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# Connecting Offshore Floating Wind to the Western Electricity Grid: Transmission Options Decision Modeling

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# *Connecting Offshore Floating Wind to the Western Electricity Grid: Transmission Options Decision Modeling*

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# Connecting Offshore Floating Wind to the Western Electricity Grid: Transmission Options Decision Modeling

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Image Credit: ABB (Øyvind Sætre)

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# 1 INTRODUCTION AND PROJECT PURPOSE

The purpose of this project is to obtain stakeholder views on a range of aspects relating to a proactive planning process to build transmission facilities in coordination with development of floating offshore wind (OSW) in southern Oregon and northern California. In the event that a transmission planning process to examine the potential need to assess and build transmission facilities to connect these wind resource areas is launched at a future date, the results of this study will assist planners by obtaining initial stakeholder views on the breadth of choices that should be considered, and more importantly, provide key insights on relationships between the perspectives of stakeholders and their expressed preferences between choices. The scale and nature of the offshore wind opportunity present in a relatively narrow geographic region allows for a compelling case to be made for a targeted transmission planning framework to achieve dual objectives: connecting offshore wind energy to load centers, and also providing increased connectivity between Oregon and California.

- **Add renewables to the grid.** Interconnection of large quantities of offshore wind generators to provide both the high quantity of renewable energy desired by state policies and high-quality generation profiles and capacity factors.
- **Increase inter-regional transmission network strength.** Increasing the electricity transfer capability between the Pacific Northwest and California in pursuit of economic and reliability benefits across many future decarbonization scenarios in light of the synergies between regions in terms of load and resource diversity.

The purpose of this study is to assess the extent to which stakeholders seek to pursue these objectives and obtain further insight into how they may be accomplished given that any such project will likely encounter a wide range of support and opposition from a wide range of perspectives. This study identifies non-technical, policy-oriented perspectives and employs a multi-criteria decision analysis to quantify stakeholder assessments of the impact of these perspectives on prioritizing alternatives. The results will inform a future need statement for OSW planning.

**Research Lens: Proactive Transmission Planning & Participatory Modeling**
In contrast to transmission planning processes that act in a reactionary manner to requests by generation developers for interconnection to one or more transmission service providers, an alternative approach is a proactive plan that seeks to determine transmission needs in advance of – or in close alignment with – development of generation resources. Such a framework does not currently exist in the study area. This study is undertaken in the spirit of a proactive process and is intended to support such an effort if one occurs. The methods employed herein are further intended to support participation by a wide range of stakeholders who are not traditionally involved in early stage transmission planning processes. While the focus of this analysis seeks to assist planners in early stage framing of the issues, the methods could be used to engage stakeholders in addressing the challenging questions that are likely to emerge over how to connect OSW on the west coast.

# 2 FINDINGS

This section provides a summary of findings & recommendations, which are presented in following parts:

1. Qualitative findings resulting from a review of academic literature industry documentation, and semi-structured interviews with subject matter experts.
2. Quantitative findings resulting from the multi-criteria decision analysis survey
3. Conclusions and recommendations for future study and development activities

First a review of relevant literature and industry proceedings was conducted, and second a group of subject matter experts was convened for one semi-structured group interview, and several individual semi-structured interviews. These findings helped to shape the direction of this effort in its initial phase, including development of the research questions and survey design.

## 2.1 BACKGROUND RESEARCH FINDINGS

Interest in OSW is increasing, as is momentum behind large-scale adoption of renewable energy in general to substitute for fossil fuel generated electricity. However, planning and procurement activities for solar and land-based wind in certain locations are significantly more developed than for OSW. To understand the total resource potential and means by which utilities in Oregon and California may ultimately access this potential, several areas where research is needed, including transmission. The following findings support the research questions, survey, and recommendations that are presented below.

### Transmission expansion is necessary to support a shift to reliance on wind and solar resources

As a growing number of utilities, jurisdictions, corporate electricity buyers, and retail consumers continue to express preferences for ever-higher proportions of renewable energy in their supply mix, the demand for total quantities of wind and solar electricity are set to grow substantially in the coming decades. However, a fundamental geographic mismatch exists between the best locations where wind and solar energy may be harnessed and the cities and industrial areas where electricity is most needed. After decades of declining transmission investment, a modest recent increase will likely be insufficient to meet ambitious decarbonization ambitions.[1]

Of the relatively few examples of ambitious project proposals that sought, or are currently seeking to connect large volumes of renewables to cities, a shared narrative of NIMBY opposition and a host of other obstacles has become a dominant theme.[2] As a result to accelerate the potential for constructing the necessary large facilities, new approaches are needed to both work with local communities that may oppose projects, and examine a range of locations where the correct balance of opposition and support may exist to enable a higher likelihood of success.

A recent study sponsored by the Western Interstate Energy Board also found that “significant incremental transmission upgrades” may be necessary to meet policy goals, even with increased coordination and grid management achieved through market and operations consolidation.[3]

### Renewable Energy diversity is an important contributor to cost reductions

California is one of the first areas in the United States where renewable energy diversity is emerging as central issue that planners must address in earnest. As solar energy increases as a portion of the California’s energy mix, diversifying its renewable energy mix is becoming more important to provide energy during evening and nighttime hours. In the Pacific Northwest, similar challenges exist, but to a lesser extent, for the fleet of wind generators that have been built in the last 15 years, which are nearly all located in the Columbia Basin and generally follow a common generation pattern which is prone to low output during peak load events. Adding more generation in these same locations may have diminishing returns in absence of significant storage investments. However, increasing the ability to exchange energy between regions increases diversity. A new offshore intertie would both increase renewable energy diversity by enabling connection of OSW and increase connectivity between regions.

California’s Integrated Resource Planning process administered by the California Public Utilities Commission provides an indication of potential future resource procurement trends. During the previous two planning cycles, wind resources in Wyoming and New Mexico, along with the transmission investment to connect to California were included in the lowest cost portfolios to achieve the highest GHG reduction

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[1] Joskow, Paul. “Transmission Capacity is Needed to Decarbonize the Electricity Sector Efficiency” (2020) [39] https://www.sciencedirect.com/science/article/pii/S2542435119305276

[2] Gold, Russell. *Superpower: One Man’s Quest to Transform American Energy* (2019) [40] https://www.russellgold.net/superpower

[3] Western Flexibility Assessment Final Report. (2019) [41] https://westernenergyboard.org/wp-content/uploads/2019/12/12-10-19-ES-WIEB-Western-Flexibility-Assessment-Final-Report.pdf

scenarios that were considered. In the current IRP processes, California OSW is being included for the first time and appears likely to be included the low GHG emissions portfolios going forward.[4] As this process continues to strive for lower GHG targets, wind resources are likely to continue to play a larger role in California's renewable mix.

### Increasing the capacity and reliability of the PNW – California interties has been identified as a potential contributor to economic renewable energy adoption

Recently, there has been an increase in interest in examining the benefits of increasing the transfer capability between the Pacific Northwest and California to make better use of the load and generating resource diversity between regions. This is notable because this diversity, along with the presence of surplus power in one region led to the construction of the two existing intertie systems decades ago. Today, the growing abundance of solar in California and the desert southwest is becoming an attractive option to provide energy to utilities in the Pacific Northwest during winter peak periods when load is highest. The potential for energy sharing is also benefitted by utility demand being generally low during the winter in California and the desert southwest due to low cooling loads.

The Northwest Power and Conservation Council is currently analyzing scenarios that will be included in its 2021 Power Plan, which may include an analysis of renewables external to the region and their ability to contribute to peak loads in the Pacific Northwest.[5] A coordination effort in 2018 between organizations in California and the Pacific Northwest resulted in an alignment of methodologies and assumptions to support future initiatives such as those to create regional resource adequacy standards or voluntary administrative programs.[6] With both regions likely to experience an acute need for dependable resource adequacy capability, increasing the extent to they rely upon each other may become an emerging option.

### Transmission planning for renewables in the Pacific Northwest is a reactive process and lacks thorough coordination

The current process of developing renewable projects in the Pacific Northwest involves complex procedures for obtaining transmission interconnection that commonly must be coordinated among several organizations that often do not share a common regulatory framework. Within this environment, there are many questions about how a planning process would be initiated to assess options to integrate the OSW resource, and potentially an intertie with California. Typically, wind developers must acquire control of a site prior to requesting transmission interconnection service from one or more transmission providers. Such a strategy is more likely to work if the site is relatively close to existing transmission facilities that the developer has reason to believe are able to reliably accommodate additional energy with modest upgrade costs.

However, for wind and solar resources in areas where little to no transmission infrastructure exists, an obvious chicken-and-egg problem emerges wherein developers are likely to be hesitant to invest without reason to believe transmission service will be possible. Conversely, transmission providers will be hesitant to invest without reason to believe renewable energy projects will be possible. This conundrum has been addressed before by proactive transmission planning processes, such as the Competitive Renewable Energy Zones (CREZ) initiative in Texas which designated wind energy zones and proactively built transmission facilities to serve them. The Electric Reliability Council of Texas (ERCOT) embarked on a plan in 2005 to plan, pay for, and build 3.600 right-of-way miles of 345 kV transmission lines.[7] This action was

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[4] OSW sensitivity run for the 2019-20 Reference System Plan.
https://www.cpuc.ca.gov/General.aspx?id=6442463190

[5] March 10th meeting of the System Integration Forum
https://www.nwcouncil.org/meeting/sif-2021-power-plan-scenario-review-march-10-2020

[6] Florio, Michael. "Sharing Power Among the Pacific States" (2018)
https://gridworks.org/wp-content/uploads/2018/01/Gridworks_ResourceAdequacy_online.pdf

[7] Orrell, AC. Energy Policy Case Study – Texas: Wind Markets, and Grid Modernization. [12]

taken in response to perceived market failures that blocked for-profit developers from investing in wind plants without a clear assurance that their plants would be able to connect to the grid.[8]

While there are currently processes in place for assessing transmission projects that connect remote renewables and those that span across multiple transmission planning organization boundaries, the track record in the western interconnection region has been poor with regard to achieving realized projects. FERC Order 1000 crated interregional transmission planning coordination processes that launched in 2015. While FERC required transmission planning entities to create new provisions in their tariffs for cost allocation procedures – which would be a means to actually pay for a transmission line connecting one region to another – these procedures have never been used. A further challenge is the presence of federal entities, the Bonneville Power Administration, and the Western Area Power Administration, which are not subject to the same regulatory framework as investor owned utilities, and thus do not participate in interregional planning in the same fashion.  This disparity challenges planning coordination because these federal entities own a significant portion of the transmission facilities in the western interconnection, including some of the rights of way reaching the southern Oregon coast that are considered in this study.

### The highest quality OSW location lends itself to a coordinated process between the Pacific Northwest and California

Because the quality of wind resource varies considerably along the west coast, certain locations have been prioritized for action. While there are multiple locations in central California that stand to be attractive candidate OSW centers, the best wind resource straddles the Oregon-California border, and is likely to be the subject of increasing attention. If in the coming years, California procurement entities, and state agencies such as the California Energy Commission decide that northern California OSW should be pursued as a component of the state's 100% clean energy mix, a host of planning and infrastructure support processes will be needed, transmission planning among them. California agencies have previously initiated proactive transmission planning processes, most notably the Renewable Energy Transmission Initiative (RETI) and the Desert Renewable Energy Conservation Plan (DRECP), which together assisted the growth of utility-scale solar in California.

If future initiatives are launched in California to conduct planning activities in a similar fashion for OSW in the Humboldt area, a key question may emerge: whether and how these initiatives should include integration with planning activities in the Pacific Northwest? The rationale for posing such a question of interregional coordination pertains to the geographic proximity of the existing transmission facilities in both Oregon and California which are roughly equidistant from the center of the highest quality wind area. This geographic orientation formed the basis for the offshore intertie concept and the alternatives that were created, described in section 6 below. In summary, any effort to configure seafloor cables to access the area of highest wind resource potential will have to either reach to the north from California or reach to the south from Oregon. In the event that both are under consideration, it begs the question of whether a connection should be created in the middle. Outreach with OSW stakeholders confirms that this potential connection is of increasing interest to the industry.

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https://www.osti.gov/biblio/1367391

[8] Gould, MC "Everything's Bigger in Texas: Evaluating the Success and Outlook of the Competitive Renewable Energy Zone (CREZ) Legislation in Texas [13]
https://repositories.lib.utexas.edu/handle/2152/68613

## 2.2 SURVEY FINDINGS

An online survey was created and distributed to OSW subject matter experts. Survey results are presented below. The findings are intended to provide input to future planning processes in terms of the types of potential projects and/or planning reforms that may be needed to secure OSW resources.

**Research Questions**

Given the background findings described above, research questions were developed with input from stakeholders that address the Pacific Northwest – California coordination.

> **RQ1:** Do stakeholders believe OSW should be connected via a new California-Oregon Intertie, or should radial connections be prioritized?
>
> **RQ2:** Do regulatory and political barriers exist that hinder an intertie configuration in comparison with radial connections?

**Survey Methodology & Options**

As described in greater detail in section **Error! Reference source not found.** below, an analytic hierarchy decision modeling process was employed for survey data collection. This method decomposes a complex problem of choosing between a set of options into more granular pieces that are related to each other in a hierarchical fashion. It relies upon a series of pairwise comparisons between options with respect to a set of decision criteria. These decision criteria were proposed and validated with stakeholder feedback such that they would best elicit subject matter expert preferences with respect to the research questions. Four options were assembled, described in greater detail in section 6 below.

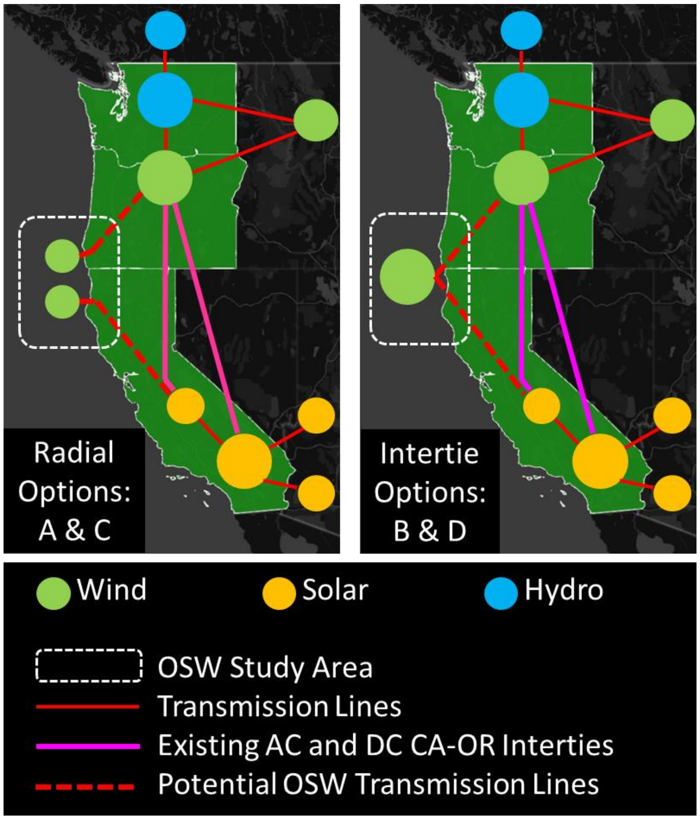

Figure 1: Diagrams of the study area and the options. General locations of non-emitting wind, solar, and hydro resources shown for comparison purposes.

**Results: Intertie vs Radial to Support Economical GHG Reductions**

The purpose of the four configurations was to present subject matter experts with a set of tangible options based on the background research and stakeholder input, not to suggest that these options should specifically be included in any future studies. Details about each option, and the overarching trend in preferences amongst the options is shown below. Additional detail about analysis of the survey and results can be found in section 5.

| Option | Intertie or Radial? | Wind Quantity (MW) | Intertie Capability (MW) | Decision Analysis Score |
|---|---|---:|---:|---|
| A | Radial | 6,000 | 0 | 0.13 |
| B | Intertie | 6,000 | 3,000 | 0.18 |
| C | Radial | 12,000 | 0 | 0.2 |
| D | Intertie | 12,000 | 4,500 | 0.49 |

Figure 2: Option configuration and decision model results

Clearly, subject matter experts prefer option D, which would enable the connection the largest quantity of OSW and the highest capacity connection between the Pacific Northwest and California. This reflects their assessment that the larger intertie would lead to greater GHG reductions and economic benefits compared with the smaller intertie and radial options. These results may provide a basis for future academic research or industry studies to investigate the feasibility and benefits provided by an offshore intertie.

**Results: Regulatory & Political**

The two decision criteria included in the model pertaining to regulatory and political barriers to an CA – OR intertie are as follows:

- Lack of organized transmission planning and cost allocation in the Pacific Northwest, and between the Pacific Northwest as a whole and California.
- Lack of organized resource adequacy in the Pacific Northwest, and between the Pacific Northwest as a whole and California.

The presence of a coherent method to allocate a large project's cost among its many beneficiaries is clearly a potential limiting factor, but resource adequacy coordination also stands to be important if the reliability value of increased connectivity is to be a contributing factor to justification of a project. Figure 3 below shows individual decision criteria scoring, which includes the environmental and economic criteria that sought to test whether subject matter experts prefer the intertie or radial configuration. When asked to judge options with respect to those criteria, the larger intertie is their clear preference – reflected in the high score for the green and grey bars for option D. Conversely, when asked to judge options with respect to political and regulatory limitations, they found the intertie options to be less feasible, reflected in the low score for the blue bars for option D.

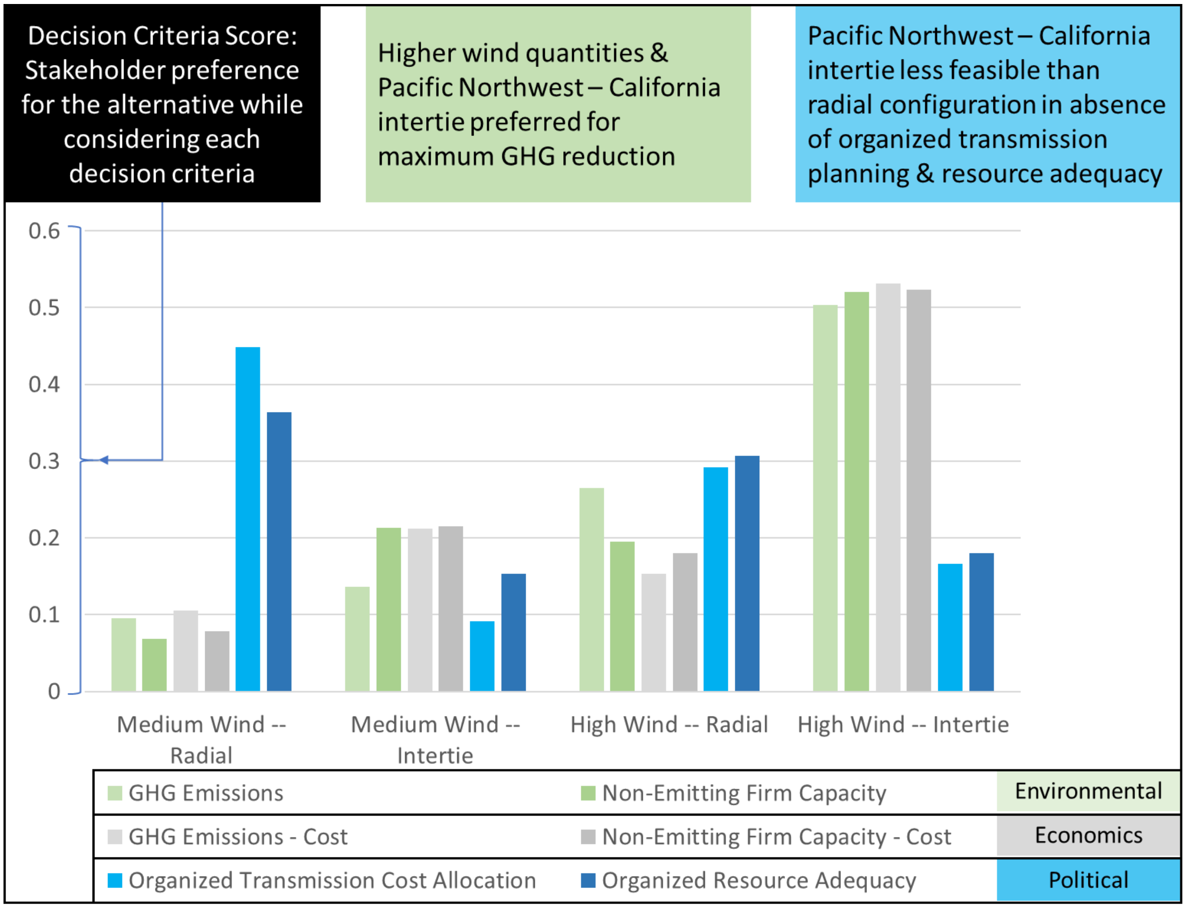

Figure 3: Decision criteria results & interpretation

## 2.3 CONCLUSIONS & RECOMMENDATIONS

The main conclusions that can be drawn from the background research and survey data collection are that future initiatives to study integration of large quantities of OSW to the Pacific Northwest or California systems should consider an intertie connection, and that regulatory and political barriers will likely need to be addressed to enable such an intertie to come to fruition. In response to these conclusions, the following recommendations are included as suggestions for future research.

1. **Improve the state of knowledge available to local stakeholders, wind developers, and renewable energy purchasers on potential transmission opportunities for OSW.**

   Progress on large projects such as an intertie is often incremental. No one study or proposal is likely to tip the scales and lead to a breakthrough. This means that a series of studies are likely needed to incrementally inform the relevant parties of the opportunities that may exist. Utilities and others who are seeking to acquire OSW need to gain a level of comfort with the resource and its ability to obtain a transmission interconnection before they will be willing to initiate steps to commit to making substantial investments. Local parties, including both those who may be opposed to certain aspects of development, and crucial local partners that will be needed to support development will also need to build their understanding of the planning processes and the potential outcomes.

   Current study work is underway in California to examine the connection of OSW in the Humboldt area to the California grid. Additional study work is being contemplated in the Pacific Northwest. The findings of this study support the creation of an initiative to bring these efforts together to jointly examine the potential of an offshore intertie.

2. **Coordinate the creation of OSW zones with potential transmission connections**

   In assembling the alternatives used in this study, a contrast became apparent between the intertie and radial options, which could impact the location and size of potential OSW lease zones. With the Bureau of Ocean Energy Management (BOEM), tasked with identifying these locations, the potential for different outcomes with respect to offtake of the energy stands to be a vital consideration in its processes. In the absence of an intertie and a broader transmission cost allocation framework applied to OSW interconnection, OSW zones may be more likely to cluster as close as possible to the offtake location. This may lead to a considerably different outcome than what may be expected for the intertie option. In contrast, an intertie could be purposely configured to provide connections at the optimal wind locations with single cable landing points at either end. Decision makers tasked with determining whether the bulk of the wind development will be placed squarely in the middle of best resource area or scattered along its edges will be benefitted by an examination of an intertie.

   A further reason to prioritize this coordination is that individual OSW developers will not necessarily prioritize benefits to the broader grid in their geographic locating decisions, especially to the extent there are incremental costs to create an intertie rather than radial hubs. These incremental costs, which cannot reasonably be expected to be borne by the first wave of developers alone, would create future interconnection points to be used by future developers. Therefore, an intertemporal choice to build the intertie earlier than a certain portion of the OSW development, if sufficient value to both future OSW developers, and the broader grid can be demonstrated.

3. **Improve the state of knowledge of regulatory and political barriers to cost allocation for large projects**

   Transmission planning and cost allocation must evolve to enable a transition to renewable energy. Given the fragmented nature of the Pacific Northwest system, and its separation from California cost allocation practices, a study of barriers that exist in both regions to an intertie is warranted. The results of this study confirm that subject matter experts believe transmission and cost allocation and resource adequacy coordination represent barriers to infrastructure projects that may be needed for decarbonization. A deeper understanding of the nature of these barriers, and ideas for how they may be overcome will be useful to policy makers tasked with implementing renewable energy transition strategies.

# 3 LITERATURE REVIEW

## 3.1 IS A NEW OFFSHORE TRANSMISSION LINK NEEDED?

Why is additional intertie transmission capability potentially valuable to the coastal region of the Western Electricity Coordinating Council (WECC) area beyond simply the delivery of wind energy generated in the study area as illustrated Figure 4. Several drivers are emerging in the complex and rapidly changing energy landscape in the west that may converge to 1) focus attention for offshore wind development on the study area, and 2) increase the need to transfer high quantities of electricity between the Pacific Northwest and California grids.

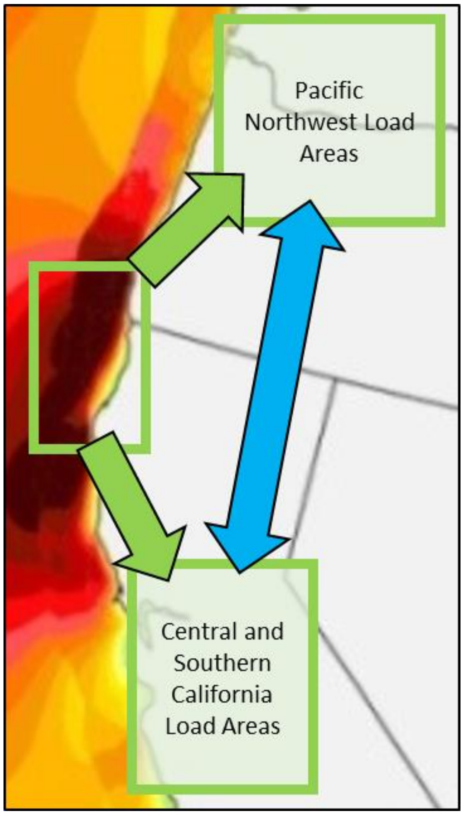

Figure 4: Study area in relation to the Pacific Northwest and California.

Several other wind energy areas are likely to be developed in the future, such as those that may be connected to the California and Oregon grids via radial connections, but in order to establish a reasonable and achievable total addressable market for offshore wind in the pacific region, it stands to reason that the Humboldt/Southern Oregon region must be addressed in some fashion. This is due to the area's superior wind potential and also the presence of fewer encumbrances that are faced by other areas that have been identified for OSW development.

These encumbrances include potentially conflicting ocean uses such as various types of military activity, fishing, shipping and other uses. In general, Humboldt and southern Oregon areas exhibit fewer of these restrictions. For one, these areas have far fewer shipping lanes than are seen in Southern California or Northern Oregon. In addition, the Department of Navy has published initial indications that northern areas of California are subject to fewer restrictions than many areas in southern California.[9]

Both regions are moving quickly toward high electricity system decarbonization goals, which will entail procurement of large quantities of wind and solar electricity. Beyond procurement of renewable energy, the need for firm electricity generation capacity is growing as existing coal plants are retired and variable wind and solar are added. To lessen the need for utilities to procure zero GHG emitting firm electricity generation resources, higher levels of transmission integration between regions may prove to be valuable to the extent that a single resource built in either region may assist in providing resource adequacy (RA) capacity to both regions.

Increasing inter-regional transmission network capability
While the western interconnection operates as a single large synchronous machine, the density of this transmission network is greater in certain zones. In between these zones, a discrete quantity of transfer capability exists to move electricity generated in one zone to serve load in another. There is often a high economic value in utilizing these transfers, such as during intervals where one region is experiencing surplus conditions and the other is in deficit conditions. The justification for building the existing California-Oregon AC intertie and the Pacific DC Intertie was based on load diversity and complimentary generation resource profiles in California and the Pacific Northwest.[10] However, there are limits to the transfer quantities between regions that may be utilized directly for reliable load service if these transfers are intended to be utilized as direct substitutes for local generation sources.

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[9] Department of the Navy California Offshore Wind Compatibility. https://navysustainability.dodlive.mil/rsc/department-of-the-navy-california-offshore-wind-compatibility/

[10] Binus, J. "Bonneville Power Administration and the Creation of the Pacific Intertie 1958 – 1964" (2008) [26]

For many zones that have high concentrations of electricity loads, maintaining reliability requires that a minimum quantity of generation capacity be online and responsive to operator instructions within those zones. In the California Independent System Operator (CAISO) operating area, these areas are identified as local capacity requirement (LCR) areas. CAISO performs studies to determine the minimum quantities of generation that must be located within an LCR area, which considers the electricity transfers into and out of that area. While there is not an exact corollary to LCRs in areas outside of the CAISO footprint, similar constraints exist in other areas of the western interconnection, such as in the Puget Sound area, where planning organizations have identified tradeoffs between local generation dispatch levels and transfers into and out of the Puget Sound zone, along with benefits from adding transfer capability via building new transmission facilities.[11]

The quantities of reliable transfers between LCRs, and the potential to increase these quantities, stands to have a major influence on total firm capacity need. Figure 5 below shows the WECC grid with two potential transmission projects for wind energy integration highlighted in relation to the regional load centers that are connected by these projects. The figure illustrates the difference between facilities that serve to strengthen the connection between load centers compared to alternative projects that are primarily radial connections to renewable facilities.

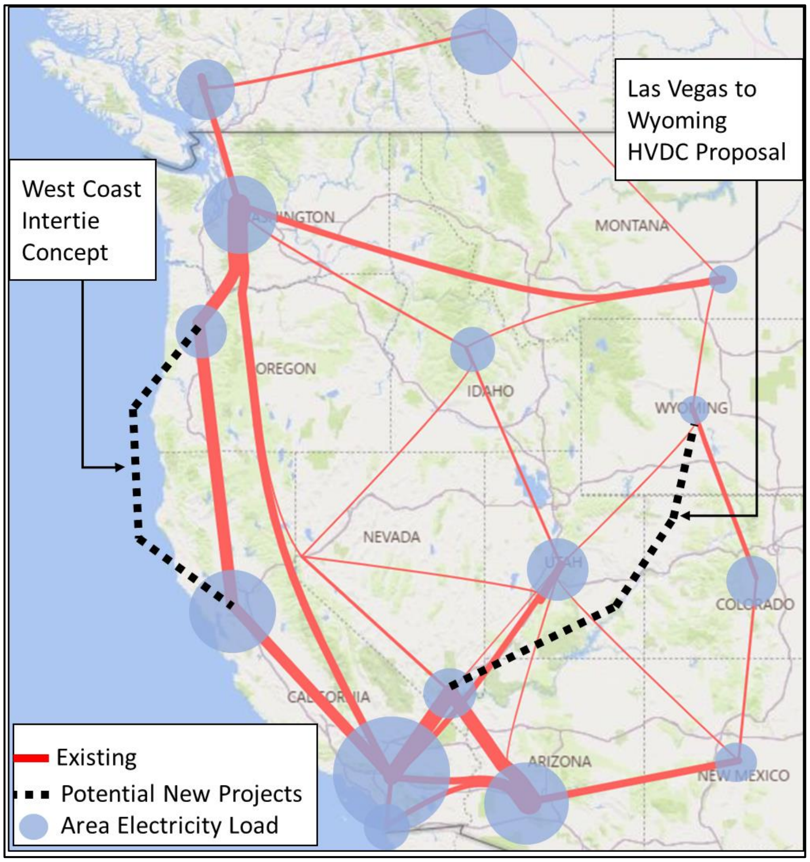

Figure 5: Western Interconnection loads, existing transmission lines, and one example of proposed new facilities. Chart Created using Microsoft Power BI. Topology and loads are a composite of 2016 WECC Loads and Resources Assumptions, and 2018-19 NTTG Regional Transmission Plan. The Las Vegas to Wyoming HVDC proposal is

One of the emerging drivers for increased utilization of a west coast intertie facility is increasing the quantity of solar energy transferred from California and the desert SW region north into the Pacific Northwest.

A study conducted by Evolved Energy Research in 2019 on an economy-wide decarbonization program in the Pacific Northwest modeled increasing transfer capability between regions, finding that allowing for selection of this option in an optimization model led to 4,500 MW of new capacity that lowered total system cost to achieve a high level of GHG reduction in part by economic transfer of solar energy.[12]

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https://pdxscholar.library.pdx.edu/open_access_etds/1724/

[11] ColumbiaGrid's 2010 Puget Sound Area Expansion Plan found that generation in the local area has a significant influence on transfers from the Puget Sound zone north to British Columbia. [8]
https://www.columbiagrid.org/download.cfm?DVID=3944&CID=0&RUID=11079

[12] The Clean Energy Transition Institute sponsored a study looking at economy-wide options [15]
https://www.evolved.energy/post/2019/06/11/northwest-deep-decarbonization-pathways-1

## 3.2 HOW MUCH NEW TRANSMISSION IS NEEDED TO DECARBONIZE THE GRID?

By some estimates, the need to construct new electricity transmission infrastructure to connect renewable energy and to accommodate new uses of electricity in the transportation and building sectors is overwhelming. A March 2019 report by the economic consultancy Brattle found that $30-90 billion in transmission investment may be needed by 2030 and $200-600 billion may be needed between 2030-2050.[13]

In his 2010 book *Smart Power*, Peter Fox-Penner described the possibility of new transmission lines for renewable energy as "the aluminum sky" while also noting that if these lines are not able to be built, states pursuing clean energy policies will turn inward toward solutions such as distributed solar that require less new transmission investment.[14] While in retrospect the latter outcome appears to be occurring as many states pursue distributed and utility-scale solar power as costs have declined, it is also becoming clear that a broader portfolio of resources are likely to be needed to achieve aggressive carbon policies.

For example, planning processes currently underway in California have identified the potential for lower costs and lower GHG emissions if renewable energy production diversity provided by wind generation is made available alongside solar in resource portfolios.[15] However, these wind generation facilities are located in remote areas and require significant new transmission projects.

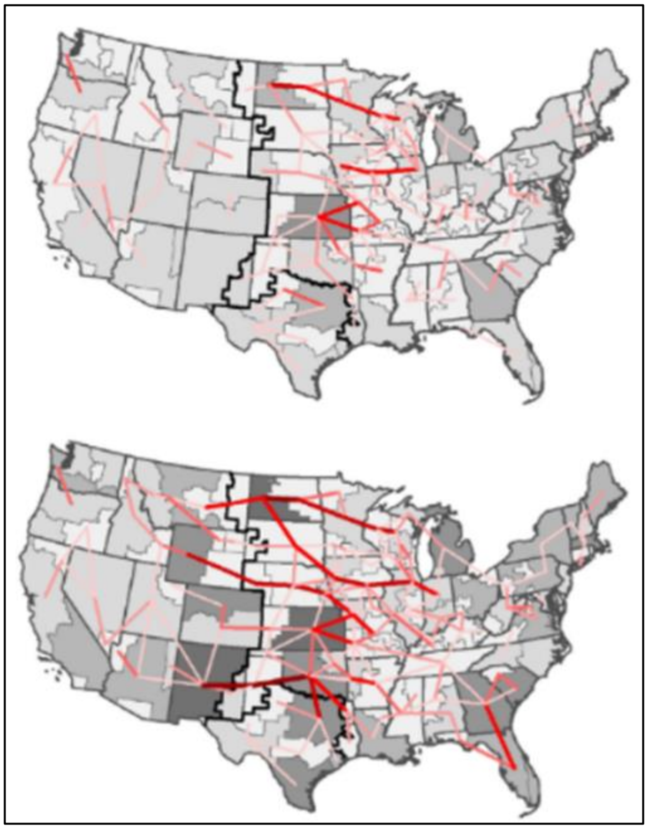

Figure 6: Comparison between transmission-constrained and non-transmission-constrained decarbonization scenarios as modeled by Mai and Mulcahy [17]

The presence of a tradeoff between increased renewable production diversity (which inherently includes a greater degree of transmission investment), and the magnitude of generation capacity buildout is shown in the academic and industry literature. Mai and Mulcahy (2014) found that 7x to 10x increase in new transmission transfer capability would be needed in a non-transmission-constrained scenario to achieve an 80% renewable energy electricity network.[16]

A similar finding is present in a recent study by the consultancy Energy + Environmental Economics for a California offshore wind project shows that investment in offshore wind offsets investments in solar and battery capacity due to generation profiles that deliver energy during nighttime hours.[17] One of the implications of this finding is that a tradeoff exists between investments in battery storage and transmission facilities to connect offshore wind.

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[13] "The Coming Electrification of the North American Economy: Why We Need a Robust Transmission Grid (2019)" https://wiresgroup.com/wp-content/uploads/2019/03/Electrification_BrattleReport_WIRES_FINAL_03062019.pdf

[14] Fox-Penner, Peter. "Smart Power: Climate Change, The Smart Grid and the Future of Electric Utilities (2010)

[15] California PUC Presentation Accessed 10.09.2019 https://efiling.energy.ca.gov/GetDocument.aspx?tn=229977-4&DocumentContentId=61472

[16] "Envisioning a renewable electricity future in the United States" T. Mai, D Mulcahy (2014) [17] https://www.sciencedirect.com/science/article/pii/S0360544213009912?via%3Dihub

[17] "The Economic Value of Offshore Wind Power in California"

## 3.3 PROACTIVE RENEWABLE ENERGY TRANSMISSION PLANNING BACKGROUND

Development of any power generation resource is inherently linked with the transmission facilities that interconnect its energy to the grid. Historically there have been numerous examples in the western US where transmission facilities were built specifically in response to a decision to build power generation facilities. This was the driver behind long-distance transmission facilities that serve many of the large coal-fired generating plants in the west. In the 1990s a wave of natural gas generating plants began to be built, which generally had more flexibility in siting due to the vast natural gas pipeline network in North America, so fewer dedicated transmission facilities were needed.

The era of renewable energy expansion that has been underway in earnest the past decade has mostly followed the latter path, which has seen most renewables sited in areas near existing transmission facilities such that the need for new dedicated projects was lessened.[18] This trend does not generally align with the best attributes of renewables, which are often found in locations were no transmission currently exists. However, there are notable exceptions to the general statement that renewables are most often proposed to be built near where they can access existing transmission facilities. In some cases, transmission facilities were built specifically with renewables in mind to facilitate their growth

### 3.3.1 TEXAS COMPETITIVE RENEWABLE ENERGY ZONES

Texas is a leader in wind energy, which is sometimes described as a result of the open electricity market structure and relative ease of development compared with other jurisdictions. But equally if not more important are the transmission planning activities conducted beginning in 2005 to expedite renewable development.

The Texas legislature created the Competitive Renewable Energy Zones (CREZ) project to first designate these zones and second build transmission facilities to serve them. The Electric Reliability Council of Texas (ERCOT) embarked on a process to plan, pay for, and build 3.600 right-of-way miles of 345 kV transmission lines.[19] This action was taken in response to perceived market failures that blocked for-profit developers from investing in wind plants without a clear assurance that their plants would be able to connect to the grid.[20]

However, upon creation of the CREZ framework, and ERCOT's process to plan, pay for, and build the network of facilities to provide transmission service to the zones, investment from renewable development firms commenced as intended.

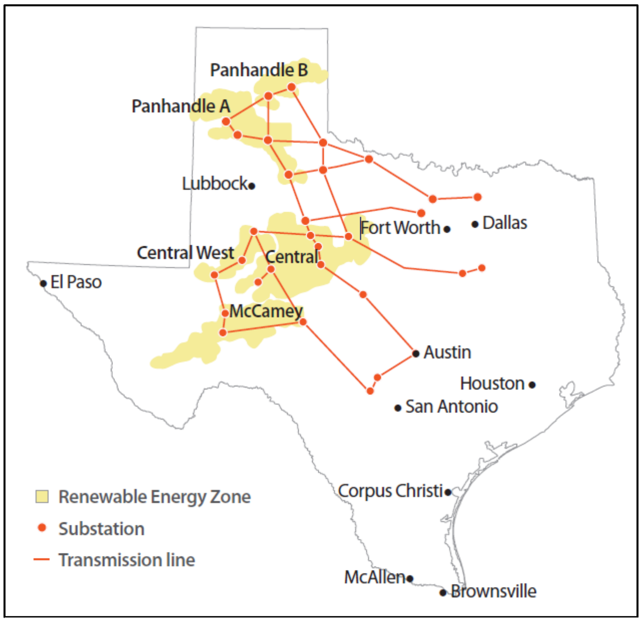

Figure 7: Competitive Renewable Energy Zones in Texas & Transmission facilities built to connect renewables in west Texas [11]

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[18] Gen-tie transmission lines and local reinforcements are needed to ensure that the energy produced by wind and solar plants can reach the bulk system.
https://www.greentechmedia.com/articles/read/what-developers-should-know-about-deliverability-in-california

[19] Orrell, AC. Energy Policy Case Study – Texas: Wind Markets, and Grid Modernization. [12]
https://www.osti.gov/biblio/1367391

[20] Gould, MC "Everything's Bigger in Texas: Evaluating the Success and Outlook of the Competitive Renewable Energy Zone (CREZ) Legislation in Texas [13]
https://repositories.lib.utexas.edu/handle/2152/68613

## 3.4 RENEWABLE ENERGY PLANNING & SOCIETY

The purpose of this component of the literature review is to examine the findings from researchers who have addressed the problems and identified potential solutions to large-scale shifts in both technology adoption and institutional processes, particularly in renewable energy adoption.

### Socio-Technical Transitions

In the management science literature, the analysis of the socio-technical transition theory and model is a useful lens through which transmission planning and large-scale renewable energy development may be viewed, as suggested by Davis (2014), particularly with respect to California's RETI program.[21] This is because the journey from a largely fossil fuel-based energy supply to one motivated primarily by carbon-free energy sources is likely to include a significant degree of socio-technical shift in both the technical systems and engineering processes used to plan transmission systems, and also the cultural norms that underlie those systems.

Large scale technical systems of which electric power system is an excellent example as suggested by Hughes (1987), represent an alignment of a large number of heterogenous, tangible, and measurable elements and artifacts.[22] Technological regimes on the other hand, are the 'rules' or 'norms' that guide participants in a semi-coherent fashion as they conduct their work, as suggested by Rip and Kemp (1998):[23]

> *A technological regime the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures*

An example of the difference between a socio-technical system and regime is provided by professor Matthew Hannon in an analogy with soccer. The system is represented by the players, referee, stadium, field, formal rules, and team investment, while the regime is represented by the rivalries, chants, customs, celebrations, fair play, and tactics. Projecting this type of analogy to energy planning institutions elicits a useful thought exercise in imagining the extent to which regime structure will have negative impacts on the ability of niche innovations to grow due to entrenched customs and cultural practices absent a driver strong enough to overcome those practices.[24]

Cusick et al. (2019) suggest that a class of assets called advanced transmission technologies face barriers to adoption due to limitations in planning processes that may be interpreted as socio-technical system and also regime limitations.[25] The authors note that the conservative practices related to the stringent reliability standards to which planners' work will be subjected tends to shape a limited view of the technology solutions available to solve a given problem, especially those without a long and proven track record. This is an example of a socio-technical regime that exists with embedded cultural norms that generally do not encourage innovation and adoption of new practices.

Verbong and Geels (2009) suggest that abrupt transitions in regime are not likely to occur quickly or take the form of a radical step change in large scale systems like electricity, but rather start slowly in 'niches' and progress toward larger transitions via four transition pathways.[26] These pathways describe the means by which niche innovations and landscape pressure combine to drive transitions. Shared among these pathways is the notion that the drivers

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[21] Davis, S "Electricity Transmission Expansion: What Does Successful Planning Look like? [20] https://www.sciencedirect.com/science/article/pii/S1040619014002334

[22] Geels, F, Kemp, R "Dynamics in socio-technical systems: Typology of change processes and contrasting case studies." [23] https://www.sciencedirect.com/science/article/pii/S0160791X07000516

[23] Rip, A, Kemp, R, "Technological Change" [21] https://research.utwente.nl/en/publications/technological-change

[24] https://twitter.com/hannon_matthew/status/1176148097875021825

[25] Cusick, K, Wellinghoff, J, Kristov, L. "Transmission Planning Protocol: Leveraging Technology to Optimize Existing Infrastructure. [24] https://www.center4ri.org/publications/#tpp

[26] Verbon, G, Geels, F, "Exploring sustainability transitions in the electricity sector with socio-technical pathways" [22] https://www.sciencedirect.com/science/article/pii/S0040162510000752

integral to a socio-technical transition will experience some type of stimulation that opens up previously hidden choices.

Geels et al (2017) apply the social-technical approach – and need for a stimulant to drive transitions -- to decarbonization, noting that solar photovoltaic technology was the recipient of a significant stimulus from feed-in-tariff subsidies in the early 2000s which was one of the main causes for its rapid growth.[27] Today, with solar PV having the fastest growth of any renewable energy source in the WECC region, a need exists to look toward yet more stimulations to advanced technology development in areas such as storage and complimentary renewables like both onshore and offshore wind. The nature of the types of stimulations that stand to accelerate socio-technical transitions often relates to the presence of some type of perturbation from outside influence(s), combined with the tensions internal to the regime that may make the large-scale system more likely to undergo a transition.

**Key Finding: stimulation to existing planning processes**

Because the socio-technical regime transition approach indicates the need for such an outside perturbation, and the offshore wind sector – which may rightly be considered a niche sector when considering offshore floating applications – is so highly dependent on a transmission capability step change to enable growth, a stimulation to the transmission planning process itself is likely needed

The framework which such a stimulation might occur is informed by the technology management literature, which highlights the role of interdisciplinary approaches and inclusion of outside perspectives in technology development. Van de Poel (2000) suggests that changes to the trajectory of a socio-technical regime are more probable with the influence of outsiders because these outsiders do not share the same regime, and they “may well initiate radical innovations that depart from that regime.” [28] Van de Poel further classifies three groups of outsiders that stand to play a role in technical development:

- Societal pressure groups
- Professional engineers & scientists
- Outsider firms

These groups are differentiated by the resources they may use to become involved in a technical development and the influence they wield. While societal pressure groups generally do not possess the technical capabilities needed to influence technical development directly, they may wield a large and diffuse influence over public opinion, especially in cases where they are able to influence other actors, which may extend to insiders, to motivate activities for or against a certain technology or approach. The inclusion of these outside groups in an effort to “democratize technical development” is one approach that stands to improve outcomes.

Because of the “insider” nature of several aspects of energy system planning, in particular transmission planning, the inclusion of outside perspectives may be needed to achieve the much higher levels of throughput that many energy system modelers believe is needed to achieve a highly decarbonized outcome. Cusick’s suggestion that advanced transmission technologies are often overlooked due to the presence of an insular planning process echoes this sentiment, stating that one of the main problems is that there are “limited opportunities for non-incumbents to submit alternative proposals, or may lack transparent and effective criteria for comparing them”

In response to these shortfalls, the participatory modeling approach may be considered to bring a wider range of perspectives to bear, and also to identify trouble spots early enough that they may be remedied without derailing a project.

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[27] Geels, F, Sovacool, B. “The Socio-Technical Dynamics of Low-Carbon Transitions” [25] https://www.sciencedirect.com/science/article/pii/S2542435117300922

[28] Van De Poel, I. “On the Role of Outsiders in Technical Development.” 2010. [27] https://www.tandfonline.com/doi/abs/10.1080/09537320050130615

**Participatory Modeling**

Participatory modeling refers to a range of techniques that are used to include "a broad range of stakeholders in the process of formal decision analysis" as defined by Stave (2010).[29] Typically these techniques involve creation of a computer model. While many planning processes perform analyses using computer models, the difference between a partially participatory process and one that is fully participatory is the extent to which stakeholders assist in structuring the problem statement and the model used to assess interventions to the system under consideration.

The extent to which stakeholders are engaged in structuring the problem from the very earliest stages of a project's conception is informed by the adoption of a participatory modeling approach, and decisions that are made as to extent, timing, and support for stakeholder involvement. There are several means by which stakeholders perform their participation activities. Voinov, et al. (2018) provide an overview of the tools and methods that may be used in participatory modeling, ranging from quantitative modeling to qualitative approaches.[30]

# 4 ASSEMBLING THE DECISION MODEL

This section provides background on the modeling methodology, the processes used to establish this methodology and, and the intended role of this work in the broader landscape of current and future planning activities relating to OSW.

**Research Lens: Framing the issues for OSW, Identifying Future Participatory Modeling Opportunities.**

While the current study was conducted with an eye toward use of decision analysis tools to enable deep involvement of a wide range of stakeholders in the very challenging issues facing electric transmission line planning, the work is intended as an initial phase that primarily seeks to frame the larger issues that will help craft the need statement that would underline any future process to configure transmission proposals for detailed study. A need statement for a potential future transmission study is informed by the following questions, to which the methodology employed herein seeks to address.

- How much transmission capacity should ultimately be built to connect OSW in the study area?
- Should this transmission investment be configured to provide stronger connections between regions?
- How does the industrial organization structure in the utility industry impact the ability to consider regional connectivity in a planning process?
- How should tradeoffs between economies of scale and local impacts be addressed at the outset of a proactive planning process?
- Should the OSW zones in the study area be located centrally between Oregon and California or separately in each state?

**The purpose of this study is to assist in establishing a need statement, and provide a starting place for stakeholder involvement in a planning process to address this need statement. This study does not seek to configure a specific transmission proposal or OSW lease zone pattern.**

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[29] Stave, K. Participatory System Dynamics Modeling for Sustainable Environmental Management: Observations from Four Cases. 2010. [28]
https://www.mdpi.com/2071-1050/2/9/2762/htm

[30] Voinov, A. "Tools and Methods in Participatory Modeling: Selecting the Right Tool for the Job" (2018) [29]
https://www.sciencedirect.com/science/article/pii/S1364815218303098#bib158

### Multi-Criteria Decision Analysis (MCDA)

The MCDA method used in this study provides a structured decision framework to address a problem situation where multiple objectives are present, and some of which may in with each other from the frame of reference of an individual decision maker. The use of MCDA tools provides decision makers a way to distill the input from a set of subject matter expert stakeholders in a structured fashion in support of the ultimate decision objective. MCDA processes usually have three steps, as described below according to Heinrich et al. in a paper that used MCDA for an electricity generation expansion problem.[31] In general, these steps were followed in in this study.

- **Problem structuring.** In this phase, "stakeholders are identified and agreement is reached on the options to be included for consideration as well as the criteria that will be used to judge the performance of the alternatives."
- **Problem Analysis.** In this phase, the alternatives are evaluated based on the criteria selected by the decision maker for given preferences."
- **Selection of the preferred alternative or set of alternatives.**

### Problem Structuring: Initial questions & Steering Committee Feedback

A review of academic and industry literature informed the problem structuring phase, including the formation of the key questions that are being asked herein. Following the formation of these questions, a stakeholder steering committee was convened for the purposes of providing feedback on the appropriateness of these questions. The committee consisted of the following members:

- PSU Professor with experience researching energy facility siting
- NGO renewable energy advocate experienced in regulatory affairs
- Transmission planning engineer experienced with regional study processes
- OSW industry association representative
- Southern Oregon energy consultant experienced with environmental assessment processes

One steering committee meeting was convened, and the following research questions were discussed relating to the initial problem structuring questions.

| | |
|---|---|
| 1 | Should the Humboldt/ S. OR area be prioritized in this study over the other areas? |
| 2 | Do you agree with the problem statement that PNW-CA connectivity should be a key objective? |
| 3 | Should an independent study process be initiated? Why isn't the current planning processes sufficient? |

In general, the feedback received from the steering committee was supportive of the 1) the decision to focus on the study area, and 2) the decision to include PNW-CA connectivity in the study. While OSW development efforts in California are underway outside the study area, the steering committee believes that several factors are currently leading the industry to choose the Humboldt area as a first priority. The general belief that exchanging more energy between the PNW and CA will be helpful in meeting climate goals was shared among the members.

However, the presence of potential friction within some stakeholder groups with respect to a new PNW-CA intertie connection was identified, given the perception that such a large project would be associated with regionalization of the CAISO, which may open up new opportunities for onshore wind development outside of California. To the extent OSW developers active in California perceive these potential opportunities as competitive threats, they may oppose an intertie. Alternatively, these developers may stand to benefit from an intertie if its costs are shared broadly across the region.

All committee members agreed that the current transmission planning framework is insufficient to accommodate a proactive planning process for OSW. However, an asymmetry exists between the PNW and CA, given the greater degree of organization of transmission cost allocation in California.

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[31] Heinrich, G. "Ranking and selection of power expansion alternatives for multiple objectives under uncertainty" [37] https://www.sciencedirect.com/science/article/pii/S0360544207001053

### Problem Structuring: Constructing the Options & Perspectives & Decision Criteria

As described in greater detail below, while the purpose of the study was not to ask for judgement on the particulars of a transmission configuration as they relate to technical or engineering feasibility matters, tangible choices were constructed with the intent of eliciting feedback from participants about the choices that must be made between the options.

The criteria were assembled using inspiration from the steering committee discussion, as well as additional academic and industry literature review. Feedback was obtained from steering committee members on an individual basis to validate the choices of perspectives and criteria as describe further below.

### Problem Analysis: Analytic Hierarchy Process

This method compiles stakeholder input on the decision problem by way of a series of pairwise comparisons that are structured in a hierarchical fashion as shown in the table below. Perspectives at the top level of the hierarchy are weighted in importance by comparing them to each other on a ratio scale basis. Then, the decision criteria nested under each perspective are used to drive stakeholder data collection via pairwise comparisons of each option against these criteria. This method was originally developed by Saaty, with one of its cornerstones being the notion that when complexity of a problem exceeds the capability of human cognition to process this problem at once, it should be broken into smaller pieces.[32]

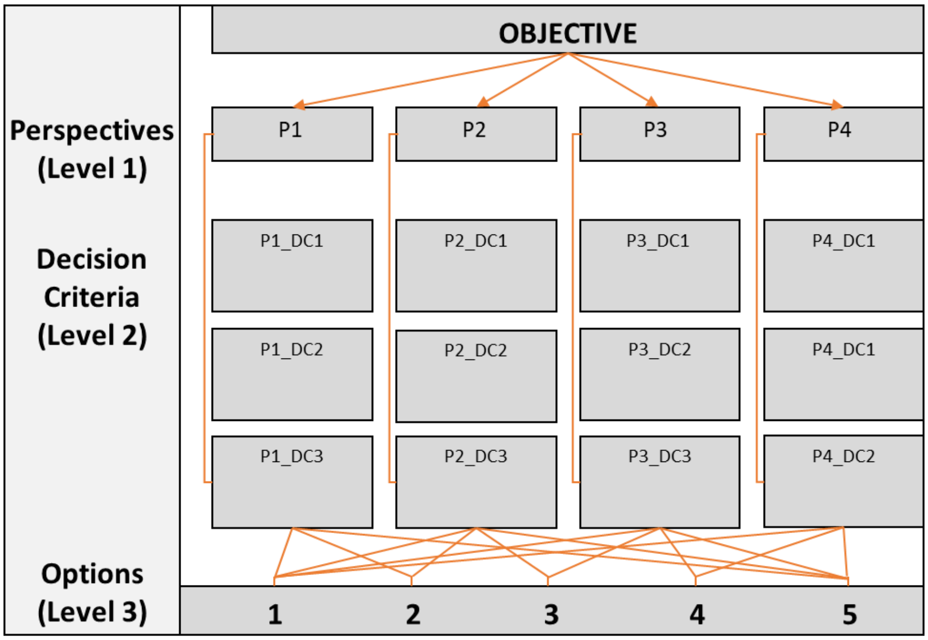

Figure 8: Conceptual diagram of an AHP model

### Selection of Perspectives

MCDA for energy systems often utilize the STEEP (social, technological, economic, environmental, political) perspective structure, often with modifications.[33] In a review of 47 MCDA studies relating to energy & technology, Wimmler, et al. found that the most common perspectives are environmental, economic and social, while significant variations exist as researchers tailor perspectives to their research questions.[34] In keeping with

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[32] Saaty, T. 1980. "The Analytic Hierarchy Process: Planning, Priority Setting, Resources Allocation"

[33] Sheikh, N. 2011 "A comphrehensive review of solar technologies: literature review." https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6017908

[34] Wimmler, C. "Multi-Criteria Decision Support Methods for Renewable Energy Systems on Islands" [38] http://www.jocet.org/index.php?m=content&c=index&a=show&catid=38&id=481

objectives of this study that do not emphasize stakeholder input on technical issues, the technical perspective was removed to focus the analysis on the following perspectives: Social, Environmental, Economic, Political.

**Validation of Perspectives and Decision Criteria**

Through engagement with the steering committee, the perspectives and criteria were refined. The political perspective was added in response to the steering committee feedback about challenges in that a planning project could encounter due to regional differences and specific stakeholder interests. The social perspective was removed to narrow the criteria on the research questions and prioritize social issues for future analysis that could not all have been considered in this study.

As described further in section 6 below, the alternatives were assembled primarily to represent intertie and radial configurations. At the outset of the process of assembling alternatives, a "non-wire" solution was included, in keeping with many transmission studies that include "no action" or "non-wire" alternatives in the analysis. After discussion with stakeholders, this option was deemed to be outside the scope of the intended analysis and removed.

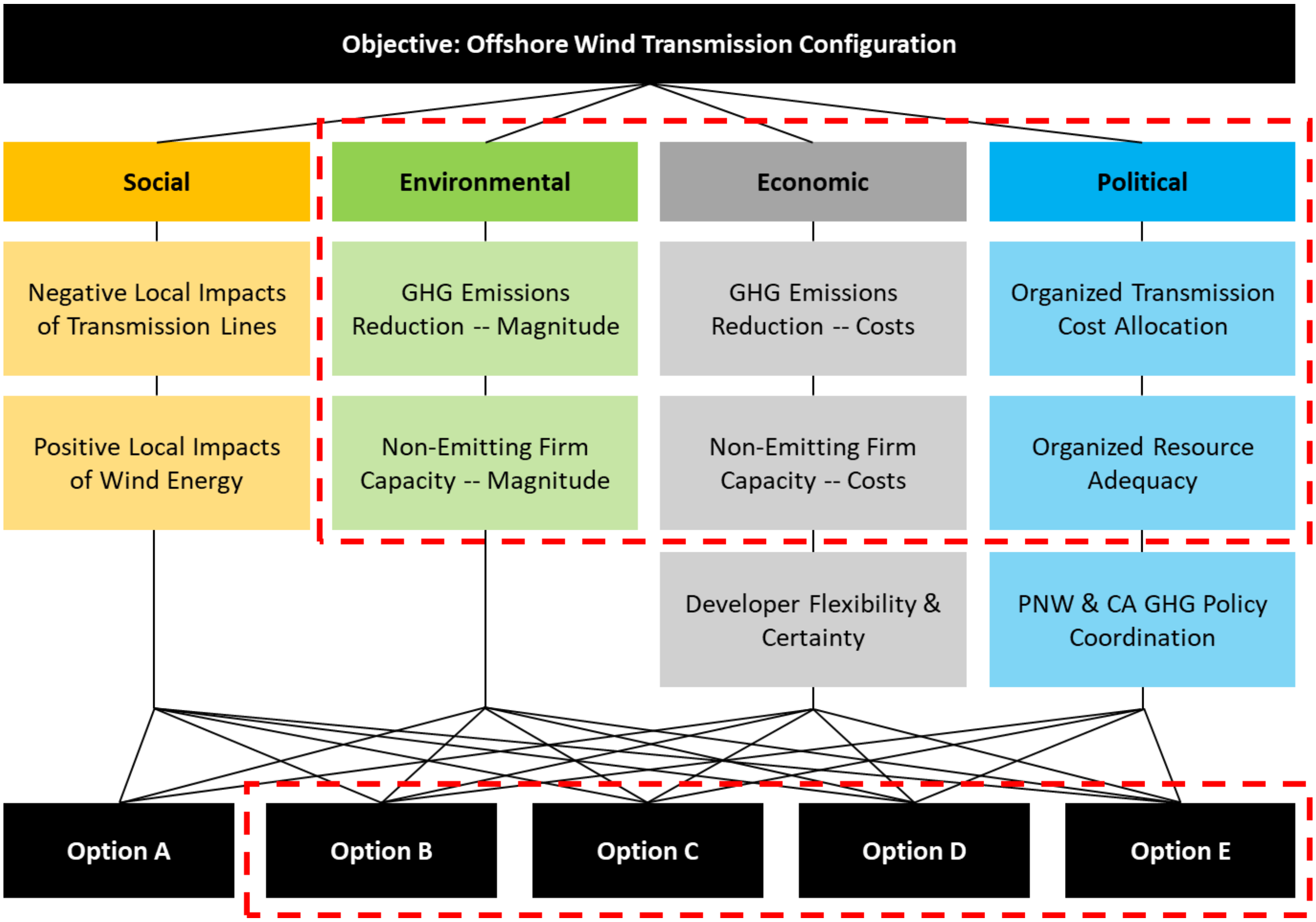

Figure 9: Original and final criteria, perspectives, and options. Final outlined in red.

## 4.1 SUMMARY OF DECISION CRITERIA

| Environmental | Economic | Political |
|---|---|---|
| **GHG Emissions Reduction**<br>The relative extent to which either option will reduce total GHG emissions in both the PNW and CA | **GHG Emissions Reduction**<br>The relative extent to which either option provides the most economic GHG emissions reductions in both the PNW and CA | **Organized Transmission Cost Allocation**<br>The relative extent to which either option is feasible in absence of an organized cost allocation framework between the PNW and CA |
| **Non-Emitting Firm Capacity**<br>The relative extent to which either option will reduce the need for utilization of firm fossil generation for resource adequacy capacity | **Non-Emitting Firm Capacity**<br>The relative extent to which either option will assist in providing the most economical solution to obtaining clean resource adequacy capacity capability to the PNW and CA | **Organized Resource Adequacy**<br>The relative extent to which either option is feasible in absence of an organized resource adequacy framework between the PNW and CA |

**GHG Emissions Reduction – Total Magnitude & Cost**
The total GHG reduction that an option may enable the entire west coast region to achieve.

This is a very broad and challenging criteria. You will compare two options for their ability to reduce total GHG emissions. This includes both the quantity of renewable electricity each option will connect to the grid, but also any other factor that you believe would lead to one option to cause greater GHG reductions than the other.

**Non-Emitting Firm Capacity**
The ability to provide sufficient firm resource adequacy capacity across the entire west coast region.

Participants are asked to compare options while considering any factor they believe will influence firm capacity outcomes, which may include but are not limited to the following suggestions:

- Renewable Production Diversity. Increasing diversity will likely reduce need for firm capacity.
- Load Diversity. While temperature trends are changing, seasonal diversity will continue to exist between California and the Pacific Northwest.
- Pacific Northwest Hydro Flexibility. Many believe the PNW hydro system may be utilized differently to better support reliable integration of renewables across the west.
- California Solar + Storage. California utilities are likely to continue investing in solar and potentially in significant quantities of various emerging and existing storage technologies. Due to the risk of continued high cost of storage, outcomes that decrease the need for storage or share its cost among a larger pool of beneficiaries may become sufficiently attractive to overcome the institutional barriers that may prevent these opportunities.

**Organized Transmission Cost Allocation**
A significant asymmetry exists between California and the Pacific Northwest with respect to the means by which costs for transmission facilities may be shared between multiple beneficiaries.

The California Independent System Operator (CAISO) is a regional transmission organization that provides transmission planning services to its member utilities, and a centralized means by which revenue is collected from electricity market participants for distribution to transmission owners for cost recovery. This allows for a streamlined process by which many different electricity market participants may pay for a single transmission facility.

In the Pacific Northwest, a centralized transmission cost allocation framework does not currently exist. While allocation of a single large transmission project's cost across multiple beneficiaries may be possible, there is currently significant uncertainty as to how such an outcome would come about.

**Organized Resource Adequacy**

Resource adequacy (RA) organization refers to a system wherein all participating load serving entities agree to acquire sufficient firm capacity to meet their individual share of total system need. While a centralized RA coordination scheme is present in the CAISO footprint, efforts to create one in the PNW remain in the early stages. Sharing capacity between PNW and CA may require further coordination efforts.

# 5 DECISION MODELING ANALYSIS AND RESULTS

This section provides additional detail on the modeling analysis and results. After framing the problem statement, a decision was made to utilize hierarchical decision modeling (HDM), which is a variant of AHP, to analyze the input from subject matter experts in quantifying the model.

**Data collection method and data sources**

After creating the underlying HDM structure, an online survey was created using the Qualtrics software to enable distribution to participants and collection of their data. Qualtrics was selected to allow for customization with respect to the information available to the participant when quantifying the model, and the user interface, which took the form of a slider bar. Data entry into the Qualtrics survey by participants was anonymous, and Qualtrics-generated user identification numbers were used for further data processing steps. After downloading data from Qualtrics, the Portland State University HDM Online software was used to process results.[35]

The online survey link and accompanying background document were distributed to subject matter experts known to has sufficient experience and background in the survey topic. At the time of this report, six participants provided full survey responses.

**Inconsistency and disagreement**

To be considered a reliable measure of stakeholder preferences, each of the participants in an HDM process should demonstrate a certain level of consistency in order for their judgements to be considered reliable. An inconsistency threshold of 0.1 has been recommended in previous research and is used in this case.[36] All participant inconsistency scores were equal to or less than 0.10, and the aggregate disagreement metric was 0.68.

| Subject Matter Expert | Inconsistency |
|---|---|
| 1 | 0.05 |
| 2 | 0.06 |
| 3 | 0.03 |
| 4 | 0.03 |
| 5 | 0.10 |
| 6 | 0.05 |

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[35] http://research1.etm.pdx.edu/hdm2/

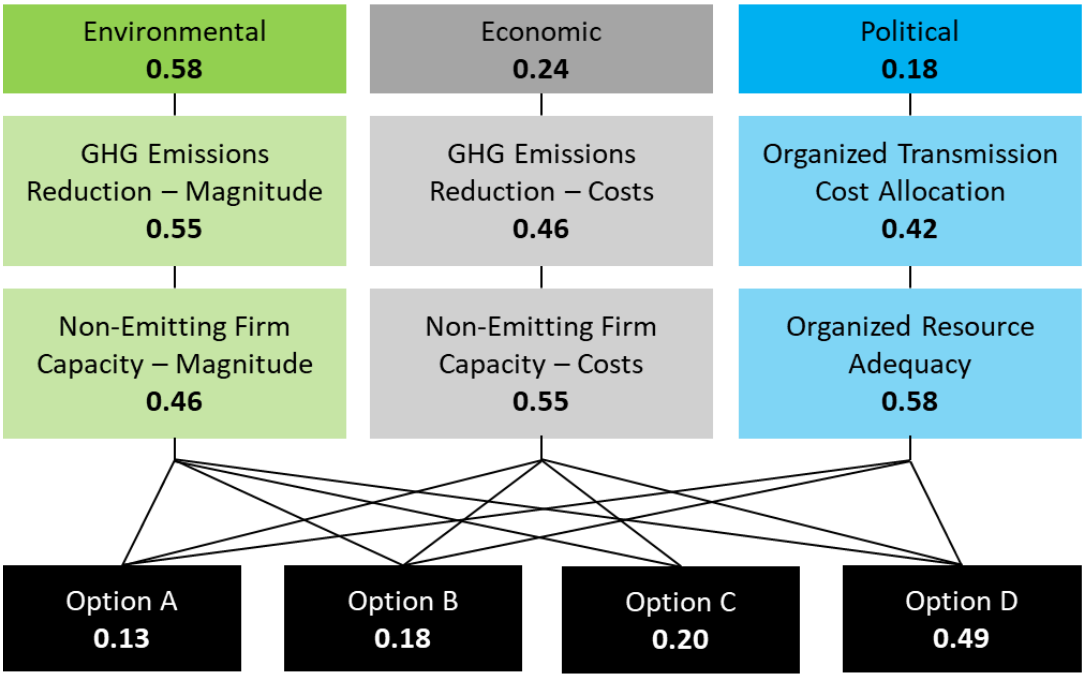
[36] Abbas, M. "Consistency Thresholds for Hierarchical Decision Model" (2016) [42] https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=1106&context=etm_fac

Drilling further into the drivers of inconsistency, very little inconsistency was present for the top-level perspectives, however certain criteria showed higher levels. GHG emissions, in particular exhibited the highest level of inconsistency. This is potentially related to the phrasing of the question, which was the most broad and wide-reaching. Therefore, a potential improvement to this analysis would be to narrow the question of GHG emissions reduction to smaller components, which could be accomplished by adding decision criteria.

| Environmental | | Economic | | Political | |
|---|---|---|---|---|---|
| GHG Emissions | Non-Emitting Firm Capacity | GHG Emissions - Cost | Non-Emitting Firm Capacity - Cost | Organized Transmission Cost Allocation | Organized Resource Adequacy |
| **0.12** | **0.09** | **0.08** | **0.09** | **0.07** | **0.05** |

Figure 10: Criteria inconsistency

Below is the fully quantified decision model. It can be seen that the environmental perspective is clearly preferred by the participants. While the political aspects of central importance to the research questions, it is notable that participants generally do not believe these aspects should exhibit very much influence in decisions. Nevertheless, insight into the political research question may be obtained by assessing the individual option scores for each political criteria, which are shown in Figure 3 above.



Additional insights may be gained into participant preferences by examining options A-C, which were all clustered between 0.13 and 0.20, whereas the preferred option was much higher at 0.49. It is notable that option C, which includes a substantially higher quantity of wind was only ranked 0.02 higher than option B. This shows the high value participants assigned to the intertie feature contained in option B but not in option C.

# 6 ASSEMBLING THE ALTERNATIVES

Given that one of the primary purposes of this study is to examine the relative merits of an offshore intertie configuration compared to a radial scheme, an initial effort to define a rough sketch of a conceptual intertie options was undertaken. Detail about the rationale behind the configuration of each option are included below.

**The assumptions identified for construction of the options are primarily intended as a vehicle to elicit feedback relating to comparison between options, rather than feedback on the reasonableness of the assumptions or options themselves**

Because emphasis is not placed on the construction of the options themselves, a detailed engineering analysis was outside the scope of this work. In keeping with this approach, a significant engineering decision in the selection of AC or DC technology for both subsea cables and the onshore transmission was not addressed. The further implication of this limited scope is that subsea cables between the study area and load centers were also not considered as these longer distances will require use of DC. However, as described in section 6.1 below, the distances between the identified subsea cable landing points fall in a range where use of AC cables cannot be ruled out based on the initial level of research conducted for this report. Therefore, with the planning and decision modeling implications of AC versus DC set aside for consideration by a future study, an AC subsea cable system was selected, as were conventional AC onshore upgrades in the 500 kV and 765 kV voltage classes.

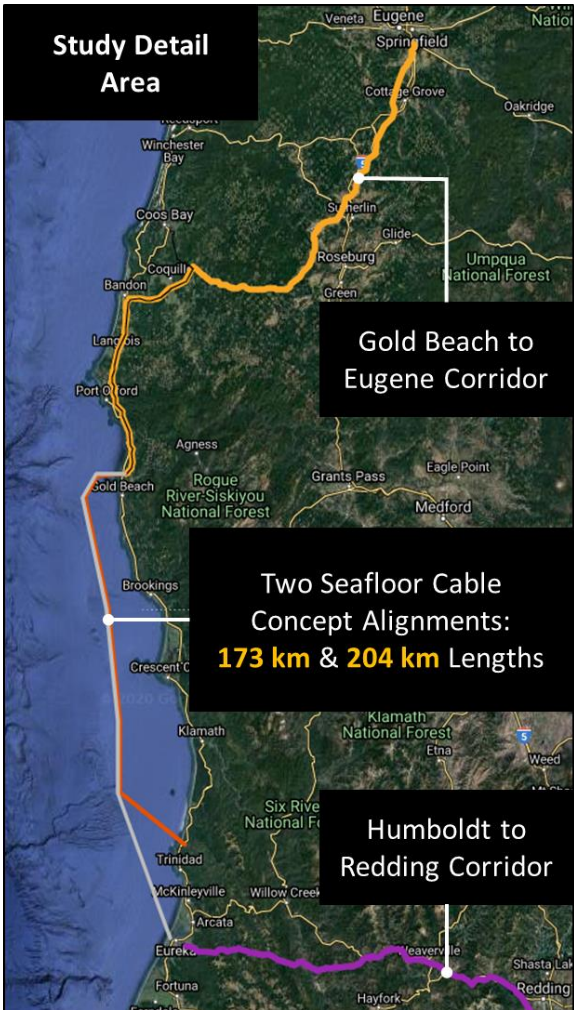


Figure 11

**Gold Beach to Eugene corridor assumptions.**

Because the Gold Beach substation is the southernmost extent of the 230 kV system in the Oregon south coast, it was selected as the cable landing location for the purposes of this study. It is assumed that new transmission may only be built in existing corridors. The corridor between Gold Beach and Coos Bay currently has one 230 kV, and one 115 kV line. It is assumed that one or two 500 kV lines may be built on this corridor. Between Coos bay and Eugene, it is assumed one of the existing 230 kV corridors may be rebuilt in a similar fashion for one or two 500 kV lines. A single 765 kV line may be built along the entire corridor.

**Seafloor Cable Assumptions:**

With the general north and south landing areas identified, the cable distances are shown at left, estimated using Google Maps. For the purposes of seafloor cable layout, the shorter route was chosen which would entail an approximately 48 km new onshore transmission facility in an existing corridor between Eureka and the cable landing location.

**Humboldt to Redding**

Two 115 kV transmission corridors link the Humboldt area to the Redding area. Similarly to Gold Beach-Eugene, it is assumed that one or two 500 kV lines may be built on one or both of these corridors, or that a single 765 kV line may be accommodated. Note that these alignment assumptions are not based on robust stakeholder input and are included only for the purposes of obtaining input on higher-level framing of the issues identified for study.

## 6.1 SEAFLOOR CABLE & WIND ENERGY ZONES

To assemble the conceptual configuration of the subsea cable and wind zones, the starting place was an assessment of the maximum potential buildout within the study area. The level of installed wind generation capacity that could be supported at maximum buildout is constrained by two factors:

1. The available export transmission capability, and
2. The total potential area of the ocean that is available to site floating wind platforms

To determine a resolution to the first constraint, the single largest conventional transmission line available is a 765 kV AC line, which will have an expected transfer limit of 3,600 – 7,200 MW.[37] To determine a resolution to the second constraint, information from NREL OSW potential studies for Oregon and California was used to create an initial configuration of a new central zone. Using an approximate 7.75 MW/square mile which is consistent with the NREL studies, this zone yields in excess of 9000 MW. In addition, the current Humboldt call area, and the southern Oregon zone identified in the Oregon OSW potential study each add 1,500 MW. This 12,000 MW total is consistent with observations of initial planning activities that have considered wind potential in the area.[38]

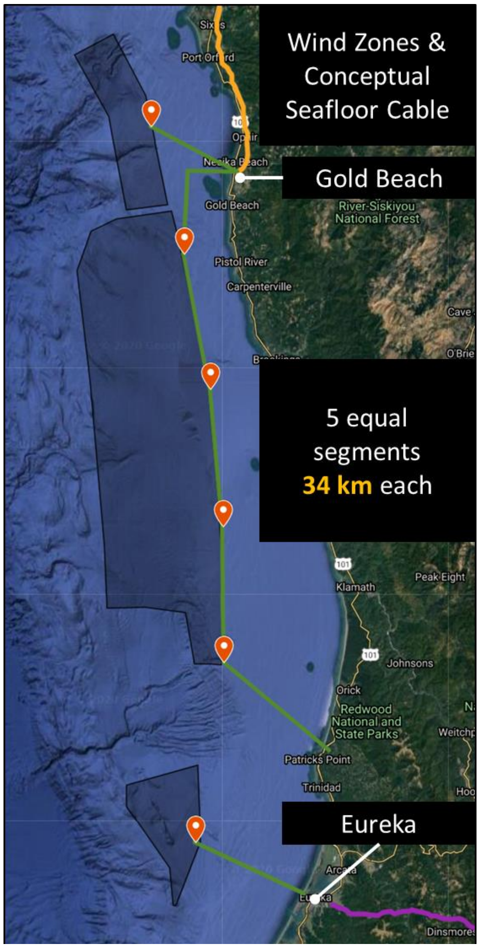


Figure 13: Conceptual AC cable and central wind energy zone configuration

It is assumed that sufficient compensation support may be provided to a 765 kV line to transfer 6,000 MW to Eugene and Redding. Further transmission upgrades required to integrate this line into the PNW and California systems are not considered. Because the conceptual cable alignment is likely too long for a single AC cable, and the choice between AC and DC was omitted in this analysis, the alignment was split into five equal segments by placing four floating substations that provide reactive power compensation, which is needed for any AC cable system of appreciable length, and serve as collector stations for low voltage AC cable networks connected to the dispersed floating platforms.

The number of intermediate substations was chosen to balance the need for reactive power compensation, which is needed for AC cable systems of any appreciable length and the transformer capacity that would be needed at each substation to total 9,000 MW of wind energy integration.

| Number of Segments | 3 | 4 | 5 | 6 |
|---|---|---|---|---|
| Segment Distance (km) | 58 | 43 | 35 | 29 |
| Number of Substations | 2 | 3 | 4 | 5 |
| Substation Capacity (MW) | 4,500 | 3,000 | 2,250 | 1,800 |

Figure 12: AC substation options

A four-substation configuration was chosen for the purposes of establishing a tangible option for consideration by stakeholders. Further engineering analysis is needed to assess whether this configuration is reasonable or optimal, especially in comparison with DC alternatives. In addition to the central zone, the two additional zones are connected by floating substations and an additional AC cable that terminate at the same cable landings.

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[37] "Interstate Transmission Vision for Wind Integration" September 2007. http://large.stanford.edu/publications/coal/references/docs/Wind_Integration.pdf

[38] Approximately 15 GW of potential exists between the Cape Mendocino and the Oregon Border. https://efiling.energy.ca.gov/getdocument.aspx?tn=231527

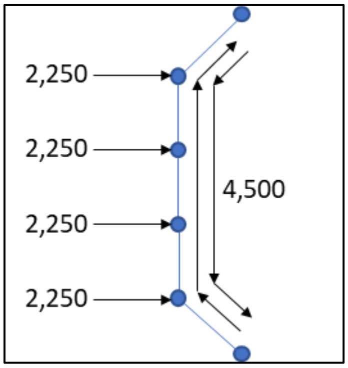


Figure 14: Maximum wind buildout collector and intertie configuration

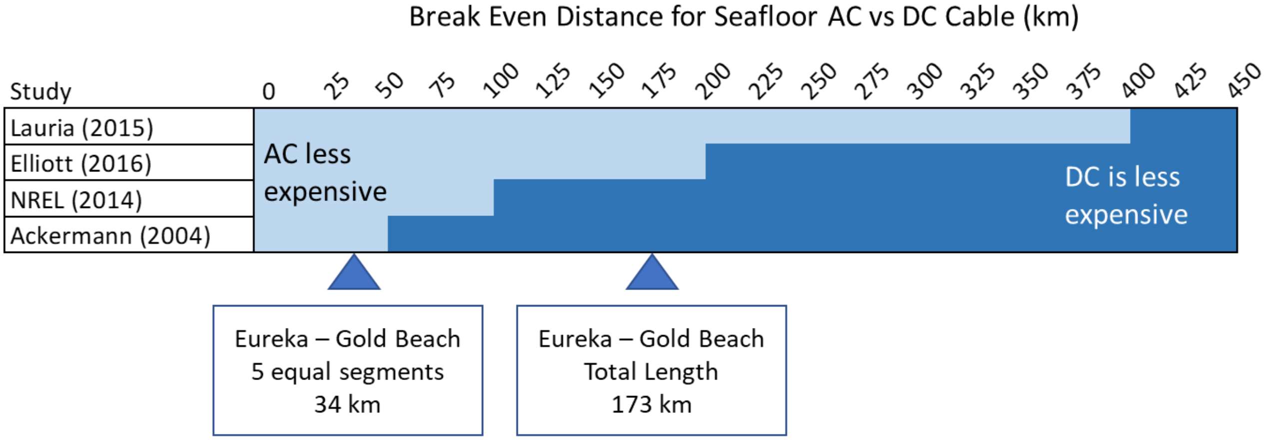
The seafloor cable transfer capability between Humboldt and Gold Beach is related to the total quantity of wind from the central zone that must be connected to the onshore transmission segments. With a total of 9,000 MW, 4,500 MW of transfer capability in each direction is needed, assuming that no redundancy is built into the network to allow some portion or all of the wind energy to flow in one direction if an outage occurs on the opposite end. While this may be desirable from a reliability perspective it stands to limit the quantity of wind generation that may be placed in the central zone.

At maximum generation, the central zone would export in both directions at the maximum transfer capability of each line, and in the case of an outage on one end, a generation drop protection scheme would be needed to prevent an overload at the other end. Several engineering questions for future research have been identified relating to these configuration decisions and are not addressed here.

A lower capacity intertie option was included for the mid-range case which was formulated to maximize the existing corridors by using two 500 kV circuits, which are assumed to transfer 1,500 MW each, and limiting wind capacity in the central zone to 6,000 MW. For purposes of comparing intertie vs non-intertie options three radial configurations were included by omitting the connection between California and Oregon across the central zone.

## 6.2 AC VS DC SEAFLOOR CABLE

The rationale for omitting DC options is provided in this section. At the outset of this work, it was assumed that a DC seafloor cable would be the preferable choice, however an initial level of research yielded the likely presence of a closer comparison between the two technologies. This is due to two factors. Frist, in recent years there has been an increase in research interest into longer AC cables, and second, DC equipment costs continues to place it at a disadvantage compared to AC for shorter distances.[39,40] The distance between Gold Beach and Humboldt appears to place the intertie concept within a range where more detailed analysis is needed before a preferred technology emerges. This is especially true with the likely need for multiple intermediate collector substations, which would be able to provide the reactive power compensation required for AC cables. Studies by Lauria[41], Elliott[42], NREL, and Ackermann[43] are shown in the figure below.



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## 6.3 DESCRIPTION OF THE ALTERNATIVES

This section provides an overview of the five alternatives. The overarching goal of constructing these alternatives was to balance the desire to present tangible options to be judged by stakeholders with the purpose of this initial study, which is to frame the broader issues in advance of future studies that will delve into greater detail with regard to specific transmission facility options. These options provide stakeholders with tangible choices that have a cursory level of grounding to the real constraints that planners will be faced with in future OSW activities in the study area. As such, the quantities of wind generation that is assumed to be available in the study area are generally consistent with prior studies, and the alignments were new onshore facilities are built have been identified as existing transmission corridors. A summary table of the options is provided below.

| | Description | Wind Quantity | Intertie Capability |
|---|---|---|---|
| **A** | Medium Wind, Radial | 6,000 MW | 0 |
| **B** | Medium Wind, Intertie | 6,000 MW | 3,000 MW |
| **C** | Max Wind, Radial | 12,000 MW | 0 |
| **D** | Max Wind, Intertie | 12,000 MW | 4,500 MW |

Figure 15: summary of conceptual options

## 6.4 CONFIGURATION QUESTIONS FOR FUTURE STUDY

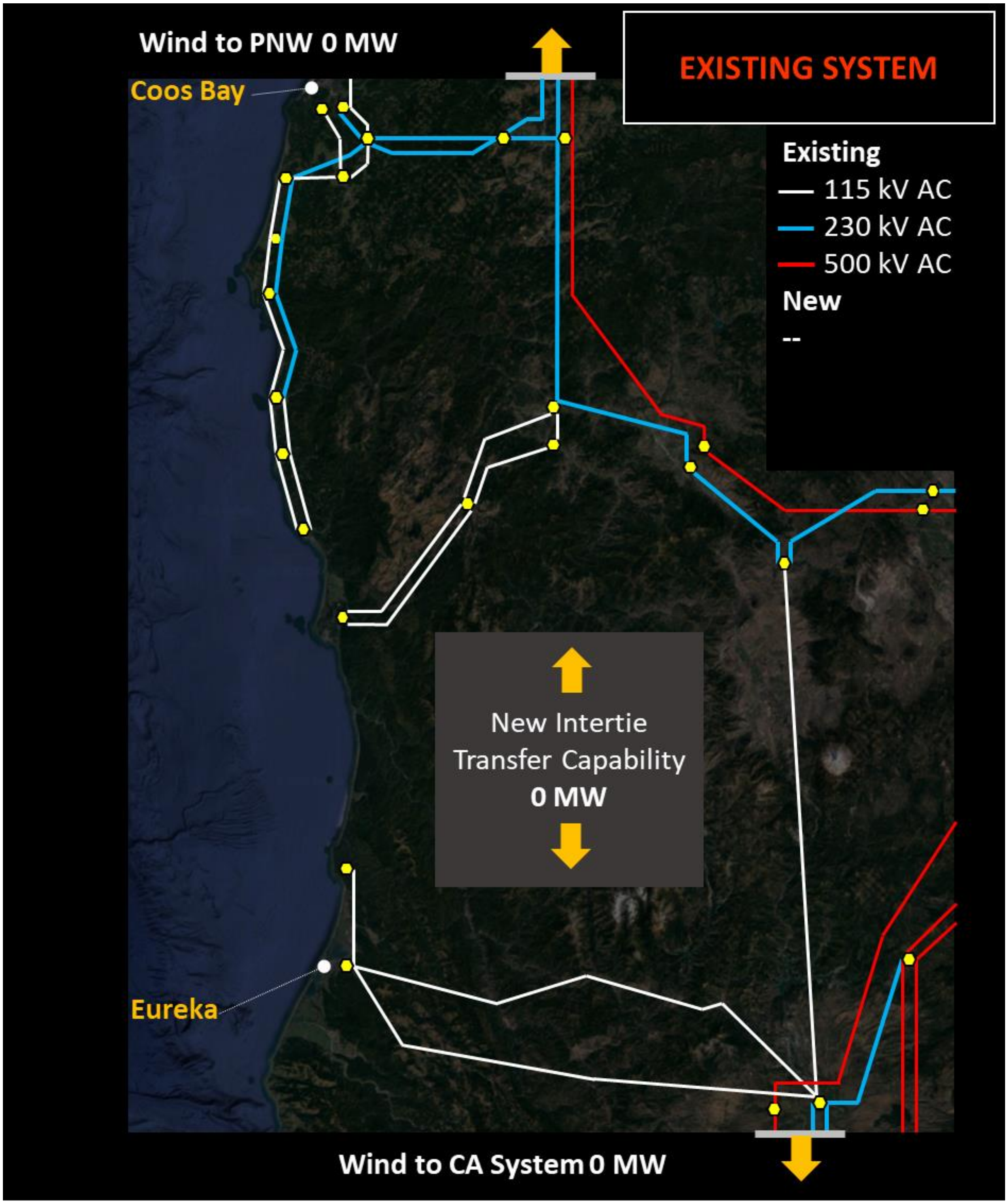
The following technical questions were identified as future research needs:

- AC vs. DC cable, floating substation, and onshore converter station comparison.
- AC floating substation configuration. For configuration of an AC system, an analysis of the optimal number, type, and size of floating substations needed.
- Level of export capability redundancy that is appropriate.
- Use of existing corridors to host transmission facilities that are significantly larger than the facilities that exist today.
- Potential asymmetry between connectivity between CA and the PNW. CA may ultimately have higher demand for OSW, but existing corridors reaching the study area may favor the PNW for transmission planning purposes.

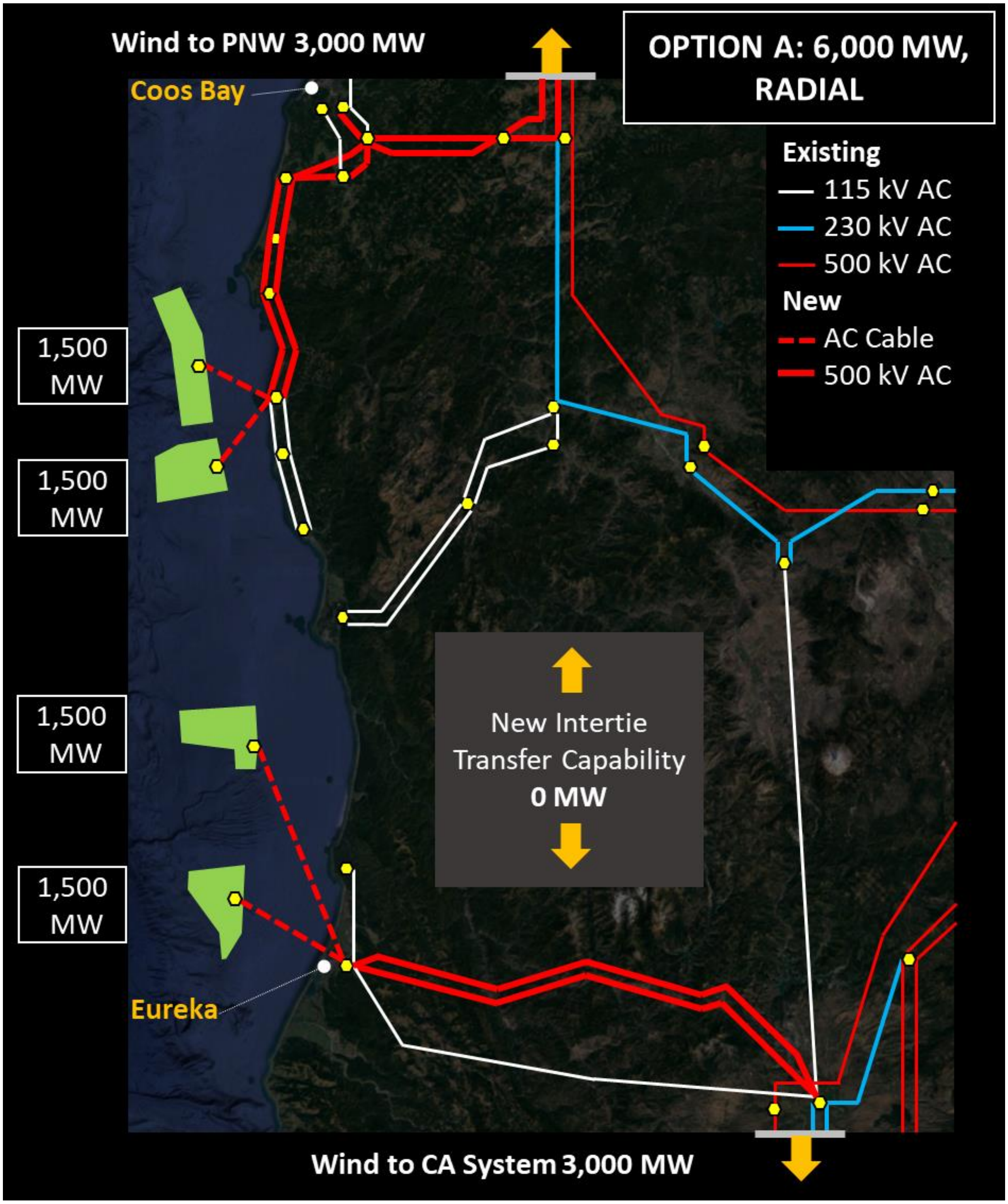
# 7 DIAGRAMS OF THE ALTERNATIVES

The section below contains diagrams of each alternative for reference.

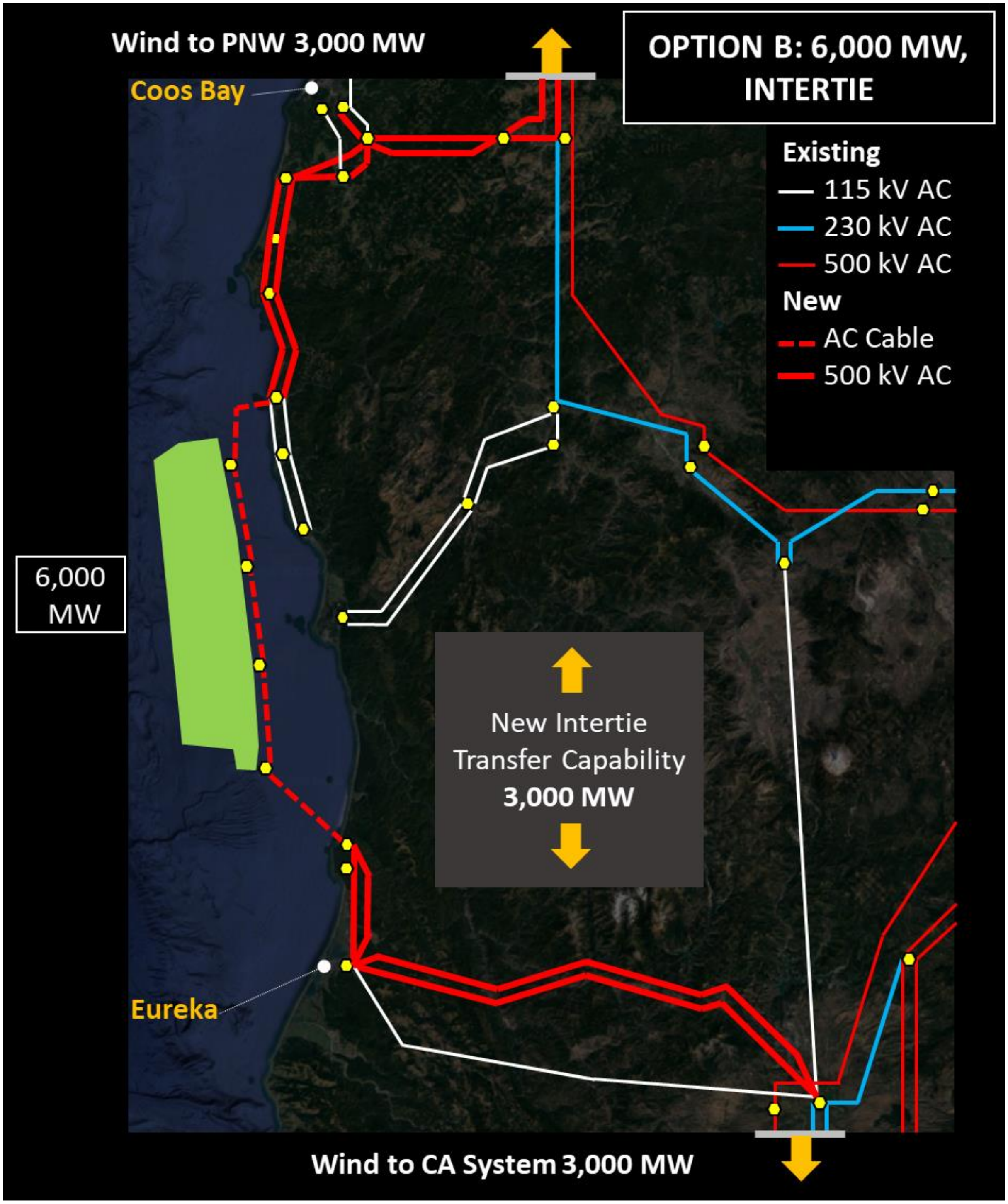
## 7.1 EXISTING SYSTEM IN THE STUDY AREA



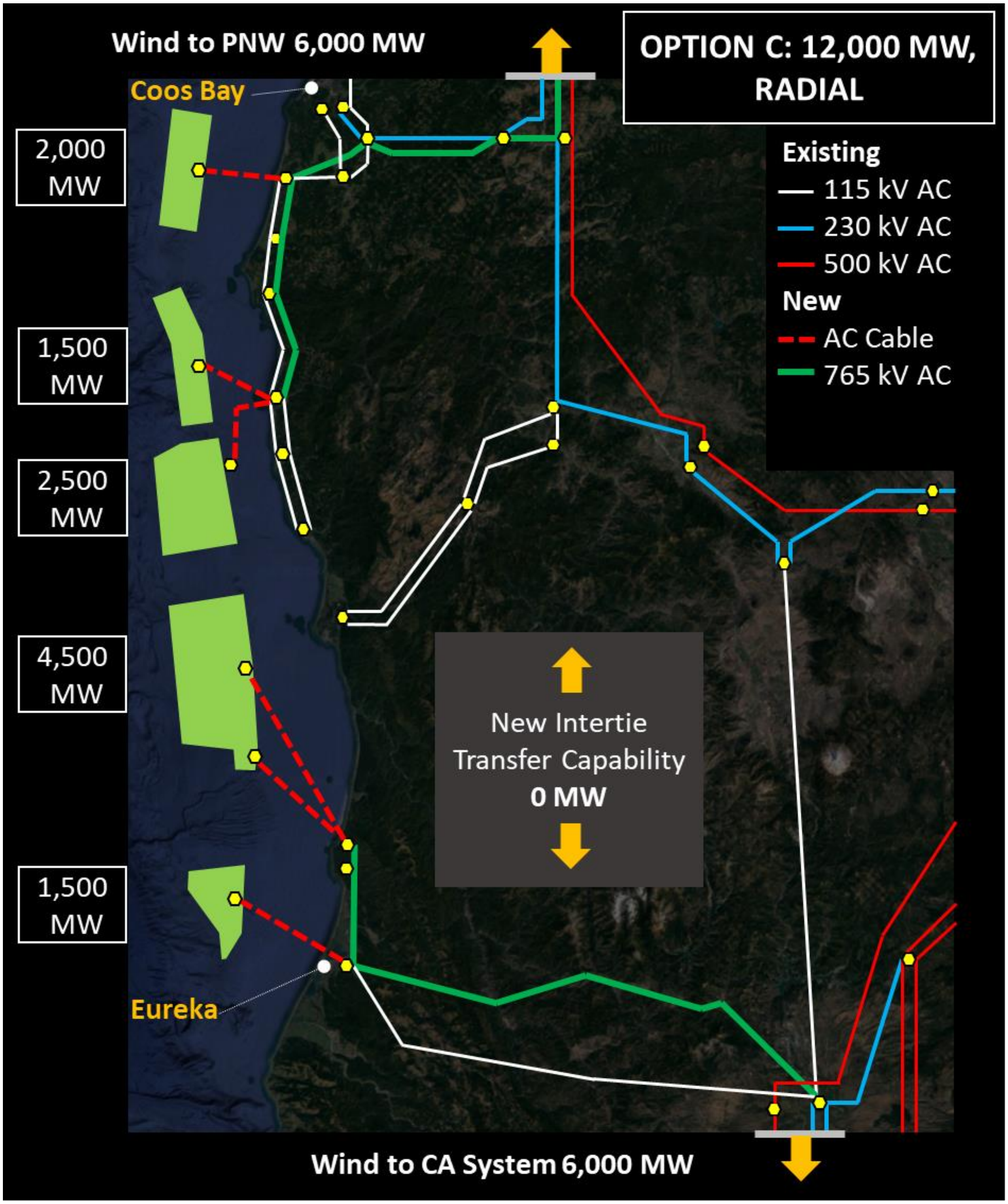
## 7.2 OPTION A


Wind to PNW 3,000 MW
OPTION A: 6,000 MW, RADIAL
Coos Bay
Existing
115 kV AC
230 kV AC
500 kV AC
New
AC Cable
500 kV AC
1,500 MW
1,500 MW
1,500 MW
1,500 MW
New Intertie Transfer Capability
0 MW
Eureka
Wind to CA System 3,000 MW

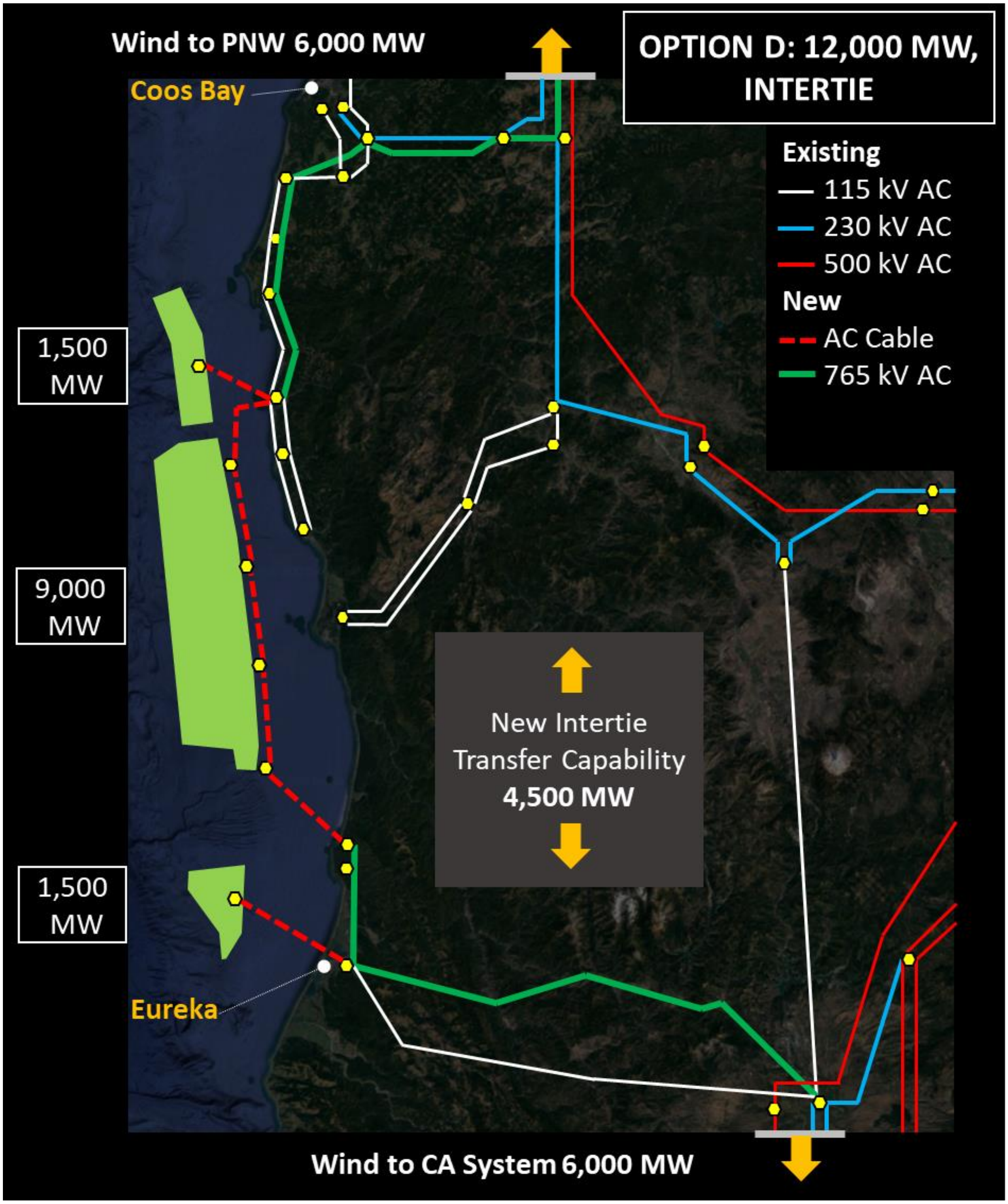
## 7.3 OPTION B


Wind to PNW 3,000 MW
OPTION B: 6,000 MW, INTERTIE
Coos Bay
Existing
115 kV AC
230 kV AC
500 kV AC
New
AC Cable
500 kV AC
6,000 MW
New Intertie Transfer Capability 3,000 MW
Eureka
Wind to CA System 3,000 MW

## 7.4 OPTION C


Wind to PNW 6,000 MW
OPTION C: 12,000 MW, RADIAL
Coos Bay
2,000 MW
1,500 MW
2,500 MW
4,500 MW
1,500 MW
Eureka
Existing
115 kV AC
230 kV AC
500 kV AC
New
AC Cable
765 kV AC
New Intertie Transfer Capability
0 MW
Wind to CA System 6,000 MW

## 7.5 OPTION D


Wind to PNW 6,000 MW
OPTION D: 12,000 MW, INTERTIE
Coos Bay
Existing
115 kV AC
230 kV AC
500 kV AC
New
AC Cable
765 kV AC
1,500 MW
9,000 MW
1,500 MW
New Intertie Transfer Capability 4,500 MW
Eureka
Wind to CA System 6,000 MW

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