California North Coast Offshore Wind Studies

Economic Development and Impacts

This report was authored by Steve Hackett of the Humboldt State University's Economics Department and Julia Anderson of the Schatz Energy Research Center. It is part of the *California North Coast Offshore Wind Studies* collection, edited by Mark Severy, Zachary Alva, Gregory Chapman, Maia Cheli, Tanya Garcia, Christina Ortega, Nicole Salas, Amin Younes, James Zoellick, & Arne Jacobson, and published by the Schatz Energy Research Center in September 2020.

The series is available online at schatzcenter.org/wind/

Schatz Energy Research Center
Humboldt State University
Arcata, CA 95521 | (707) 826-4345

Disclaimer

This project was funded by the California Natural Resources Agency, Ocean Protection Council. The content does not represent the official views of policies of the State of California.

This report was created under agreement #C0304300

About the Schatz Energy Research Center

The Schatz Energy Research Center at Humboldt State University 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.

Learn more about our work at schatzcenter.org

Rights and Permissions

Hackett, S., and Anderson, J. (2020). Economic Development and Impacts. 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-R10.pdf.

EXECUTIVE SUMMARY

The purpose of this report is to assess the economic impact to the State of California from offshore wind farm and associated port and transmission infrastructure (the "offshore wind industry complex") development on the California north coast. Economic impacts reflect the "ripple effect" of new jobs and economic output that occurs when direct investments in the offshore wind industry complex lead to expansion in the production of upstream supply-chain inputs, and induced spending as new employee households increase local spending (e.g., grocery stores, auto dealerships, and restaurants). It should be noted that economic impacts are different from economic viability or profitability. Economic impacts reflect expenditures and the extent to which inputs are locally sourced. Higher costs (that would reduce economic viability and profit) in fact lead to larger economic impacts.

A customized cost model was developed by Schatz Energy Research Center project staff for various wind farm and transmission scenarios. These costs include wind farm construction and operations, as well as port and transmission infrastructure investments. Scenarios include three dimensions – wind farm scale in megawatts (MWs); wind farm site; and transmission infrastructure pathways for delivering energy to load centers. Estimated job and economic output impacts from wind farm development are substantial.

- Construction-phase impacts on California economic output range from about $330 million (smallest farm scale) to over $2.5 billion for the largest wind farm scale; this economic activity is associated with creating between about 1,600 (smallest farm scale) to over 13,000 (largest farm scale) new construction jobs in California.
- Annual operations-phase impacts on California economic output range from about $3.2 million to about $117 million, and the creation of roughly 26 to 960 new jobs.

Economies of scale in wind farm development are revealed in the relatively larger job and economic output impacts per MW of installed capacity for the smallest wind farm scenarios. Economies of scale mean that a doubling of output results from less than a doubling of total cost. OSW farm development (along with associated port and transmission infrastructure improvements) is a substantial source of economic development for the State of California, creating potentially thousands of jobs and billions in new economic output.

Economic development benefits are particularly important to the rural economy of Northwestern California, with a long history of boom-and-bust economic cycles, and where declines in timber and lumber-based manufacturing jobs have been substantial. OSW farm development could be particularly beneficial to the Port of Humboldt Bay. Loss of several pulp mills and the resulting loss of freight shipping, combined with a sharp decline in the size of the Humboldt-based commercial fishing fleet, has to some extent undermined the fiscal health of the port (Hackett et al, 2017). Over time, economic impacts can change. As installed wind farm capacity in California increases, one might expect not only cost-reducing learning effects, but also an increase in the local share of input sourcing due to in-state investment in manufacturing specialized OSW inputs. Were this to occur, then the result would be larger California economic impacts for a given expenditure in project development and operations.

TABLE OF CONTENTS

1. INTRODUCTION

The economic impact analysis in this memo is performed using the National Renewable Energy Laboratory (NREL) Jobs and Economic Development Impact (JEDI) model. JEDI is an input-output model (I-O model). In I-O models, such as the IMPLAN model (IMPLAN, 2020) upon which JEDI is based, the regional economy is modeled as a set of input-output production relationships. Final goods such as wind energy are the outputs. In order to produce those outputs, a variety of "upstream" (supply-chain) input purchases are required in constructing and operating the wind farm, including intermediate goods (e.g., manufactured parts such as turbine blades, or more basic inputs such as concrete and steel) and labor. Some of these inputs are locally sourced (the "local share"), while others are imported from outside the region under study. I-O models thus use economic data to create a simplified and static quantitative depiction of a regional economy. This depiction includes fixed numerical coefficients that quantify the various inputs required to produce a given quantity of a particular output such as wind energy.

Through this quantitative approach to modeling the regional economy, I-O models such as JEDI are used to estimate new job and economic output creation linked to projects such as a wind farm and related development. Broadly speaking, economic impact estimates from JEDI include the sum of jobs and economic output created in a regional economy from a new project (Figure 1). These include the direct jobs and output created on the job site, those created upstream in the regional supply chain due to expanded demand for inputs, and the additional jobs and output linked to "induced" spending in the local economy by the households of newly-employed workers. These economic impacts can be summarized using multipliers. For example, for a given region and industry, every $1 of new direct job-site spending may result in, say, another $0.85 in supply-chain and induced expenditures in the regional economy.

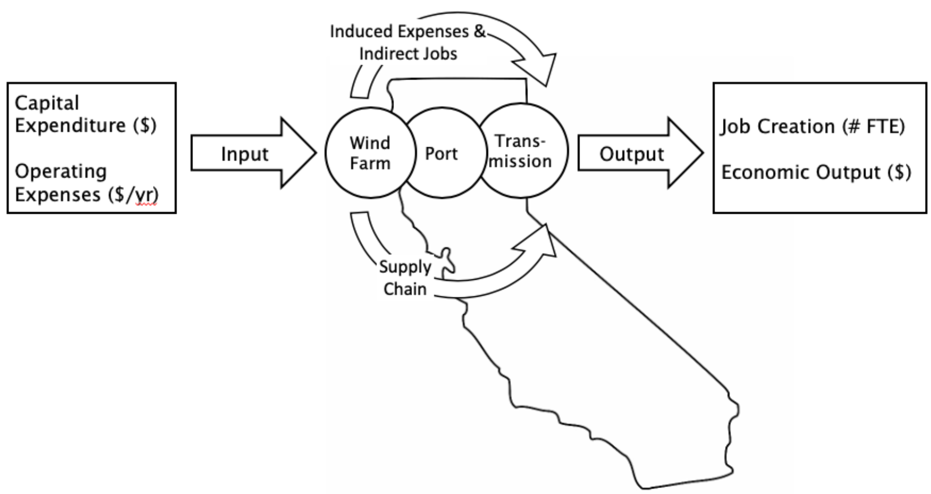

Figure 1. Graphical description of model framework.

Over time, regional input-output production relationships change due to changes in relative prices, technology, demographic patterns, consumer preferences, and other economic factors. As a result, over time, IMPLAN (and thus JEDI models) become outdated as depictions of the regional economy, and must be updated. This is done by way of periodic updating of basic regional economic data that leads to new production coefficients, household consumption patterns, and other elements of impact assessment. Note too that there are different JEDI models for different types of renewable energy generation. State multipliers for employment, wage and salary, output, and personal spending patterns in JEDI are derived from the IMPLAN accounting software using currently available data (NREL, 2020).

Economic impacts are sensitive to the level of total project expenditure, the local share of those expenditures by category occurring within the regional economy, and the economic attributes of the region. For example, a small, remote rural county will tend to have relatively small local shares for production of manufactured inputs and specialized labor, compared to a populous and industrialized region with a highly diversified economy such as the State of California. For the purpose of using JEDI for impact assessment in this study, the region is considered to be the State of California (following Speer et al. (2016)). Information is not readily available to conduct a reliable analysis using a sub-state geography for the region. Project expenditure estimates for construction and operation of the wind farm (including related investment in port and transmission infrastructure) are drawn from the customized Schatz Center cost model. Local share estimates are drawn from the recent offshore wind energy literature.

2. METHODS

Schatz Center analysts developed a customized cost model for a number of offshore wind farm scenarios. The cost model reflects the available published scholarly and technical literature as well as feedback from industry participants. Overall wind farm costs derive from component-level modeling, some of which are "bottom-up" while others make use of industry-standard cost factors. Wind farm component costs are dis-aggregated where required (for example, maintenance costs are separated into material costs, labor costs, and vessel costs). Values in the cost model take into account different construction and commercial operation dates (CODs), and are in constant 2019 dollars. The line items in the JEDI model all assume different expenditure proportions, which lead to different impact results. For example, the 'piling, anchors, and mooring' are considered manufactured items, while the 'foundation' is fabricated, which have different supply-chain expenditure patterns in the regional economic model that underlies JEDI.

It is important to note that wind farm industry complex investment expenditures included in the Schatz Center cost model for impact assessment include costs borne by wind farm developers, investors, or operators, as well as necessary upgrade costs for port infrastructure in Humboldt Bay, and upgrade costs for transmission infrastructure improvements necessary to move wind farm energy to load centers. Economic impacts are increased by higher expenditures or by a larger share of locally-sourced inputs. This is distinguished from economic viability (or profitability) analysis, where higher expenditures (all else equal) reduce economic viability. Economic viability analysis of OSW farms is usually limited to direct wind farm capital and operations/maintenance costs (and required return on investment) recovered by way of revenues deriving from power purchase agreement prices. Port and transmission infrastructure improvements are not usually included in economic viability analysis. Port infrastructure investments would likely be made by a terminal operator, with costs recovered by way of various fees paid by users of terminal facilities. Transmission infrastructure improvement costs would likely be recovered by way of transmission access charges (TACs) paid by regional energy consumers.

Cost factors estimated in the custom Schatz Center cost model (Hackett & Anderson, 2020) were used to replace many default JEDI values in order to create customized JEDI offshore wind models for each scenario under study. Speer et al. (2016) estimated local share percentages by component system for California-based offshore wind farms, and those local shares were used in the JEDI model customization in the project under study.

Building on Speer et al. (2016), there are several assumptions in JEDI that should be understood when analyzing results:

- JEDI economic impact results are gross rather than net, and as such may somewhat overstate actual impacts. This distinction means that impacts not immediately deriving from the construction and operation of an offshore wind facility are omitted. For example, expenditure on a wind farm in California may displace expenditures on expansion of an existing thermal generation power plant. A net economic impact assessment would need to take into account displaced economic activity.

- JEDI results are given in terms of total impacts during the construction period, and annual impacts during the operations period. One can expect that the duration of the construction period will vary directly with the installed capacity of the wind farm project.
- JEDI implicitly assumes fixed prices for all required inputs within any given year. Any required quantity of input is assumed to always be available at the same price. In contrast, a region may encounter a sharp increase in construction-related prices for contractor services, for example, to rebuild following a fire that destroys thousands of homes. Such price effects are beyond the scope of JEDI and IMPLAN.
- Economic impacts derived from the JEDI model (and IMPLAN) are based on fixed input-output coefficients, meaning that production of a given quantity of new output is assumed to derive from a specific fixed combination of inputs that does not vary with the quantity of output produced. In addition, consumers are assumed to purchase the same sets of goods and services with a given quantity of expenditure, in the same proportions, as those contained in IMPLAN. In contrast, in a dynamic economy, expanded output in a sector would normally change relative input prices that in turn leads to changing combinations of inputs. Likewise, consumers will typically substitute away from relatively more expensive goods, thereby changing the basket of goods and services that they buy. This fixed proportions assumption in JEDI and IMPLAN derives from the snapshot nature of the regional economy's production and other data that are used when the model is assembled.

Economic impacts are assessed for a number of project scenarios that differ based on:

- OSW farm site:
  - BOEM call area offshore of Humboldt Bay, California (HB); or
  - a notional site located offshore from Cape Mendocino, California (CM).
- OSW farm scale:
  - 48 MW;
  - 144 MW; or
  - 1,836 MW.
- Pathway for transmission upgrades:
  - East to Round Mountain (e), considered for all scenarios;
  - South to Vaca-Dixon (s), considered for the 1,836 MW farms; or
  - subsea cable to the San Francisco Bay area (submarine), considered for the 1,836 MW farms.

The scenarios under consideration in this report are shown in Table 1:

Table 1. Scenario abbreviations and description.

Abbreviated Scenario Name	*Location*	*Wind Farm Capacity*	*Pathway for Transmission Upgrades*
HB-48-e	Humboldt Bay	48 MW	East to Round Mountain
HB-144-e	Humboldt Bay	144 MW	East to Round Mountain
HB-1836-e	Humboldt Bay	1,836 MW	East to Round Mountain
HB-1836-s	Humboldt Bay	1,836 MW	South to Vaca-Dixon
HB-1836-submarine	Humboldt Bay	1,836 MW	Subsea to San Francisco Bay Area
CM-144-e	Cape Mendocino	144 MW	East to Round Mountain
CM-1836-e	Cape Mendocino	1,836 MW	East to Round Mountain
CM-1836-s	Cape Mendocino	1,836 MW	South to Vaca-Dixon
CM-1836-submarine	Cape Mendocino	1,836 MW	Subsea to San Francisco Bay Area

As a final point, it is important to note that economic impact assessment is very different from economic viability (profitability). All else equal, a relatively expensive and inefficient wind farm with a high levelized cost of energy (LCOE) and a strong likelihood of being unprofitable will have the strongest economic impacts per MW of installed capacity. This is because economic impact is driven by total project expenditure and the local content or sourcing of upstream inputs. Relatively efficient wind farms with lower LCOE's and a better prospect for profitability (and thus being built) will have lower economic impacts per unit of installed capacity than less efficient wind farms with higher LCOE's, and weaker prospects for profitability (and thus being built).

3. RESULTS

One can see from Figure 2 that total construction-phase jobs created by the OSW industry complex range from just under 2,000 for the smallest (48 MW) farm scenario, up to about 13,000 for the largest farm scenarios that transmit energy to load centers by way of new subsea cables. Subsea cable transmission is far more costly than either of the terrestrial transmission pathway alternatives (e or s), which is the primary reason for the larger job impacts.

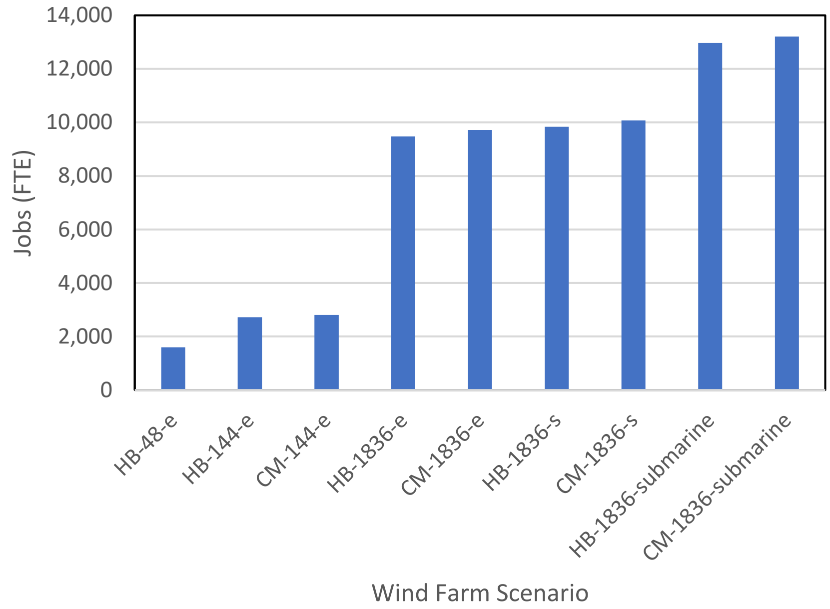

Figure 2. Construction period full time-equivalent job impacts by scenario, State of California. See Appendix A for an explanation of source factors.

Total job impacts per MW of wind farm capacity provides a measure of impact intensity per unit of capacity. Job impacts per MW are inversely related to wind farm scale, which reflects the intrinsic economies of scale in wind farm development for the scenarios under study, as shown in Figure 3. The smallest scenario (48 MW) produces more than 30 jobs per MW during the construction phase, while the largest scenarios (1,836 MW) using terrestrial transmission improvements produce roughly 5 jobs per MW during construction.

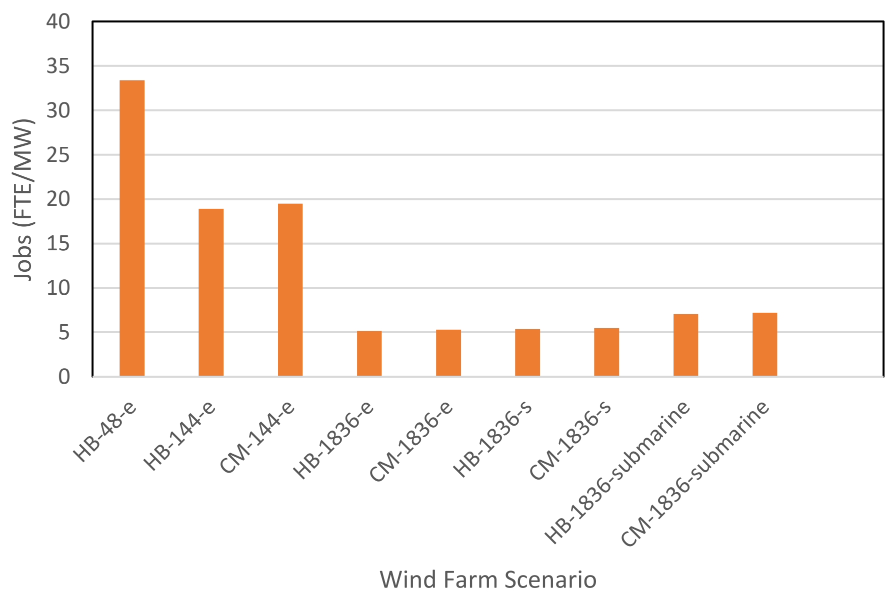

Figure 3. Construction period full time-equivalent job impacts per unit of installed wind farm capacity, by scenario, State of California. See Appendix A for an explanation of source factors.

Annual operations-phase job impacts for the State of California increase with wind farm scale, as shown in Figure 4. The smallest farm sizes result in fewer than 100 new operations-phase jobs, while the largest farm sizes produce over 900 new operations-phase jobs.

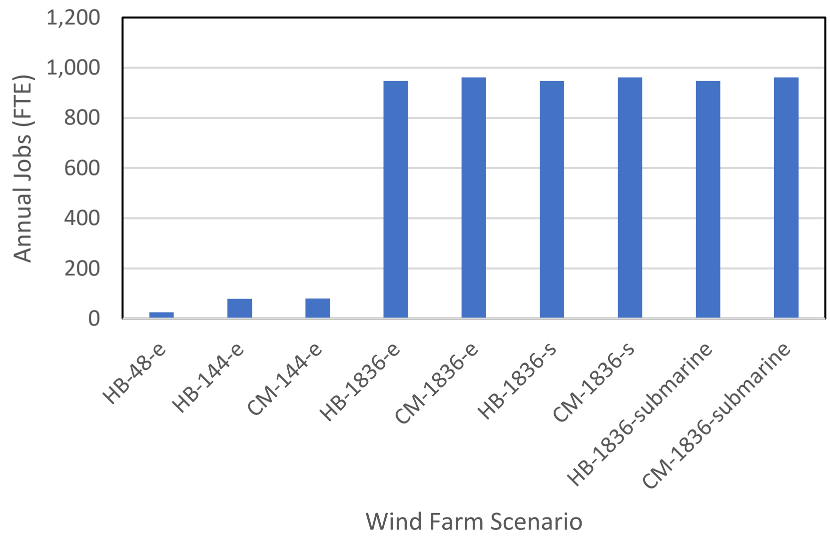

Figure 4. Operational period full time-equivalent job impacts by scenario, State of California. See Appendix A for an explanation of source factors.

While from Figure 4 one can see that operations-phase total job impacts rise with wind farm scale, they do so less than proportionately with installed capacity -for large capacity differences- as shown in Figure 5. For wind farm scales that are relatively close such as the 48 MW and 144 MW scales, the effect of the economy of scale is not significant, and is only noticeable between the relatively small 48MW and 144MW wind farms and the large 1836 MW wind farm. This overall economy of scale is due to the relatively high cost per MW of installed capacity to operate smaller-scale wind farms, a manifestation of economies of wind farm scale.

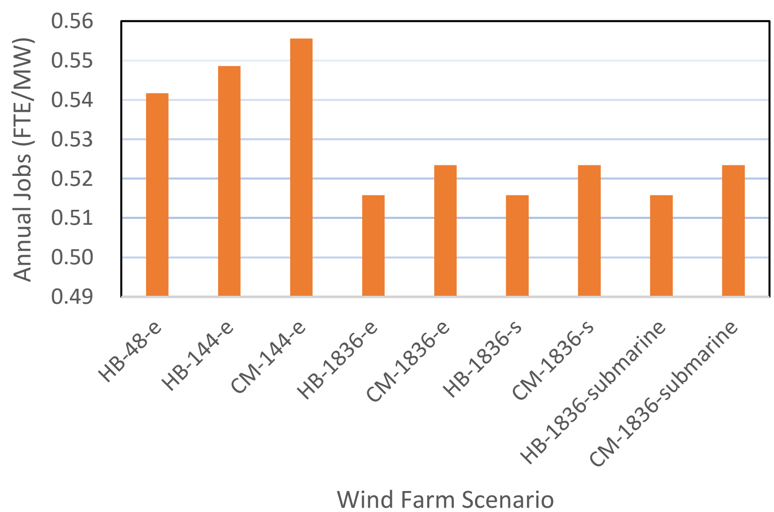

Figure 5. Operational period full time-equivalent job impacts per unit of installed capacity, by scenario, State of California. See Appendix A for an explanation of source factors.

Undiscounted lifetime job impacts were calculated by multiplying the operational period of the project by the estimated number of annual operational period jobs, and then adding that to the estimated construction period jobs. On a per-MW of installed capacity basis, from Figure 6 one can see that the smaller-scale wind farms produce the most undiscounted job impacts over the projected lifetime of the wind farms. Again, this result reflects the relative inefficiency or higher cost per installed MW for smaller farm size scenarios. Moreover, construction-phase jobs dominate total wind farm lifetime job impacts for the smaller-scale scenarios, whereas annual operations-phase jobs dominate total wind farm lifetime job impacts for the larger-scale scenarios.

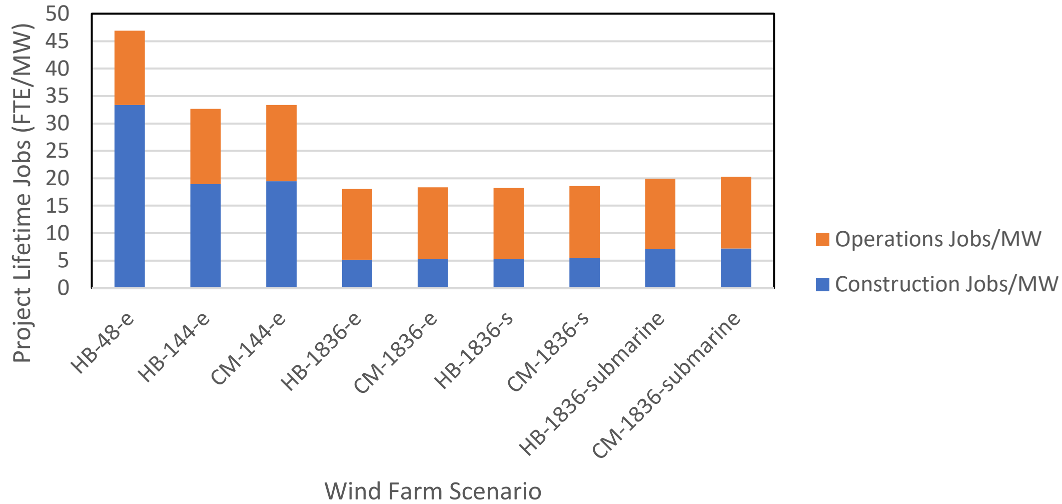

Figure 6. Undiscounted wind farm lifetime job impacts per unit of installed capacity, by scenario, State of California. See Appendix A for an explanation of source factors.

From Figure 7 one can see that construction-phase impacts on California economic output range from roughly $300 – 600 million for the smaller wind farm scenarios up to roughly $2.4 – $2.9 billion for the larger wind farm scenarios. Construction-phase output impacts are greatest for the subsea cable scenarios due to the greater investment expenditure required to use that approach to transmit energy to load centers.

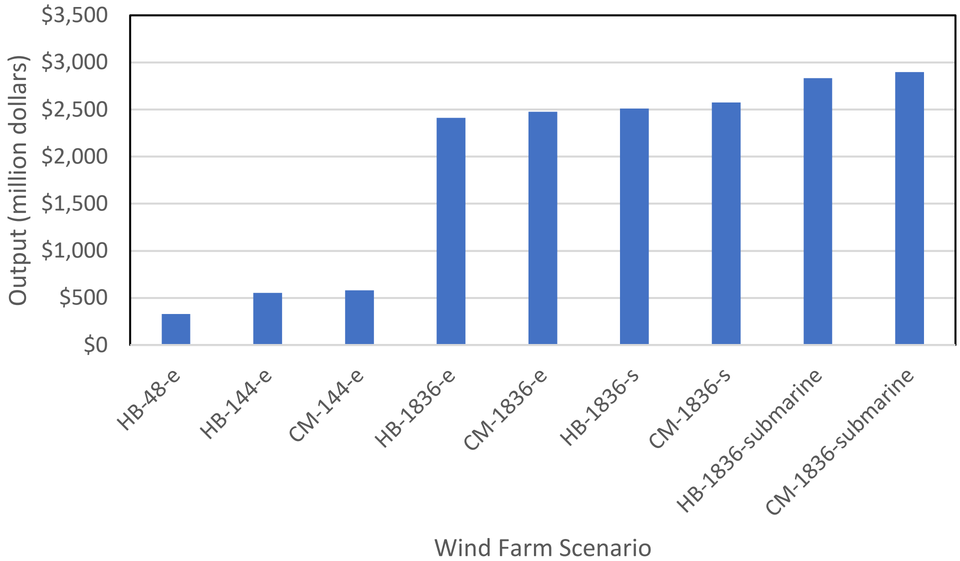

Figure 7. Construction period output impacts, by scenario, State of California. See Appendix A for an explanation of source factors.

As with job impacts per MW of installed capacity, in Figure 8 we can see that construction-phase economic output impacts per MW of installed capacity likewise is highest for the smallest-scale wind farms (roughly $3.9 – 6.9 million), and smallest for the largest-scale wind farms (between roughly $1.2 – 1.6 million).

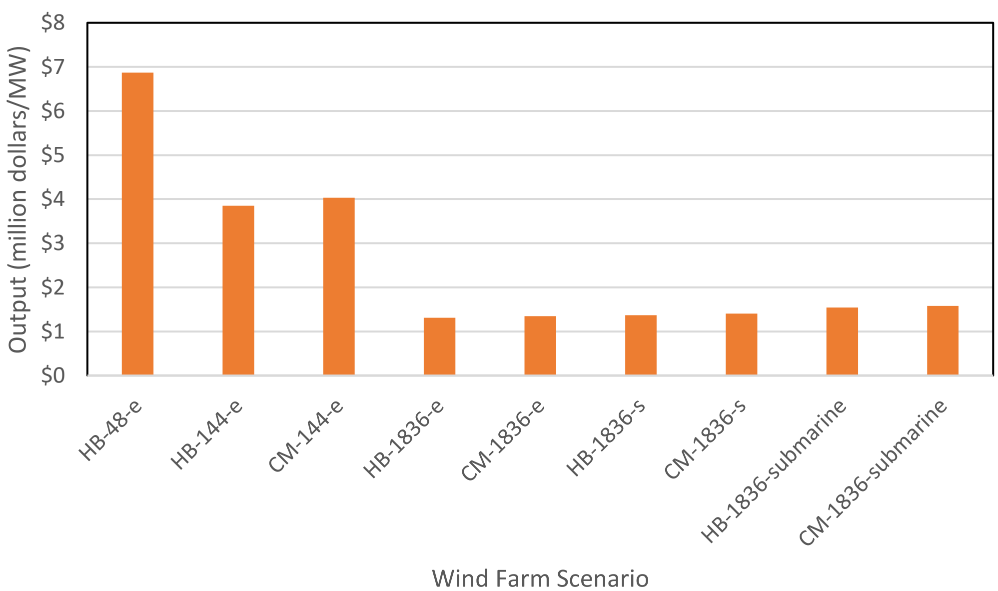

Figure 8. Construction period output impacts per unit of installed capacity, by scenario, State of California. See Appendix A for an explanation of source factors.

As with total new jobs created by wind farm operations, likewise, Figure 9 reveals that total new annual operations-phase economic output in California also increases with wind farm scale, from around $3 million for the smallest wind farms, up to about $117 million or more for the largest wind farms.

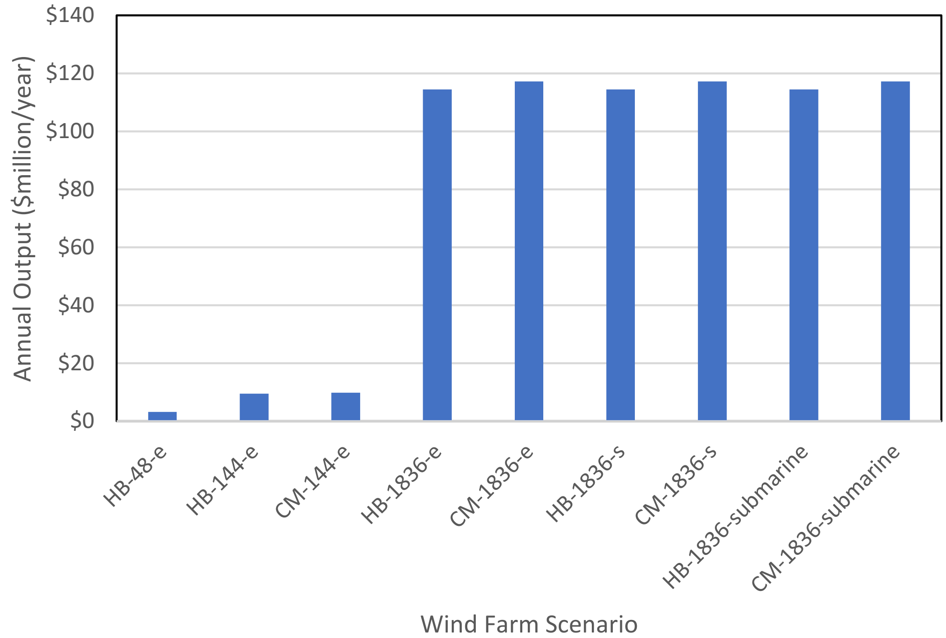

Figure 9. Operational period output impacts, by scenario, State of California. See Appendix A for an explanation of source factors.

As with operational-phase job impacts per MW of installed capacity, likewise, one can see in Figure 10 that economic output impacts are largest for the smallest wind farm scenarios, reflecting the economies of scale in wind farm development.

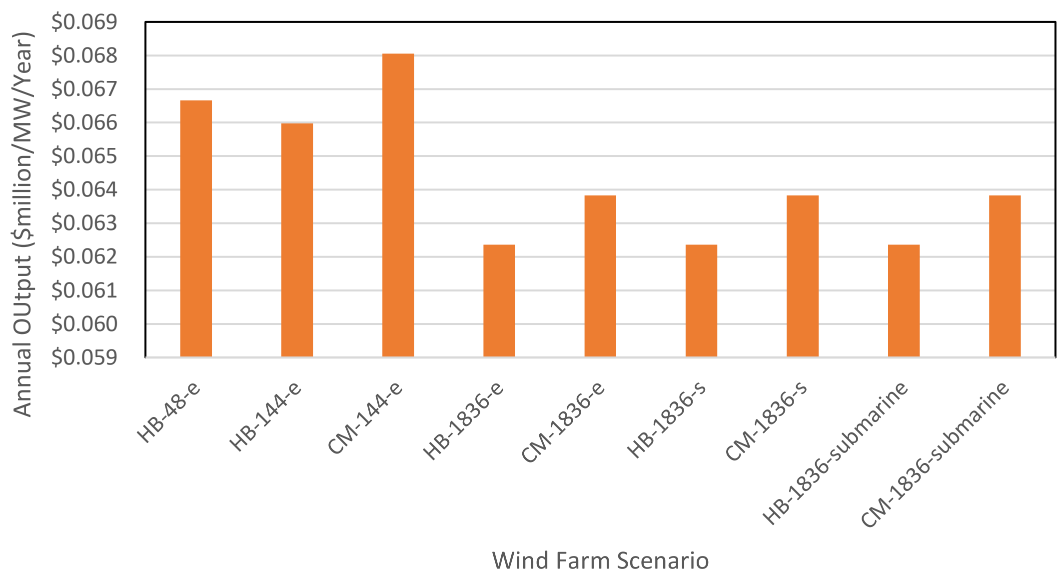

Figure 10. Operation period output impacts per unit of installed capacity, by scenario, State of California. See Appendix A for an explanation of source factors.

4. CONCLUSIONS

Job and economic output impacts from building and operating an offshore wind farm and associated industry complex are substantial. Construction-phase impacts on California economic output range from about $330 million (smallest farm scale) to over $2.5 billion for the largest wind farm scale, and the associated economic activity is associated with creating between about 1,600 (smallest farm scale) to over 13,000 (largest farm scale) new construction jobs in California. Annual operations-phase impacts on California economic output range from about $3.2 million to about $117 million, with the creation of roughly 26 to 960 new jobs. These impacts on economic output and jobs include port terminal and transmission infrastructure improvements as well as wind farm development and operations.

Developing an offshore industry complex is a substantial source of economic development for the State of California, creating potentially thousands of jobs and billions in new economic output. These economic development benefits are particularly important to the rural economy of Northwestern California. Structural changes to the economy in Northwestern California have led to sharp declines in relatively good-paying timber-related manufacturing jobs and shipping activity at the Port of Humboldt Bay (Hackett et al., 2017). Likewise, the Humboldt-based commercial fishing fleet has shrunk sharply over the last 30 years (Hackett et al., 2017). Declining industrial and commercial activity can undermine the fiscal health of the Port of Humboldt Bay by reducing revenues available for port infrastructure improvements, maintenance, and repair. Within the regional economy, there is a history of boom-and-bust economic cycles linked first to timber production and later to cannabis production. As a result, economic development benefits from an OSW industry complex in Northwestern California could be particularly beneficial. While impacts on Humboldt County in particular are not estimated in this report, they can be expected to be disproportionately large relative to the county’s share of California economic output or population, as construction and operations are staged out of the Port of Humboldt Bay.

Economies of scale in wind farm development are revealed in the relatively larger job and economic output impacts per MW of installed capacity for the smallest wind farm scenarios. Economies of scale mean that a doubling of output results from less than a doubling of total cost.

Over time, economic impacts can change. As installed wind farm capacity in California increases, one might expect not only cost-reducing learning effects, but also an increase in the local share of input sourcing due to in-state investment in manufacturing specialized OSW inputs. Were this to occur, then the result would be larger California economic impacts for a given expenditure in project development and operations.

5. REFERENCES

Anderson, Julia. 2020. Humboldt State University. Master's Thesis [in process]

Castro-Santos, Laura, and Vicente Diaz-Casas. 2015 Cost Comparison of Three Floating Offshore Wind Platforms. Journal of Coastal Research: Volume 31, Issue 5: pp. 1217 – 1221.

Goldberg, Marshall. 2019. Personal communication, November 4, 2019. MRG & Associates, Inc.

Hackett, Steven, Laurie Richmond, and Cheryl Chen. 2017. Socioeconomics of North Coast Fisheries in the Context of Marine Protected Area Formation. MPA Baseline Program No. R/MPA-36. California Sea Grant / Ocean Science Trust. 313 pp. https://caseagrant.ucsd.edu/news/north-coast-marine-protected-areas-project-summaries#human-uses

Hackett, S., and Anderson, J. (2020). Economic Viability of Offshore Wind in Northern California. 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.

IMPLAN. 2020. https://www.implan.com/. Website accessed February 6, 2020.

National Renewable Energy Laboratory. 2020. JEDI Methodology. https://www.nrel.gov/analysis/jedi/methodology.html. Website accessed February 6, 2020.

National Renewable Energy Laboratory. 2019. Jobs and Economic Development Impacts (JEDI) Offshore Wind Model version REL.OSW10.24.17. Site accessed on various dates beginning in April 2019. https://www.nrel.gov/analysis/jedi/wind.html

Speer, Bethany, David Keyser, and Suzanne Tegen. 2016. Floating Offshore Wind in California: Gross Potential for Jobs and Economic Impacts from Two Future Scenarios. National Renewable Energy Laboratory.

APPENDIX A: ECONOMIC IMPACTS MODEL CUSTOMIZATION

Appendix A summarizes the process of customizing the Jobs and Economic Development Impact (JEDI) offshore wind (OSW) model for the northwestern California project context. Customization involved replacing JEDI model default cost factors with those deriving from the Schatz Center OSW cost model (Anderson, forthcoming). The JEDI Offshore wind model is used to assess the economic impacts of OSW scenarios developed by Schatz Center staff (NREL, 2020). A description of JEDI and the IMPLAN model from which it derives (IMPLAN, 2020) is described in the main body of this report.

JEDI model inputs include descriptive project information including location (by state), year, project size, turbine size, water depth, distance to shore, distance to port, etc. In advanced analysis, project costs and local content share ("local share") can be customized. As noted in the report, local share by line item in this study derives the "year zero" values in Speer et al. (2016). Selected line item-level descriptions are provided in Table A-1.

Table A-1: Selected Line-Item JEDI Input Descriptions

JEDI Model Line Item Name	*Location in JEDI "Project Data" Excel Worksheet*	*Description*
Nacelle/drivetrain	B40	Includes all turbine system costs
Piling, anchors, and mooring	B47	All substructure and mooring system costs are input here (personal communication, Goldberg, 2019)
Grid interconnection	B60	Also, all transmission infrastructure upgrade costs are included here (personal communication, Goldberg, 2019)
Ports and staging	B69	Included all port infrastructure upgrade costs (personal communication, Goldberg, 2019)
Marine transport	B72	Included in the Ports and Staging line, as there is no difference in local share and these are bundled in the Schatz Center cost model
Erection/installation equipment services	B73	Included in the Ports and Staging line, as there is no difference in local share and these are bundled in the Schatz Center cost model
Monitoring	B92	Assumed to be similar to costs for condition-based maintenance (see Schatz Center cost model methods for description)
Administrative	B93	Includes insurance and administration based on estimate in Castro-Santos (2015)
Water Transport	B97	Includes all vessel costs – assumed that vessels are chartered so this line item also includes crew wages
Site Facilities	B98	Value includes annual BOEM lease fee
Machinery & Equipment	B99	Included in water transport estimate
Subcontractors	B100	Assumed that subcontractors are included in basic technician labor cost estimate

Excel files used for this analysis are accessible through the following link:

https://drive.google.com/drive/folders/1UhNsvcg4hOh41WsnbOq7GaUccj9Lz99d?usp=sharing

Note that the JEDI model used in this project includes port infrastructure upgrade expenditures for the Port of Humboldt Bay, deemed necessary for OSW farm development (see Table A-2). Project collaborator Mott MacDonald produced a range of estimated values for port infrastructure upgrades for various project scenarios, and the midpoint of this range was used as the port infrastructure upgrade cost value and placed in the “Ports and Staging” line (Cell B69 in the Project Data worksheet). It is expected that a terminal operator will fund these improvements and then charge terminal users a fee to generate revenue and recoup their investment.

Table A-2: Range of Port Infrastructure Upgrade Expenditures Estimated by Mott MacDonald

Farm size	*Low estimate*	*Midpoint*	*High estimate*
Large scale (1,800 MW)	$400 million	$575 million	$750 million
Small scale (50 or 150 MW)	$130 million	$165 million	$200 million