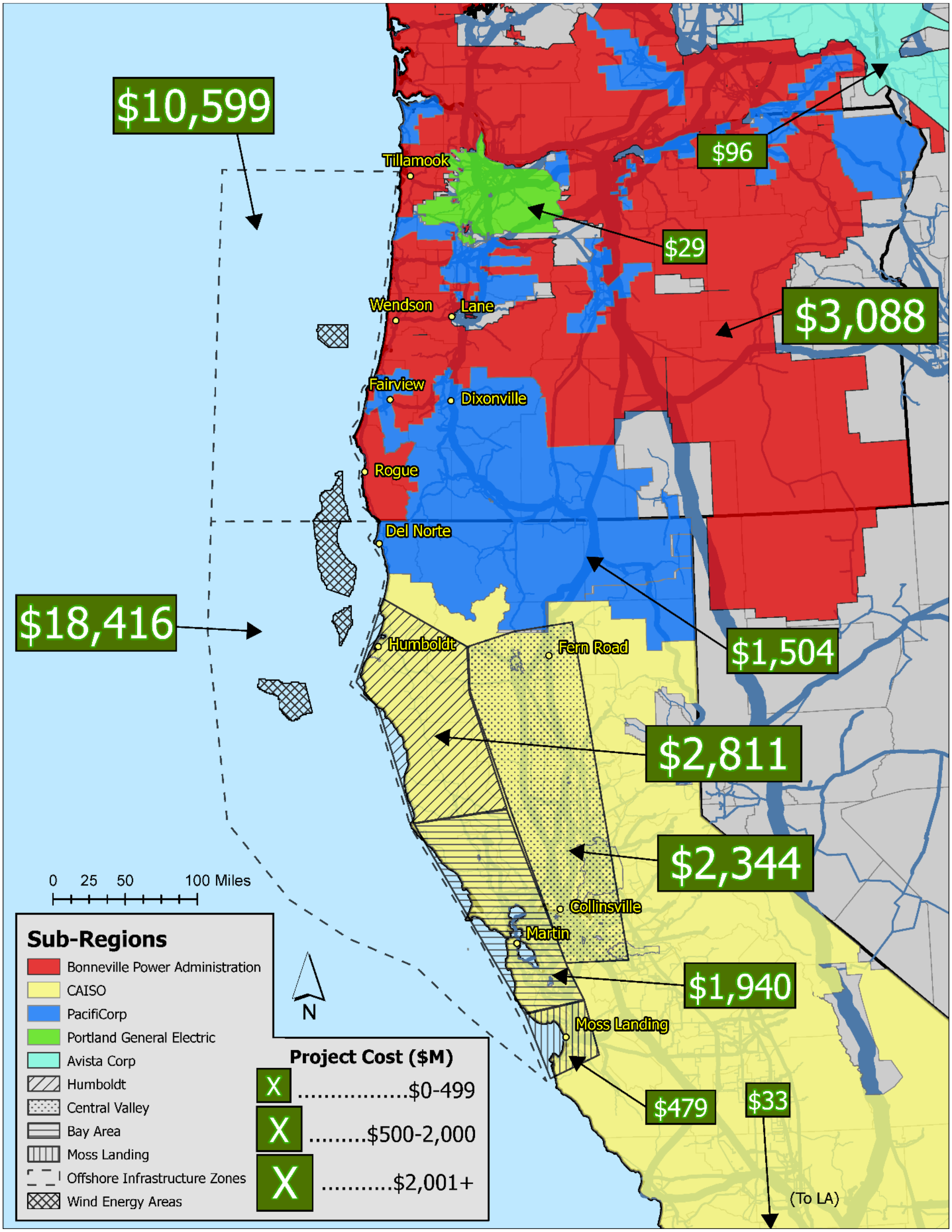

Figure L9 - Regional Cost Figure for Transmission Alternative 25.8a

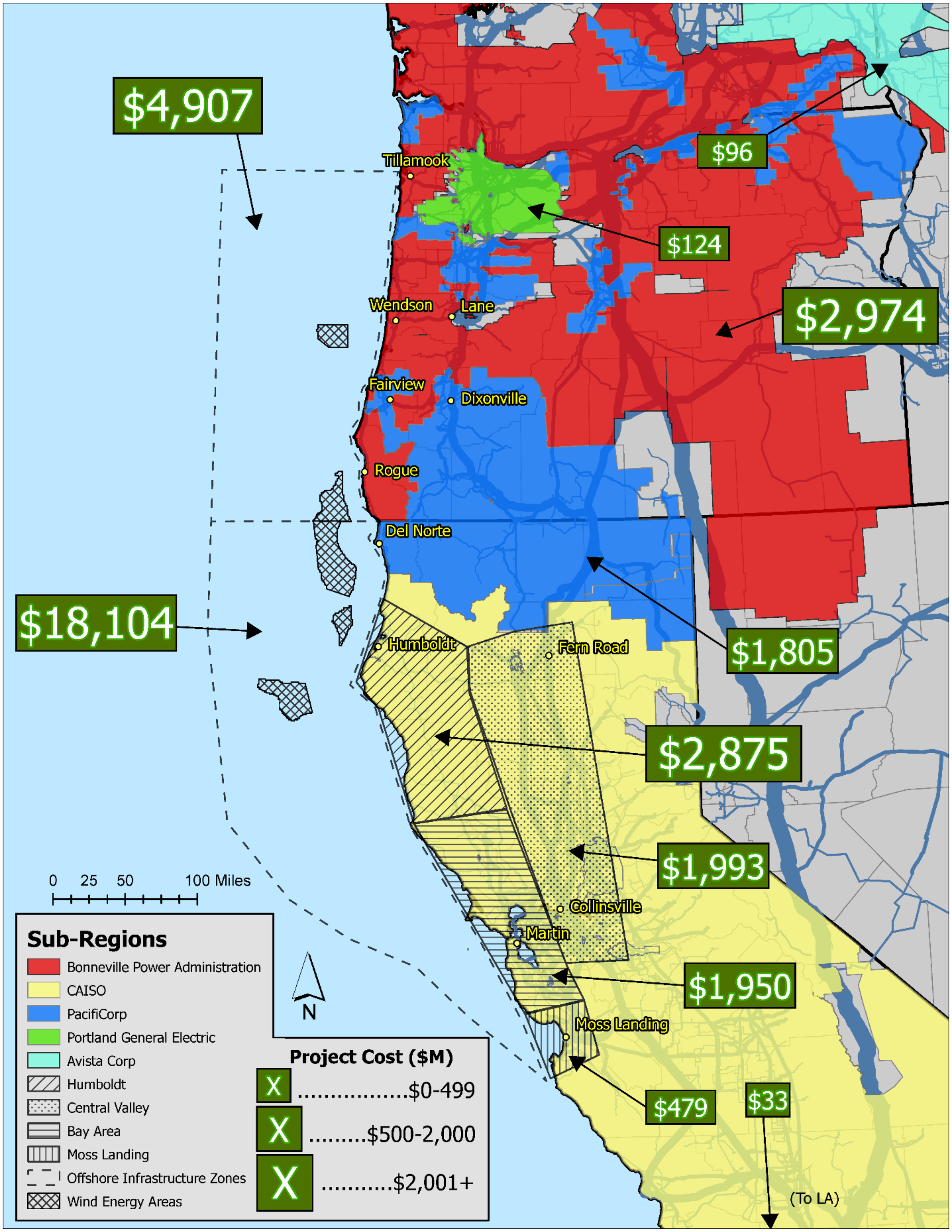

Figure L10 - Regional Cost Figure for Transmission Alternative 25.8b

APPENDIX M: PRODUCTION COST MODEL RESULTS
(prepared by Quanta Technology)

Alternative 7.2a - Production cost model results (2032 study year, 2022 dollars)

Unit Name	MaxCap (MW)	Avg LMP Weighted by Generation ($/MWh)	Simple Avg LMP ($/MWh)	Total Gen (MWh)	Cap Factor	Curtailed (MWh)	% Curtailed	Revenue (M$)	Net Revenue * (M$)
OSW_Brookings	1,800	24.6	25.7	7,890,046	50%	63,120	0.80%	194	391
OSW_CoosBay	1,300	26.3	26.2	4,775,585	42%	38,205	0.80%	126	245
OSW_Del Norte	2,100	31.5	34.1	9,225,376	50%	46,127	0.50%	290	521
OSW_Humboldt	2,000	33.5	35.2	8,341,783	48%	25,025	0.30%	280	488
Total	7,200	29.4	30.3	30,232,790	48%	172,477	0.57%	889	1,645

*Net revenue includes the Production Tax Credit revenue assumed to be $25/MWh.

Alternative 7.2b - Production cost model results (2032 study year, 2022 dollars)

Unit Name	MaxCap (MW)	Avg LMP Weighted by Generation ($/MWh)	Simple Avg LMP ($/MWh)	Total Gen (MWh)	Cap Factor	Curtailed (MWh)	% Curtailed	Revenue (M$)	Net Revenue * (M$)
OSW_Brookings	1,800	2.8	12.2	7,454,408	47%	469,628	6.30%	21	207
OSW_CoosBay	1,300	27.1	26.9	4,776,852	42%	38,215	0.80%	130	249
OSW_Del Norte	2,100	28.3	32.0	9,249,402	50%	27,748	0.30%	262	493
OSW_Humboldt	2,000	35.7	36.6	8,277,286	47%	91,050	1.10%	296	503
Total	7,200	23.8	26.9	29,757,948	47%	626,641	2.11%	707	1,451

*Net revenue includes the Production Tax Credit revenue assumed to be $25/MWh.

Alternative 12.4a - Production cost model results (2032 study year, 2022 dollars)

Unit Name	MaxCap (MW)	Avg LMP Weighted by Generation ($/MWh)	Simple Avg LMP ($/MWh)	Total Gen (MWh)	Cap Factor	Curtailed (MWh)	% Curtailed	Revenue (M$)	Net Revenue * (M$)
OSW_Brookings	1,800	20.84	22.21	7,780,187	49%	168,830	2.17%	162	357
OSW_CoosBay	1,300	22.98	23.28	4,772,617	42%	40,090	0.84%	110	229
OSW_Del Norte	6,700	16.26	22.21	28,387,313	48%	740,909	2.61%	462	1171
OSW_Humboldt	2,600	23.96	25.77	10,581,631	46%	265,599	2.51%	254	518
Total	12,400	19.2	23.4	51,521,749	47%	1,215,428	2.36%	987	2275

*Net revenue includes the Production Tax Credit revenue assumed to be $25/MWh.

Alternative 12.4b - Production cost model results (2032 study year, 2022 dollars)

Unit Name	MaxCap (MW)	Avg LMP Weighted by Generation ($/MWh)	Simple Avg LMP ($/MWh)	Total Gen (MWh)	Cap Factor	Curtailed (MWh)	% Curtailed	Revenue (M$)	Net Revenue * (M$)
OSW_Brookings	1,800	20.84	22.21	7,780,187	49%	168,830	2.17%	162	357
OSW_CoosBay	1,300	22.98	23.28	4,772,617	42%	40,090	0.84%	110	229
OSW_Del Norte	6,700	16.26	22.21	28,387,313	48%	740,909	2.61%	462	1171
OSW_Humboldt	2,600	23.96	25.77	10,581,631	46%	265,599	2.51%	254	518
Total	12,400	19.2	23.4	51,521,749	47%	1,215,428	2.36%	987	2275

*Net revenue includes the Production Tax Credit revenue assumed to be $25/MWh.

Alternative 12.4c - Production cost model results (2032 study year, 2022 dollars)

Unit Name	MaxCap (MW)	Avg LMP Weighted by Generation ($/MWh)	Simple Avg LMP ($/MWh)	Total Gen (MWh)	Cap Factor	Curtailed (MWh)	% Curtailed	Revenue (M$)	Net Revenue * (M$)
OSW_Brookings	1,800	12.38	18.26	7,861,510	50%	204,399	2.60%	97	294
OSW_CoosBay	1,300	20.02	21.85	4,757,902	42%	52,337	1.10%	95	214
OSW_Del Norte	6,700	18.2	24.81	28,521,556	49%	598,953	2.10%	519	1232
OSW_Humboldt	2,600	25.72	28.25	10,649,451	47%	202,340	1.90%	274	540
Total	12,400	19.0	23.3	51,790,420	48%	1,058,028	2.04%	986	2280

*Net revenue includes the Production Tax Credit revenue assumed to be $25/MWh.

Alternative 12.4d - Production cost model results (2032 study year, 2022 dollars)

Unit Name	MaxCap (MW)	Avg LMP Weighted by Generation ($/MWh)	Simple Avg LMP ($/MWh)	Total Gen (MWh)	Cap Factor	Curtailed (MWh)	% Curtailed	Revenue (M$)	Net Revenue * (M$)
OSW_Brookings	1,800	16.73	19.97	7,957,450	50%	111,404	1.40%	133	332
OSW_CoosBay	1,300	24.2	22.44	4,573,869	40%	228,693	5.00%	111	225
OSW_Del Norte	6,700	18.55	24.29	28,874,209	49%	259,868	0.90%	536	1257
OSW_Humboldt	2,600	29.96	30.77	10,661,374	47%	191,905	1.80%	319	586
Total	12,400	21.1	24.4	52,066,903	48%	791,870	1.52%	1099	2401

*Net revenue includes the Production Tax Credit revenue assumed to be $25/MWh.

Alternative 12.4e - Production cost model results (2032 study year, 2022 dollars)

Unit Name	MaxCap (MW)	Avg LMP Weighted by Generation ($/MWh)	Simple Avg LMP ($/MWh)	Total Gen (MWh)	Cap Factor	Curtailed (MWh)	% Curtailed	Revenue (M$)	Net Revenue * (M$)
OSW_Brookings	1,800	21.55	24.22	7,943,645	50%	127,098	1.60%	171	370
OSW_CoosBay	1,300	24.83	23.08	4,604,142	40%	197,978	4.30%	114	229
OSW_Del Norte	6,700	21.1	26.3	28,905,056	49%	231,240	0.80%	610	1333
OSW_Humboldt	2,600	28.33	29.63	10,684,753	47%	170,956	1.60%	303	570
Total	12,400	23.0	25.8	52,137,596	48%	727,273	1.39%	1198	2502

*Net revenue includes the Production Tax Credit revenue assumed to be $25/MWh.

Alternative 12.4f - Production cost model results (2032 study year, 2022 dollars)

Unit Name	MaxCap (MW)	Avg LMP Weighted by Generation ($/MWh)	Simple Avg LMP ($/MWh)	Total Gen (MWh)	Cap Factor	Curtailed (MWh)	% Curtailed	Revenue (M$)	Net Revenue * (M$)
OSW_Brookings	1,800	20.99	24.13	8,014,999	51%	56,105	0.70%	168	369
OSW_CoosBay	1,300	25.65	24.38	4,630,798	41%	175,970	3.80%	119	235
OSW_Del Norte	4,600	22.47	26.61	20,339,993	50%	61,020	0.30%	457	966
OSW_Humboldt	2,600	27.94	29.85	10,770,693	47%	86,166	0.80%	301	570
OSW_Cape Mendocino	2,100	31.72	33.04	9,304,330	51%	241,913	2.60%	295	528
Total	12,400	25.3	27.6	53,060,812	49%	621,173	1.17%	1340	2667

*Net revenue includes the Production Tax Credit revenue assumed to be $25/MWh.

Appendix N. LCOE and LCOT equations and financing assumptions

(prepared by NREL)

The levelized cost of energy (LCOE) expresses the total cost to build, finance, and operate a power plant, per megawatt-hour (MWh) of electricity generation. We calculate LCOE based on the definition from Short et al. (1995) given in Equation 1:

Equation 1

$$LCOE = \frac{(CapEx \times FCR) + OpEx}{(AEP_{Net} \div P)}$$

where:

LCOE	=	levelized cost of energy ($/MWh)
FCR	=	fixed charge rate (5.7% per year)
CapEx	=	offshore wind plant capital expenditures (excluding substations and export cables) ($/kW)
AEP_{net}	=	net average annual energy production (MWh/year)
OpEx	=	average annual operational expenditures ($/kW-year)
P	=	total wind plant capacity (kW).

Similarly, we represent transmission costs in terms of the levelized cost of transmission (LCOT), which Gorman et al. (2019) define as shown in Equation 2:

Equation 2

$$LCOT = \frac{C * r}{AEP_{net} * [1 - (1 + r)^{-n}]}$$

where:

C	=	capital cost of transmission investment
r	=	discount rate (assumed to be 4.4%)
AEP_{net}	=	net average annual energy production (MWh/year)
n	=	transmission asset lifetime (assumed to be 60 years).

Both LCOE and LCOT are calculated relative to the average annual energy output from offshore wind in each scenario, which provides a common basis for comparison. Details regarding the estimation of average annual energy output can be found in Appendix C. We present transmission and generation costs separately because these two types of assets may have different financing sources and terms and different useful lifetimes. The boundary between transmission and generation components could conceptually be drawn at various points between the individual wind turbines and the existing electric grid in California and Oregon. In this study, we draw the boundary at the connection between the intra-array cables and the offshore substation. This choice of boundaries allows us to group all of the elements that vary between scenarios (HVAC or HVDC offshore substations, subsea backbone segments, subsea export cables, new overland transmission lines, and onshore substations) into LCOT. This grouping may not be reflective of how financial responsibility and ownership are ultimately divided between parties in California and Oregon.

We rely on the Annual Technology Baseline (NREL 2023) for OpEx estimates for floating offshore wind plants between 2030 and 2050. We use OpEx for Offshore Wind Class 8 (based on annual average wind speed) to represent Brookings, Del Norte, and Cape Mendocino, and Offshore Wind Class 12 to represent Humboldt and Coos Bay.

Table N-1 presents the financing assumptions used to calculate the fixed-charge rate (FCR). This data reflects NREL's understanding of recent (summer 2023) financing conditions for offshore wind projects in the United States and is informed by conversations with industry partners. While recent inflation rates have been much higher than the long-term average, we assume that long-term inflation rate will be closer to 2.5%. The resulting real FCR value is 5.69%. The real fixed-charge rate accounts for long-term inflation over the project's financial life.

Table N-1. Summary of financing parameters

Financial Parameter	Value
Capital recovery period	30 years
Share of debt	60%
Nominal debt rate	5.9%
Nominal equity return	9%
Tax rate	26%
Long-term inflation rate	2.5%
Real, after-tax capital recovery factor	5.4%
Project finance factor	105%
Depreciation basis	100%
Depreciation schedule	5-year MACRS
Present value of depreciation	86%
Real, after-tax weighted average cost of capital	3.49%
Real, after-tax fixed-charge rate (FCR)	**5.69%**