



# Economic Impact from Large-Scale Deployment of Offshore Marine and Hydrokinetic Technology in Oregon

T. Jimenez and S. Tegen



*Produced under direction of the Bureau of Ocean Energy Management by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-12-1867 and Task No. WFQ4.1005.*

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## Executive Summary

The overall United States' marine and hydrokinetic (MHK) resource is comprised of river currents, ocean currents, and ocean wave energy. Of the three, wave energy has the greatest resource potential for electricity generation in the country. Within the continental United States, the West Coast in general, and Oregon in particular, appear to have the best wave energy resource. Wave energy resources are transformed into power by using wave energy converters, or WECs. MHK power is still in the stage of prototype devices and small demonstration projects<sup>1</sup>; however, this report explores scenarios with high deployment levels of WEC technology to investigate economic impacts for the State of Oregon, with the assumptions that technological advancements are made and costs are significantly decreased in the future.

To better understand the potential economic impacts of large-scale WEC technology, the Bureau of Ocean Energy Management commissioned the National Renewable Energy Laboratory to conduct this economic impact analysis of large-scale WEC deployment in Oregon.

The analysis examined two deployment scenarios in the 2026–2045 timeframe. The first scenario assumed 13,000 megawatts (MW) of WEC technology deployed in Oregon during the analysis period and the second scenario assumed 18,000 MW of WEC deployments. Sensitivity studies examined the effects of a robust in-state WEC-based supply chain and WEC device exports outside of Oregon.

The impacts highlighted here could be used in policy and planning discussions and could be scaled to get a sense of the economic development opportunities associated with other WEC deployment scenarios. In addition, the analysis can be used to inform stakeholders in other states about the potential economic impacts of this scale of WEC technology development. All estimates are based on currently available data, with caveats discussed in Section 2.1. It should be noted that scenarios in this report are hypothetical, and deployments of this magnitude would not realistically happen without advancements in technology and a very significant reduction in the cost of energy for WEC technology.

According to the analysis conducted in this study, deploying 13,000 MW of WEC installations in Oregon and assuming a medium-level in-state supply chain could<sup>2</sup>:

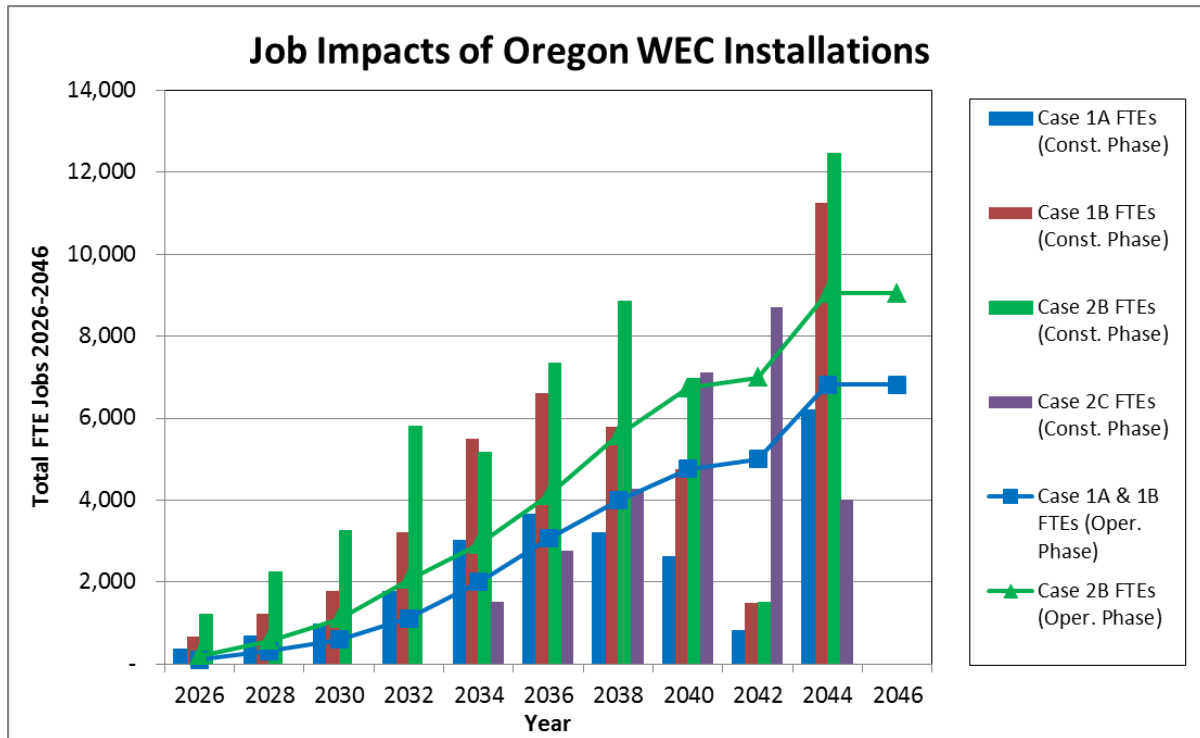
- Support a total of 6,800 operation-phase FTE jobs by 2045 when 13,000 MW have been deployed. Support 6,800 operation-phase jobs annually in the years following the analysis period for the remaining lifetime of the MHK projects
- Generate a total of \$8.0 billion in economic activity for Oregon during the construction phases
- Support a total of \$1.0 billion in economic activity by 2045 during operation phases. Generate \$1.0 billion in annual economic activity in the years following the analysis period for the remaining lifetime of the MHK projects
- Provide \$7.4 million in annual lease payments to the State of Oregon.

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<sup>1</sup> According to the December 2013 Ocean Energy Systems Annual Report, the United Kingdom has 3,850 kilowatts of MHK capacity installed (Ocean Energy Systems 2013).

<sup>2</sup> Analysis results are provided in real 2012 inflation-adjusted U.S. dollars.

Figure ES-1 shows the estimated jobs in construction and operations for the years of the analysis.



**Figure ES-1. Estimated jobs in Oregon supported by WEC deployment scenarios**

One key finding from this work is the sensitivity of the results to the magnitude of the in-state supply chain. Establishing an in-state supply chain that can manufacture even a modest portion of WEC installations would dramatically increase the economic impact of large-scale WEC deployment within the state.

# Table of Contents

<b>Executive Summary</b> .....	<b>iv</b>
<b>List of Figures</b> .....	<b>vi</b>
<b>List of Tables</b> .....	<b>vii</b>
<b>1 Introduction</b> .....	<b>1</b>
<b>2 Methodology</b> .....	<b>3</b>
2.1 The Jobs and Economic Development Impact Model .....	3
2.2 Research Data and Assumptions and Methodology .....	6
<b>3 Results</b> .....	<b>14</b>
3.1 Gross Economic Activity .....	16
3.2 Employment Impacts .....	18
3.2.1 Construction Jobs .....	18
3.2.2 Operation and Maintenance Jobs .....	19
3.3 State Lease Revenue .....	19
<b>4 Oregon Manufacturing Sensitivity Analysis</b> .....	<b>19</b>
<b>5 Conclusion</b> .....	<b>22</b>
<b>References</b> .....	<b>23</b>
<b>Appendix</b> .....	<b>25</b>

## List of Figures

Figure ES-1. Estimated jobs in Oregon supported by WEC deployment scenarios .....	v
Figure 1-1. Wave energy conversion device topologies .....	1
Figure 1-2. Annual estimated U.S. wave power density .....	2
Figure 2-1. JEDI Wind model economic development impact categories .....	5
Figure 2-2. Construction cost breakdown assumptions .....	11
Figure 3-1. Economic ripple effect from 13,000 MW of WEC facility deployments in Oregon from 2016 to 2045 (assuming 20% in-state device share) .....	14
Figure 3-2. Estimated local spending supported by 13,000 MW of WEC facilities in Oregon during project construction (assuming 20% device local share) .....	17
Figure 3-3. Estimated total economic impacts from WEC deployment in Oregon throughout the analysis period .....	17
Figure 3-4. Estimated annual employment impacts from WEC deployment in Oregon .....	18
Figure 4-1. Manufacturing scenarios and associated job impacts during construction comparing WEC devices with 20% (1A) and 60% (1B) local components .....	20
Figure 4-2. Manufacturing scenarios and associated economic impacts during the construction phase with 20% and 60% local share .....	21

## List of Tables

Table 2-1. Analysis Cases .....	7
Table 2-2. Oregon Wave Energy Deployment Scenarios ( <i>Costs given in 2012 dollars</i> ).....	9
Table 2-3. Construction Cost Assumptions .....	10
Table 2-4. Operating Cost Assumptions.....	11
Table 2-5. Additional Study Parameters Considered .....	13
Table 3-1. Oregon Summary Impacts from WEC Deployment (2026–2045).....	15
Table A-1. Case 1A Results – FTE Jobs Based on Annual Installations.....	25
Table A-2. Case 1A Results – Earnings .....	26
Table A-3. Case 1A Results – Total Economic Impacts .....	27
Table A-4. Case 1B Results – FTE Jobs Based on Annual Installations.....	28
Table A-5. Case 1B Results – Earnings .....	29
Table A-6. Case 1B Results – Total Economic Impacts .....	30
Table A-7. Case 2B Results – FTE Jobs Based on Annual Installations.....	31
Table A-8. Case 2B Results – Earnings .....	32
Table A-9. Case 2B Results – Total Economic Impacts .....	33
Table A-10. Case 2C Results – FTE Jobs, Earnings, and Total Economic Impacts.....	34



# 1 Introduction

Marine and hydrokinetic (MHK) technologies are in the early stages of development toward becoming a source of renewable energy, such as solar and wind power. MHK can be subdivided into two categories: current energy converters (CECs) and wave energy converters (WECs). CECs harness the power of river, tidal, and ocean currents and are similar to wind turbines, whereas WECs harness the energy of ocean surface waves (Thresher 2013). Figure 1-1 shows examples of some of the different WEC devices currently under development. The wide variety of topologies indicates that WEC technology is still immature. There are currently no commercial-scale, market-ready MHK devices deployed in the United States though there are some projects in the demonstration stages, with plans for larger devices. Figure 1-2 shows the U.S. wave energy resource.

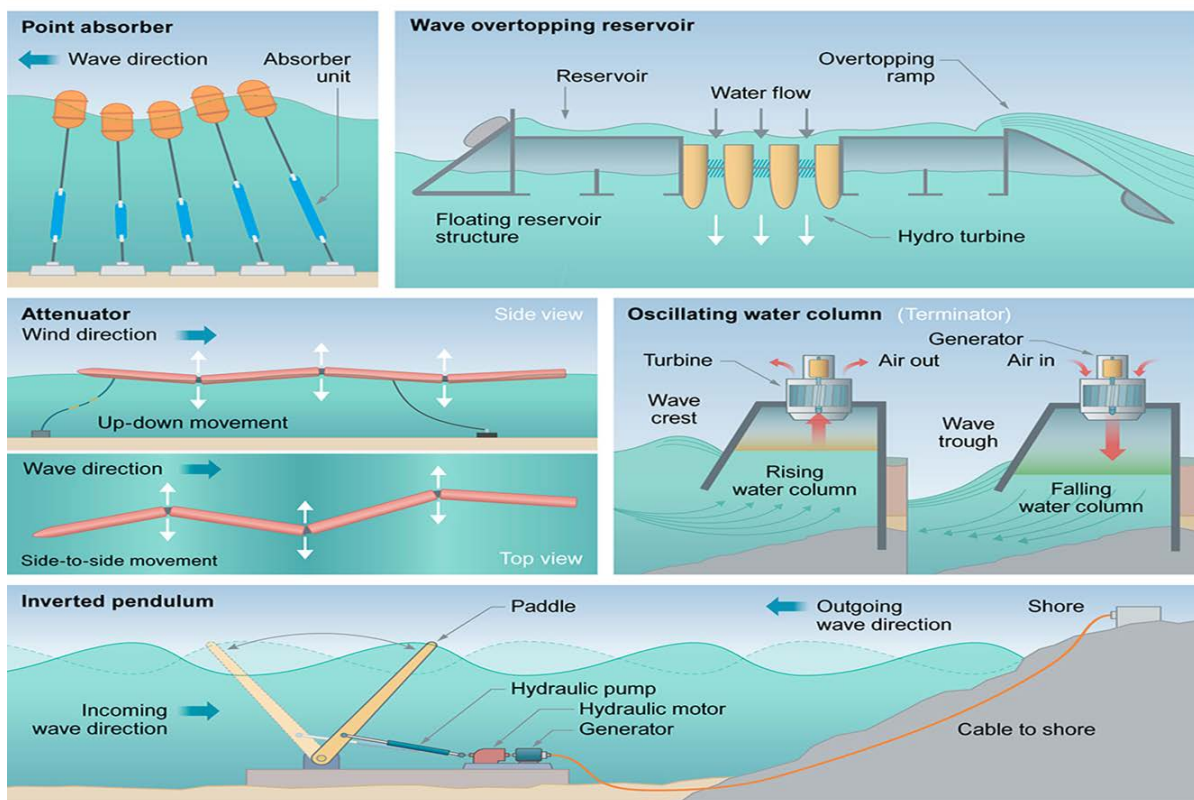
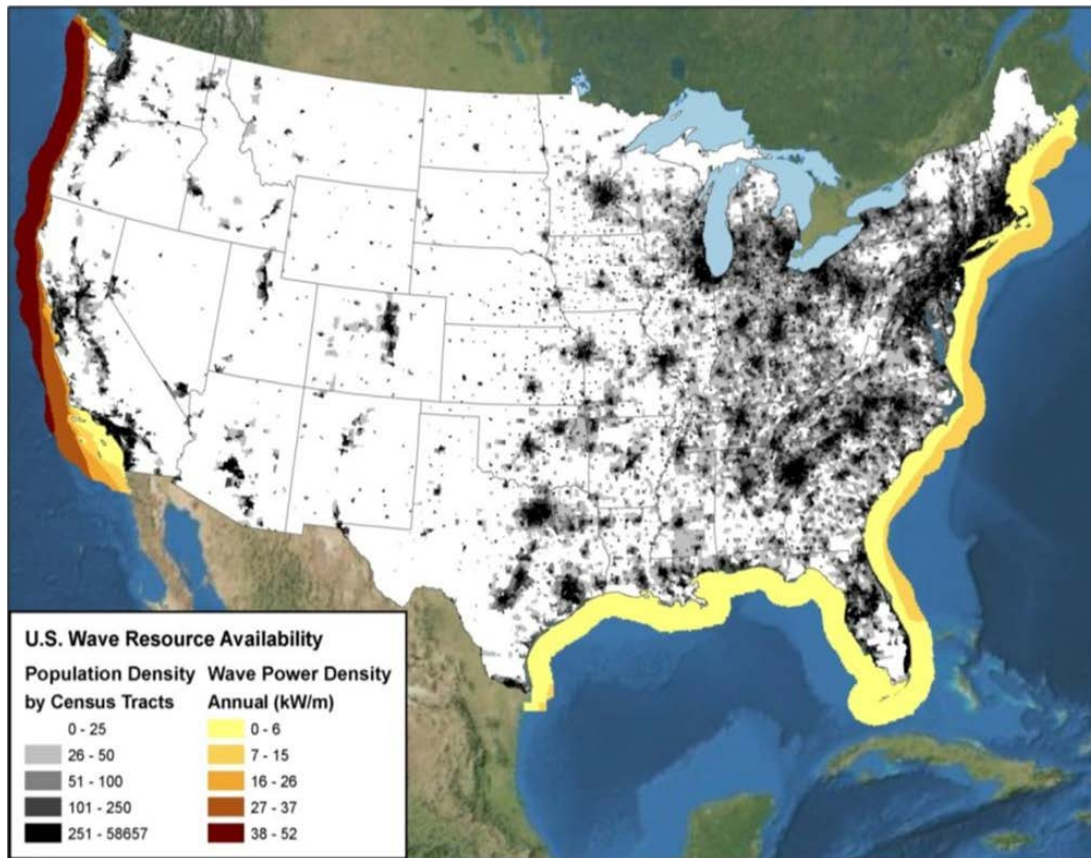


Figure 1-1. Wave energy conversion device topologies  
Source: Augustine et al. 2012



**Figure 1-2. Annual estimated U.S. wave power density**  
 Source: Thresher 2013; Resource data from [http://maps.nrel.gov/re\\_atlas](http://maps.nrel.gov/re_atlas)

At the request of the Bureau of Ocean Energy Management (BOEM), the National Renewable Energy Laboratory (NREL) conducted an analysis of the economic impacts of large-scale (10,000–20,000 megawatts [MW]) MHK, (specifically wave energy) deployment off the coast of Oregon. Oregon was selected because of its large wave energy resource and its ongoing efforts to create an Oregon-based wave energy industry. Specifically, NREL examined two different deployment scenarios using a large number of WEC deployments. Sensitivity studies were conducted to examine the effects of a larger in-state WEC supply chain and WEC device exports beyond Oregon.

Similar to utility-scale wind and solar, utility-scale MHK deployment is expected to support jobs and generate tax revenue that can be used to provide other public services. Estimating the potential economic development impacts of such power plants allows policymakers and decision makers to assess the impacts on jobs and state economic activity.

For the purposes of this study, state-level economic impacts include jobs, lease revenues, payrolls, and business activity from wave energy project development. Note that the described and quantified impacts are gross, not net impacts. In other words, the analysis does not account for potential job losses and reduced economic activity caused by the displacement of other types of electricity generating facilities and the displacement of other activities.

## 2 Methodology

### 2.1 The Jobs and Economic Development Impact Model

For this study, researchers used the MHK Jobs and Economic Development Impact (JEDI) model, which is one element of a suite of JEDI input-output (I-O) models. JEDI models provide gross estimated economic impacts that are supported by investment in a number of different energy technologies. NREL and MRG & Associates developed the MHK JEDI model to incorporate the unique aspects of MHK development into an economic impact tool that can be accessed and used by the public, at no cost.<sup>3</sup>

I-O models are widely recognized tools used to estimate economic impacts associated with investments or expenditures. These models map how sectors in an economy such as businesses, households, workers, capital, and government organizations interact with one another via purchases and sales at a single point in time. Because sectors are related to one another, an increase in demand for one can lead to an increase in demand for another. An increase in demand for a steel plate, for example, results in an increased demand for the iron ore that is sourced within the region of analysis.

JEDI and other I-O models estimate economic impacts that are supported by changes in demand for goods and services.<sup>4</sup> JEDI estimates changes in demand for these goods and services with data from the project scenario. The JEDI project scenario is a set of data that describes an energy generation project. Each project contains two sets of line item expense categories such as equipment, materials and services, and labor: one set covers the construction of the project and the other covers the operation and maintenance (O&M) of a project. JEDI models contain default project scenario and cost data, but analysts with knowledge of project details can edit these defaults to better represent the scenario being analyzed.

The JEDI model requires users to specify the portions of expenditures that are made within the region of analysis, i.e., the “local share.” For example, the model allows users to specify the fraction of the “device” purchased from in-state manufacturers (assuming that the state is the region of analysis). JEDI uses expenditures made within the region of analysis, or “local expenditures,” to estimate economic impacts (for example, WEC devices manufactured within the State of Oregon). The JEDI model does not estimate economic impacts outside the particular region of analysis (e.g., generator parts from China).

JEDI reports economic impact estimates for two phases: construction and O&M. Construction-phase results are one-time totals that span the equivalent of 1 year,<sup>5</sup> and O&M phase results are annual and ongoing for the life of the facility.

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<sup>3</sup> The MHK JEDI model can be downloaded at <http://www.nrel.gov/analysis/jedi/download.html>. Accessed February 12, 2014.

<sup>4</sup> JEDI currently uses the IMPLAN input-output model. More information about IMPLAN can be found at <http://www.implan.com>.

<sup>5</sup> If, for example, JEDI reports a construction-phase impact of 50 workers to build a project that takes 2 years to complete, this equates to an average of 25 workers per year ( $50/2 = 25$ ). If the same project took 3 years, the average would be 17 (rounded) workers per year.

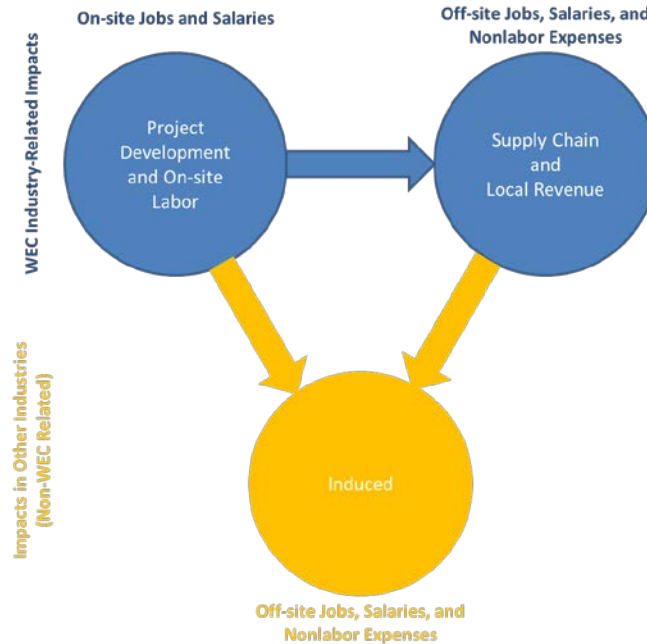
All impacts are based on expenditures and local content data contained within the project scenario worksheet. JEDI organizes these effects into different categories based on how the user-specified project scenario supports the impact. The workers who install a wave energy project, for example, are on site. The workers who manufacture the wave energy device are part of the supply chain. Installers and manufacturers earn wages and spend money within the region of analysis, which supports further economic activity (e.g., the construction workers eat lunch at local sandwich shops). The three categories of impacts used by JEDI are<sup>6</sup>:

- **Project development and on-site labor impacts.** This category represents the economic activity that is either directly involved with a project’s development and implementation or that occurs on site. These impacts typically occur in the construction, maintenance, engineering, and port-staging sectors and do not include impacts that arise from expenditures for inputs used in a project.
- **Plant and supply chain impacts.** This category represents the economic activity that is supported by inputs purchased for a project or business-to-business services. These include locally manufactured inputs, such as the WEC conversion equipment (also referred to as the “device”), and locally procured inputs used to manufacture the device, such as steel and fiberglass. This category also includes services provided by professionals such as analysts and attorneys who assess project feasibility and negotiate contract agreements, banks that finance the projects, and all equipment companies and manufacturers of replacement and repair parts.
- **Induced impacts.** This category represents the impacts of money circulating in an economy. Households spend earnings generated from employment in project development and development activities as well as turbine and supply chain activities. A portion of these earnings spent within the region of analysis supports induced impacts, examples of which include retail sales, child care, leisure, hospitality, and real estate services. (Goldberg and Previsic 2011)

Figure 2-1 shows the three categories of impact from the JEDI model.

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<sup>6</sup> Typically, I-O models organize impacts into direct, indirect, and induced effects, but JEDI categories are different. Project development and on-site labor impacts include less than direct effects from project expenditures and turbine, and supply chain impacts are more broad than the indirect effects from project expenditures. The MHK Wind JEDI User Reference Guide (<http://www.nrel.gov/analysis/jedi>) provides more information about these differences.



**Figure 2-1. JEDI Wind model economic development impact categories**

JEDI reports three different metrics for each type of impact: jobs, earnings, and gross output, and utilizes intuitive labels when reporting these metrics, such as “jobs” and “earnings.” Each metric, however, has a specific definition that informs how it should be interpreted, as follows.

- **Jobs** are expressed as full-time equivalent (FTE) jobs. One FTE job is the equivalent of one person working 40 hours per week, year-round. Two people working full-time for 6 months equal one FTE. Two people each working 20 hours/week for 12 months also equal one FTE. An FTE could alternately be referred to as a person-year or job-year. Jobs, as reported by JEDI, are not limited to those who work for an employer—and may include other types of workers, such as sole proprietors (individuals that are self-employed).
- **Earnings** include any type of income generated from work, generally an employee’s wage or salary and supplemental costs paid by employers such as health insurance and retirement. They may also include other nonwage compensation for work performed such as proprietor earnings.
- **Total economic activity (output)** is the sum of all expenditures. For example, a scenario in which a developer purchases a locally manufactured \$500,000 WEC component that utilized \$100,000 of locally procured aluminum represents \$600,000 in gross output.

As with all economic models, there are caveats and limitations to the use of JEDI. I-O models in general utilize fixed, proportional relationships between sectors in an economy. This means that factors that could change these relationships, such as price changes that lead households to alter consumption patterns, are not considered.

JEDI provides estimates of gross economic impacts based on the user-specified expenditures and economic conditions provided when the input-output data were compiled. Impacts that extend



into the future (such as O&M impacts) are assumed to do so if all else is constant. There can be any number of changes in a dynamic economy that JEDI does not consider, so these future results should not be considered as a forecast. They simply reflect how a project might look if it was completed in the current economy under the user-specified cost and local content assumptions.

JEDI results are based on project inputs, and these inputs can change from project to project. These changes in input values are especially true of nascent technologies, or technologies that have not yet been widely deployed in the United States. If an analyst wishes to estimate impacts from a specific project, tailoring inputs to that project should produce more accurate results. JEDI does not evaluate whether or not inputs are reasonable, nor does it determine whether a project is feasible or profitable.

As stated, results from JEDI models are gross, not net. JEDI estimates economic activity that would be supported by demand created by project expenditures. Other changes in an economy will take place that JEDI does not consider, such as price changes, changes in taxes or subsidies, utility rate changes, or changes in property values. JEDI also does not incorporate far-reaching effects such as greenhouse gas emissions or displaced investment, or potential effects of a project such as changes in fishing, recreation, or tourism.

## **2.2 Research Data and Assumptions and Methodology**

This analysis consists of two main parts. The first part consists of the development or selection of MHK deployment scenarios. The second part explains our analysis of the economic impacts of those deployment scenarios.

### **2.2.1 Deployment Scenarios Description**

We present four cases that examine two deployment scenarios. Sensitivity studies examine the effects of a larger in-state supply chain and WEC device exports to locations beyond Oregon. Table 2-1 summarizes the four cases analyzed for this effort. Cases 1A and 1B both assume the deployment scenario in which West Coast-based WEC installations supply 80 TWh of electricity annually by 2050.<sup>7</sup> Case 1A assumes that on average 20% of the WEC devices are sourced by in-state OEMs, i.e., a 20% local share, whereas Case 1B assumes a 60% local share for the WEC device. Case 2B assumes an even higher deployment scenario in which West Coast WEC installations supply 160 TWh of electricity annually by 2050, with a 60% WEC device local share. Case 2B is quite aggressive, representing an estimated 3% of the entire U.S. electricity demand by 2040 (likely a smaller percentage in 2050; however, the Energy Information Administration projections end in 2040 [EIA 2014b]). Each of these three cases examines the economic impact to Oregon from WEC facilities.

In contrast, Case 2C assumes that Oregon device manufacturers export out of state. Case 2C assumes that Oregon-based OEMs supply 25% of the devices for installations in Washington and California under the higher (160 TWh) deployment scenario. For this analysis, the destination of the exports does not matter. Destinations could also include Alaska, Hawaii, the East Coast, and

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<sup>7</sup> Though it is impossible to make accurate projections so far into the future, based on Energy Information Administration projections (see EIA 2014b), 80 TWh would be between 1%–2% of the United States' electricity consumption in the 2040–2050 timeframe.

foreign countries. The results for this case are the economic impacts to Oregon, from these exports. For this case, the device local share (from Oregon) is set to 25%. For all other items, the value of the local share is set to zero. Note that the impacts of exports are in addition to the impacts of in-state installations. In other words, the impacts of Case 2C are in addition to the impacts of the already optimistic Case 2B.

According to the Energy Information Administration, “[r]enewable resources contribute over two-thirds of the net electricity generation in Oregon. In years with increased or prolonged precipitation or snowmelt, renewable resources contribute as much as four-fifths of net electricity generation, because of the state’s abundant hydroelectric generation capacity [...]. From 2007 through the end of 2013, [Oregon] electricity generation from non-hydroelectric renewable resources almost quadrupled.” (EIA 2014a).

**Table 2-1. Analysis Cases**

<b>Case Label</b>	<b>Deployment Scenario</b>	<b>Sensitivities</b>
1A	80 TWh scenario	20% device local share
1B	80 TWh scenario	60% device local share
2B	160 TWh scenario	60% device local share
2C	160 TWh scenario	25% device local share (from Oregon suppliers) for installations in California and Washington

The deployment scenarios used in this analysis come from hypothetical deployment scenarios for wave energy technology that explore the potential impacts of R&D improvement pathways and manufacturing learning effects on the cost of energy over long time periods (Cohen 2013; Thresher, 2013; Thresher, 2014). The hypothetical scenarios forced the deployment of WEC technology according to a specified deployment schedule without regard for its cost and then estimated the overall capital cost under differing improvement and learning assumptions using the Regional Energy Deployment System (ReEDS) Model. ReEDS is a long-term capacity-expansion model for the deployment of electric power generation technologies and transmission infrastructure throughout the contiguous United States.<sup>8</sup> For a given set of economic, policy, and load growth assumptions, ReEDS models the deployment of transmission infrastructure as well as various conventional and renewable energy generation technologies. Within the constraints of the scenario, ReEDS will meet the anticipated load by using the least expensive (on a lifecycle cost basis) combination of transmission and generation. As stated, for the purpose of this analysis, we forced the ReEDS model to deploy WEC regardless of costs.

The ReEDS analysis examined two deployment scenarios: one in which WEC installations supply approximately 80 terawatt-hours (TWh) of electricity per year to the West Coast by 2050, and the other in which WEC technology supplies twice that amount, 160 TWh, by 2050. It is important to note that that these scenarios are hypothetical, and deployments of this magnitude

<sup>8</sup> <http://www.nrel.gov/analysis/reeds/description.html>

would not realistically happen without advancements in technology and a very significant reduction in the cost of energy for WEC technology. ReEDS estimates energy generation deployment by state, thus providing Oregon-specific WEC deployment values. Both deployment scenarios supply significant portions of the energy needs for the West Coast. We selected 2026 to 2045 as our analysis period because it captures the bulk of Oregon-based wave energy installations occurring within the ReEDS scenarios.

The scenarios for the ReEDS investigation also include cost estimates, both capital and O&M, for the wave energy facilities. Compared to wind or solar energy, wave energy technology is still immature and costly. Current estimated installed capital expenditures (CAPEX) for wave energy plants are more than \$8,272/kW. Current operating expenditures (OPEX) are estimated at \$400/kilowatt (kW)/year. These values are a composite from several studies (Prevesic 2012; Renewable UK 2010; Department of Trade and Industry 2007). Although these costs are high, cost reduction opportunities exist. The future scenarios analyzed here would require significant cost reductions over time resulting from technology improvements, acquiring knowledge, and a robust research and development program.

Table 2-2 shows the hypothetical annual wave energy deployment in Oregon, as well as the CAPEX and OPEX, for both scenarios. Also shown are combined installations for California and Washington under the 160 TWh scenario. The 80 TWh scenario shows roughly 13,000 MW of wave energy deployment off the coast of Oregon by 2045, while the 160 TWh scenario predicts over 18,000 MW. Note that the higher scenario does not represent twice the deployment, in Oregon, of the lower scenario. Because of Oregon's excellent wave energy resource, the state could reach significant levels of deployment, were technology advancements and cost reduction to occur. As overall west coast deployment increases in the scenario, Oregon is saturated, and more development starts to occur in lower wave energy resource areas.

Both deployment scenarios envision sharp drops in both CAPEX and OPEX from the present baseline values of \$8,272/kW and \$400/kW/year. In the 80 TWh scenario, CAPEX and OPEX drop to \$1,098/kW and \$53/kW/year by the end of the analysis period. For the 160 TWh scenario, the respective costs at the end of the analysis period are \$966/kW and \$47/kW/year – a very significant prescribed decrease. The cost reductions assumed here are ambitious and would take substantial technological improvements, but were modeled to show impacts from a future in which WECs have had large cost reductions. It can be noted that both wind and photovoltaic technologies have undergone similar levels of cost reduction, so the scenarios are only possible if WEC technology proves to be robust and reliable. Again, it must be emphasized that only with the development of sound technology options and cost reductions (as shown here) could the large-scale deployment of WEC technology be possible.



**Table 2-2. Oregon Wave Energy Deployment Scenarios (Costs given in 2012 dollars)**

80 TWh Scenario				160 TWh Scenario				160 TWh Scenario (WA+CA)			
Year	Installed (MW)	Installed Cost (\$/kW)	Investment (\$MM)	Year	Installed (MW)	Installed Cost (\$/kW)	Investment (\$MM)	Year	Installed (MW)	Installed Cost (\$/kW)	Investment (\$MM)
2016	5	\$8,272	\$41.36	2016	11	\$8,272	\$90.99	2016	0	\$0	\$0.00
2018	6	\$8,272	\$50	2018	11	\$8,272	\$91	2018	0	\$0	\$0
2020	12	\$4,963	\$60	2020	23	\$4,963	\$114	2020	0	\$0	\$0
2022	24	\$4,960	\$119	2022	47	\$4,464	\$210	2022	0	\$0	\$0
2024	48	\$3,122	\$150	2024	97	\$2,810	\$273	2024	0	\$0	\$0
2026	99	\$2,809	\$278	2026	197	\$2,528	\$498	2026	0	\$0	\$0
2028	199	\$2,528	\$503	2028	398	\$2,277	\$906	2028	0	\$0	\$0
2030	397	\$1,824	\$724	2030	790	\$1,663	\$1,314	2030	0	\$0	\$0
2032	775	\$1,669	\$1,293	2032	1,570	\$1,490	\$2,339	2032	0	\$0	\$0
2034	1,475	\$1,502	\$2,215	2034	1,540	\$1,349	\$2,077	2034	1,582	\$1,363	\$2,157
2036	1,945	\$1,370	\$2,665	2036	2,405	\$1,228	\$2,953	2036	3,220	\$1,235	\$3,978
2038	1,836	\$1,269	\$2,330	2038	3,117	\$1,141	\$3,556	2038	5,373	\$1,141	\$6,132
2040	1,613	\$1,182	\$1,907	2040	2,647	\$1,059	\$2,803	2040	9,579	\$1,065	\$10,203
2042	530	\$1,140	\$604	2042	593	\$1,015	\$602	2042	12,152	\$1,027	\$12,482
2044	4,117	\$1,098	\$4,520	2044	5,024	\$996	\$5,004	2044	5,810	\$986	\$5,731
<b>Cumulative</b>	<b>13,081</b>			<b>Cumulative</b>	<b>18,470</b>			<b>Cumulative</b>	<b>37,716</b>		

### 2.2.2 Methodology

Our research on costs and cost breakdowns consisted of a literature review (ECONorthwest 2009; Carbon Trust 2011; Previsic et al. 2012). We conducted interviews with internal experts and MHK stakeholders to provide depth and validation to the analysis. Data obtained from interviews included construction costs, O&M costs, percentage of goods and services acquired in-state, job generation during the construction period, job generation during the operation period, land-lease payments, tax information, payroll parameters, and the cost breakdown of different installation and operation categories.

Using the information derived from the sources noted above, we developed specific assumptions including construction cost breakdown (Table 2-3), operating cost breakdown (Table 2-4), local (in-state) share for both CAPEX and OPEX, and other relevant parameters (Table 2-5), which were used as inputs in the JEDI model.

**Table 2-3. Construction Cost Assumptions**

<b>Construction</b>	<b>% of Total Cost</b>	<b>Local Share</b>
<i>Equipment &amp; Material</i>		
Device	69.2%	20%/60%/25%
Underwater Electrical Collector System	7.8%	10%
Underwater Transmission Cable	1.3%	10%
Cable Landing and Grid Interconnection	1.9%	10%
Balance of Plant	4.1%	80%
<i>Equipment &amp; Material Subtotal</i>	<b>84.3%</b>	
<i>Installation/Labor</i>		
Mooring and Device Installation	6.8%	80%
Underwater Cable Installation	5.5%	10%
Cable Landing and Grid Connection	1.4%	80%
<i>Installation/Labor Subtotal</i>	<b>13.7%</b>	
<i>Permitting</i>		
Permitting	2.0%	75%
<i>Permitting Subtotal</i>	<b>2.0%</b>	
<i>Sales Tax (Material and Equipment Purchases)</i>		
Sales Tax (Materials and Equipment Purchases)	0.0%	100%
<i>Sales Tax Subtotal</i>	<b>0.0%</b>	
<b>Total</b>	<b>100.0%</b>	

Tables 2-3, 2-4, and 2-5 show the assumptions behind the analysis. Local share refers to the percentage of resources (e.g., labor, materials, supplies, and equipment) purchased or acquired in Oregon. Three values of the local share are given for the “device.” The lower 20% value assumes no continued special effort to develop an Oregon-based WEC industry. The higher 60% value assumes a successful, aggressive effort to develop a large Oregon-based WEC industry and that the majority of the nonelectrical equipment is sourced by Oregon-based OEMs. The 25% value for local share is used in Case 2C and assumes that Oregon-based manufacturers achieve an export volume equivalent to 25% of the combined WEC installations in Washington and California.

A large underwater electrical component industry already exists outside of Oregon, so the local share for these items is anticipated to be very low. In addition, underwater cable installation uses specialized vessels that are not based in Oregon, thus the low value for the local share of the labor for the underwater cable installation. Equipment costs represent about 84% of the total project cost, labor represents 14%, and permitting represents 2%.

Figure 2-2 shows the average cost breakdown assumptions used as inputs for this study.

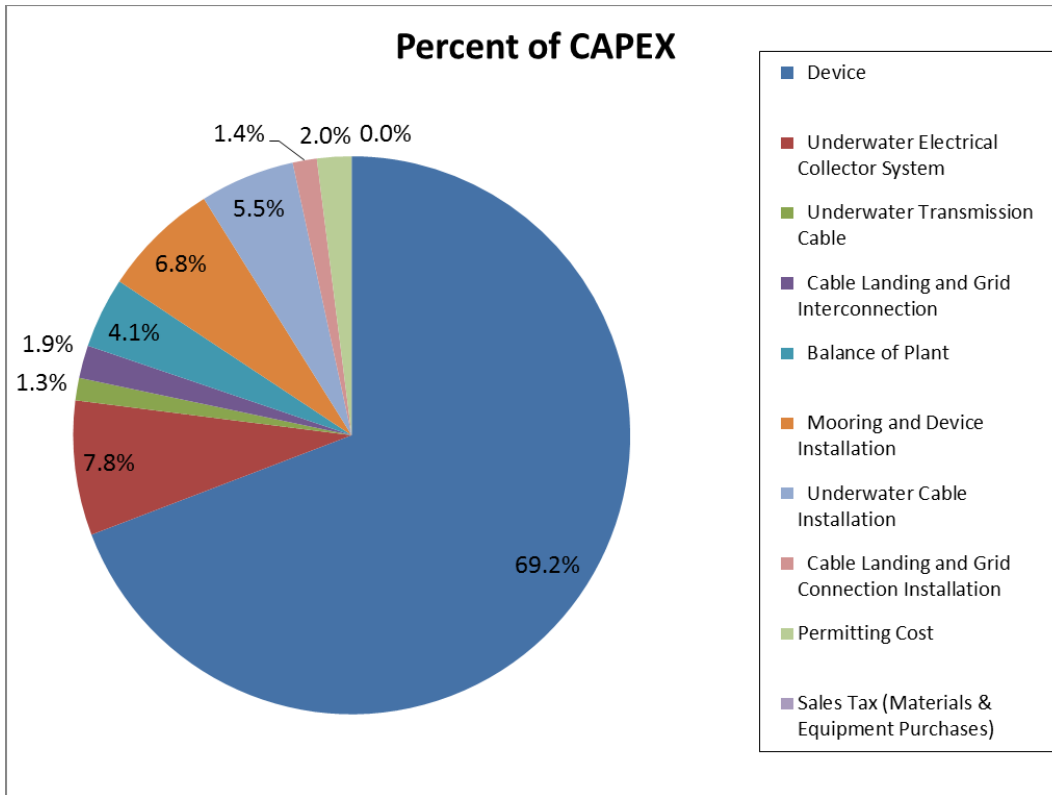


Figure 2-2. Construction cost breakdown assumptions

Table 2-4 shows the operating expenditure breakdown. Operating costs are assumed to be 4.8% of the capital cost and are comprised of just over 20% labor and fewer than 80% for materials and services. For both of these items, the local share is anticipated to be relatively high. We anticipate that most O&M workers will either already live in-state or settle within the state to perform their jobs.

Table 2-4. Operating Cost Assumptions

Wind Farm Annual Operating and Maintenance Costs	% of Total Cost	Local Share
<i>Labor</i>		
Labor	21.1%	80%
<i>Labor Subtotal</i>	21.1%	
<i>Materials and Services</i>		
Material and Services	78.9%	70%
<i>Materials and Services Subtotal</i>	78.9%	
<i>Sales Tax (Materials and Equipment Purchases)</i>		
Sales Tax	0.0%	100%
<i>Sales Tax Subtotal</i>	0.0%	
<b>Total O&amp;M Cost</b>	<b>100.0%</b>	

Table 2-5 shows the additional parameters considered in the analysis. Because of the large capital investment required, the analysis assumes that 100% of the investment for the WEC facilities comes from out of state (i.e., the local share is zero.) Deployment on the scale assumed for this analysis will require a total investment of \$10–\$20 billion.

As a result of assuming a zero local share for the investment, the only value in this section affecting the results is the lease rate. For lease purposes, the offshore facilities will fall into one of three zones. Facilities located within 3 miles of the shoreline are located in state waters and will be subject to lease rates determined by the State of Oregon. Facilities located in federal waters, greater than 3 miles from shore, must receive a lease from BOEM. For projects located 3–6 miles offshore, the state is entitled to 27% of the lease revenue. For projects located beyond 6 miles from shore, the state receives no lease revenue. Facilities located in federal waters may also be subject to Federal Energy Regulatory Commission fees. However, the state share of these fees is zero, (Bowler 2014) thus these fees have no economic impact to Oregon.

It is anticipated that most installations will be conducted in water with depths of 50 meters (m)–100 m. For Oregon, this depth of water is generally located 3–6 miles offshore. Therefore, it is reasonable to assume that the majority of the installations will be positioned within this zone. To the extent facilities are located more than 6 miles offshore; Oregon will receive less lease revenue. To the extent facilities are located within state waters, Oregon will receive more lease revenue.

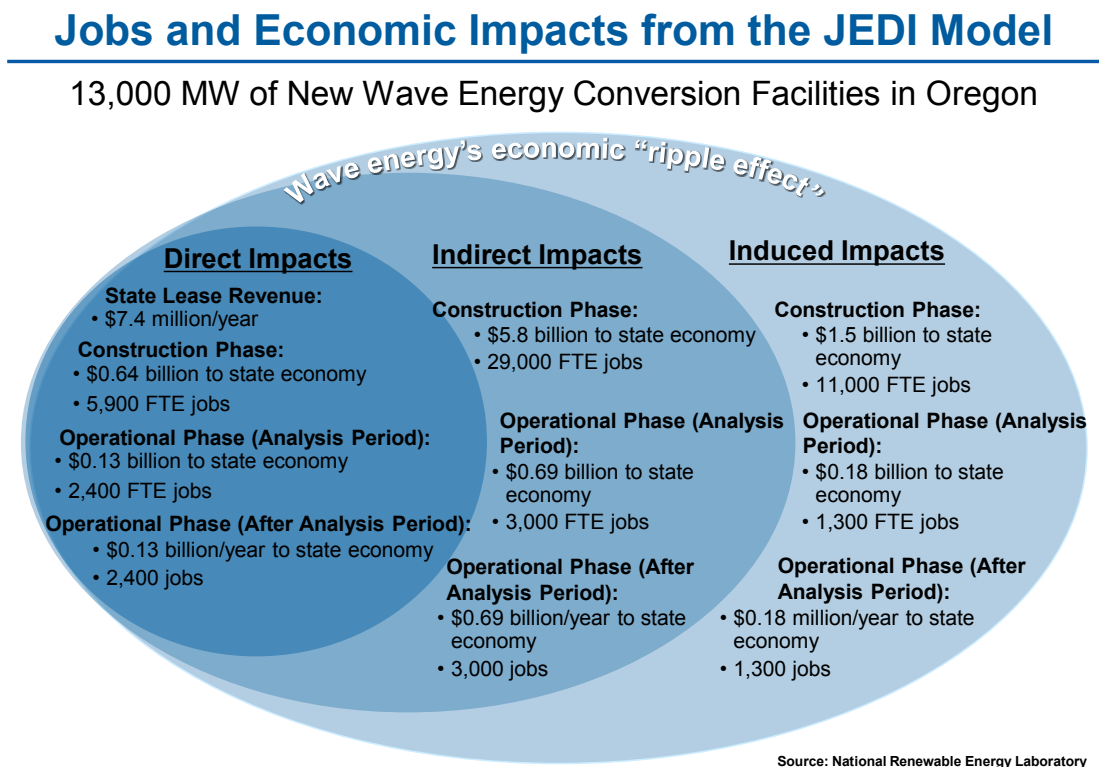
The BOEM lease rate used in the analysis is based on a precedent from four offshore leases for planned wind plants to be located in federal waters (BOEM 2010, 2013a, 2013b, 2013c). For these projects, the initial operational period lease rate is 2% of product of the facility’s energy production and the average regional wholesale electricity rate. The lease rate used in the analysis assumes a 30% capacity factor, an average wholesale price of \$0.04/kilowatt-hour. Of the total BOEM lease revenue, 27% goes to the State of Oregon. (O’Neil 2014)

**Table 2-5. Additional Study Parameters Considered**

<b>Additional Parameters</b>	<b>Value</b>	<b>Local Share</b>
<i>Financial Parameters</i>		
Percentage Financed	50%	0.0%
\$ Years Financed (term)	20	
Interest Rate	7%	
Percentage Equity	50%	
Corporate Investors (percent of total equity)	90%	0.0%
Individual Investors (percent of total equity)	10%	0.0%
Return on Equity (annual interest rate)	12%	
<i>Tax Parameters</i>		
Local Property Tax (percent of taxable value)		
Assessed Value (percent of construction cost)		
Taxable Value (percent of assessed value)		
Property Tax Exemption (percent of local taxes)		
Local Property Taxes		0%
Local Sales Tax Rate		
<i>Lease Cost (if applicable)</i>		
Lease Cost (\$/MW/year)	\$2,102	27%

### 3 Results

NREL researchers used the JEDI model to estimate the economic impact of each of the four cases, and results indicate that the impacts would be significant, given the prescribed robust deployment scenarios. Figure 3-1 summarizes the impacts for Case 1A. This case assumes the 80 TWh deployment scenario and lower local share for the WEC device.



**Figure 3-1. Economic ripple effect from 13,000 MW of WEC facility deployments in Oregon from 2026 to 2045 (assuming 20% in-state device share)**

Table 3-1 summarizes the impacts for all four cases. Impacts reported are centered on JEDI model results, which include employment, property taxes, and local economic activity during the construction and operation periods. Although estimating all WEC-related impacts was beyond the scope of this analysis, new WEC installations may have many other tangible (e.g., use tax generation, sales tax generation, water savings, vendor profits, and transmission line impacts) and intangible impacts (e.g., electricity price stability and environmental benefits). For the operations period, Table 3-1 shows the number of O&M-related jobs in the year 2045, when the scenario has reached full deployment capacity. This level of employment is expected to continue for O&M-related jobs through the end of the lifetime of the project.

**Table 3-1. Oregon Summary Impacts<sup>9</sup> from WEC Deployment (2026–2045)**

	Case 1A	Case 1B	Case 2B	Case 2C
<b>Jobs (FTE)</b>	<b>TOTAL</b>	<b>TOTAL</b>	<b>TOTAL</b>	<b>TOTAL</b>
<b>During construction and installation period</b>				
Project Development and Onsite Labor Impacts	5,899	5,899	7,648	0
Construction and Installation Labor	3,290	3,290	4,258	0
Construction and Installation Related Services	2,609	2,609	3,390	0
Equipment and Supply Chain Impacts	29,312	57,322	74,257	41,796
Induced Impacts	11,385	21,461	27,778	15,035
<b>Total Impacts</b>	<b>46,597</b>	<b>84,682</b>	<b>109,683</b>	<b>56,830</b>
<b>During operating years (by 2045)</b>				
Onsite Labor Impacts				
WEC Project Labor Only	2,436	2,436	2,765	0
Local Revenue and Supply Chain Impacts	3,058	3,058	4,420	0
Induced Impacts	1,326	1,326	1,854	0
<b>Total Impacts</b>	<b>6,820</b>	<b>6,820</b>	<b>9,039</b>	<b>0</b>
<b>Earnings (\$MM)</b>	<b>TOTAL</b>	<b>TOTAL</b>	<b>TOTAL</b>	<b>TOTAL</b>
<b>During construction and installation period</b>				
Project Development and Onsite Labor Impacts	\$ 343	\$ 343	\$ 435	\$ -
Construction and Installation Labor	\$ 153	\$ 153	\$ 188	\$ -
Construction and Installation Related Services	\$ 190	\$ 190	\$ 247	\$ -
Equipment and Supply Chain Impacts	\$ 1,732	\$ 3,482	\$ 4,509	\$ 2,611
Induced Impacts	\$ 485	\$ 913	\$ 1,182	\$ 640
<b>Total Impacts</b>	<b>\$ 2,560</b>	<b>\$ 4,738</b>	<b>\$ 6,127</b>	<b>\$ 3,251</b>
<b>During operating years (by 2045)</b>				
Onsite Labor Impacts				
WEC Project Labor Only	\$ 129	\$ 129	\$ 146	\$ -
Local Revenue and Supply Chain Impacts	\$ 179	\$ 179	\$ 260	\$ -
Induced Impacts	\$ 56	\$ 56	\$ 79	\$ -
<b>Total Impacts</b>	<b>\$ 364</b>	<b>\$ 364</b>	<b>\$ 485</b>	<b>\$ -</b>
<b>Output (\$MM)</b>	<b>TOTAL</b>	<b>TOTAL</b>	<b>TOTAL</b>	<b>TOTAL</b>
<b>During construction and installation period</b>				
Project Development and Onsite Labor Impacts	\$ 637	\$ 637	\$ 817	\$ -
Equipment and Supply Chain Impacts	\$ 5,849	\$ 12,639	\$ 16,365	\$ 10,132
Induced Impacts	\$ 1,527	\$ 2,878	\$ 3,725	\$ 2,016
<b>Total Impacts</b>	<b>\$ 8,013</b>	<b>\$ 16,154</b>	<b>\$ 20,907</b>	<b>\$ 12,148</b>
<b>During operating years (by 2045)</b>				
Onsite Labor Impacts				
WEC Project Labor Only	\$ 129	\$ 129	\$ 146	\$ -
Local Revenue and Supply Chain Impacts	\$ 692	\$ 692	\$ 1,008	\$ -
Induced Impacts	\$ 178	\$ 178	\$ 249	\$ -
<b>Total Impacts</b>	<b>\$ 999</b>	<b>\$ 999</b>	<b>\$ 1,403</b>	<b>\$ -</b>

<sup>9</sup> Results are provided in real 2012 U.S. dollars.

### 3.1 Gross Economic Activity

As shown in Table 3-1, the modeled scenario's construction and operation of WEC facilities is combined with significant economic activity in Oregon. From rented accommodations that host the influx of construction workers to the suppliers and transportation companies that provide equipment, supplies, and services to the WEC facilities, this modeled WEC development results in a substantial impact to the state economy.

Depending on the device local share, 13,000 MW of WEC facilities in Oregon (Cases 1A and 1B) could generate approximately \$8–\$16 billion in gross economic activity during the construction phase and a total of \$1 billion in economic activity by 2045 during the operations phase. The lower \$8 billion construction phase value assumes a device local share of 20%, which means that Oregon-based OEMs provide 20% of the WEC device capacity for Oregon installations. The higher value, \$16 billion, assumes that Oregon-based device suppliers provide 60% of Oregon installations. Raising the device local share from 20% to 60% increases the total equipment and supply chain construction phase impacts from \$5.8 to \$12.6 billion. In turn, the increased supply chain economic activity increases the induced construction phase impacts from \$1.5 to \$2.9 billion.

The large variation in construction phase economic activity shows the importance of the in-state or “local” content of the parts and equipment used in MHK power generation. Recall from Table 2-3 or Figure 2-2 that the “device,” (the WEC energy conversion equipment) represents almost 70% of the capital cost of a WEC installation. Thus, the total economic impact of a WEC installation depends heavily on the proportion of the “device” that is supplied from within the analysis area (the State of Oregon in this case). The device local share would have a similarly large impact on overall construction-phase jobs and earnings impacts.

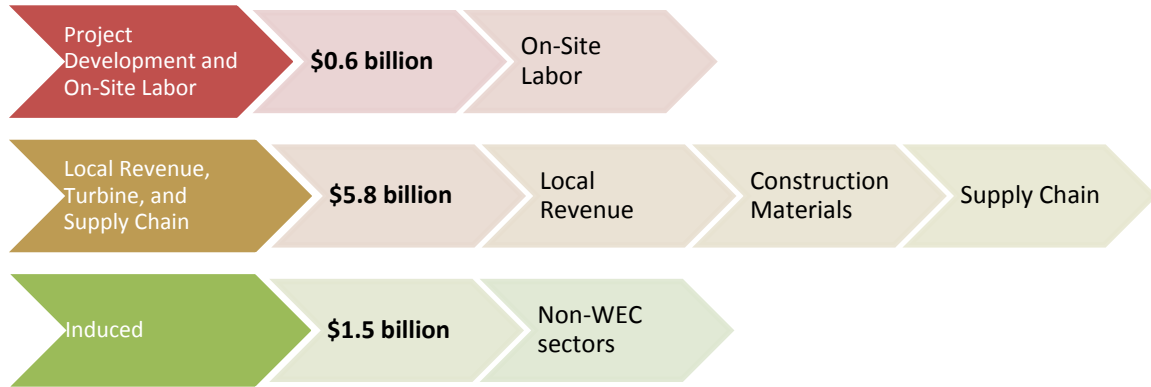
Assuming the larger deployment scenario of more than 18,000 MW of WEC facilities, along with a 60% device local share (Case 2B), results in almost \$23 billion of construction-phase gross economic activity and \$1.4 billion total operations phase economic activity by 2045. Finally, assuming that Oregon-based suppliers export a volume of devices equal to 25% of combined Washington and California installations (Case 2C), results in an additional \$12 billion in construction-phase economic activity over the study period.

The impacts noted above include only the portion of transactions that take place in Oregon. For example, equipment and components that were purchased from other states or other countries are treated as monetary leakages and are not included in these estimates. Case 1A assumes that 13,000 MW of WEC installations represent \$17 billion<sup>10</sup> in investment, which supports over \$8 billion in state-level economic activity. This \$8 billion in economic activity is comprised of approximately \$0.6 billion in on-site project labor, \$5.8 billion in construction materials and supply chain equipment, and \$1.5 billion in induced activities during the construction period (Figure 3-2).

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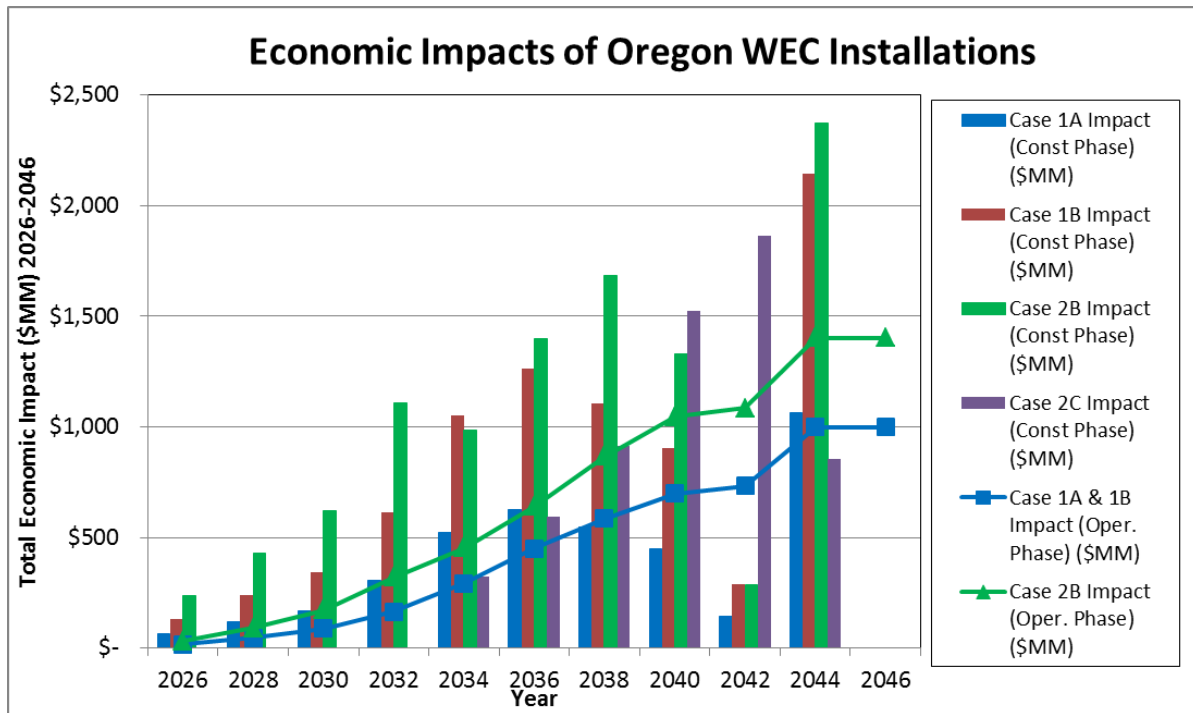
<sup>10</sup> 2012 U.S. dollars





**Figure 3-2. Estimated local spending supported by 13,000 MW of WEC facilities in Oregon during project construction (assuming 20% device local share)**

Figure 3-3 shows the impacts of each case throughout the analysis period. The figure goes two years beyond the end of the analysis period to show the operational period impacts of the WEC facilities installed during the final 2-year installation cycle (2044–2045). As shown in Figure 3-3, construction-phase impacts vary over time depending on the amount of WEC capacity installed in each period. Operation phase impacts grow over time as the cumulative WEC capacity increases.



**Figure 3-3. Estimated total economic impacts from WEC deployment in Oregon throughout the analysis period**

## 3.2 Employment Impacts

### 3.2.1 Construction Jobs

During the construction phase, construction workers, engineers, surveyors, WEC installers, electrical contractors, administrative employees, and managers who live in the project location boost local economic activity. Local workers may be employed directly at the new WEC facility, depending on the talent pool and skill set in the area. Other workers from outside the state may settle within the state. Another category of workers reside out of state and only live within the state during the construction phase, moving on when construction is complete. Workers who reside in-state spend their earnings on mortgage payments, insurance, childcare, education, utilities, tax payments, family entertainment and recreation, clothing, and so on. Workers from out of state generate a different set of economic impacts. These temporary workers support a smaller ripple effect in the state economy because most of their earnings are spent outside of the state, with a smaller portion circulating through the Oregon economy. Most of their impacts are limited to spending on lodging, food, beverages, and transportation, which is often subsidized by the construction company. Out-of-state workers' earnings were not included in this analysis.<sup>11</sup>

The number of employees building a WEC facility depends on the construction stage of the project. For example, the peak construction stage may require a significantly higher number of workers than the initial and final stages. Figure 3-4 shows the year-by-year job impacts for the four cases.

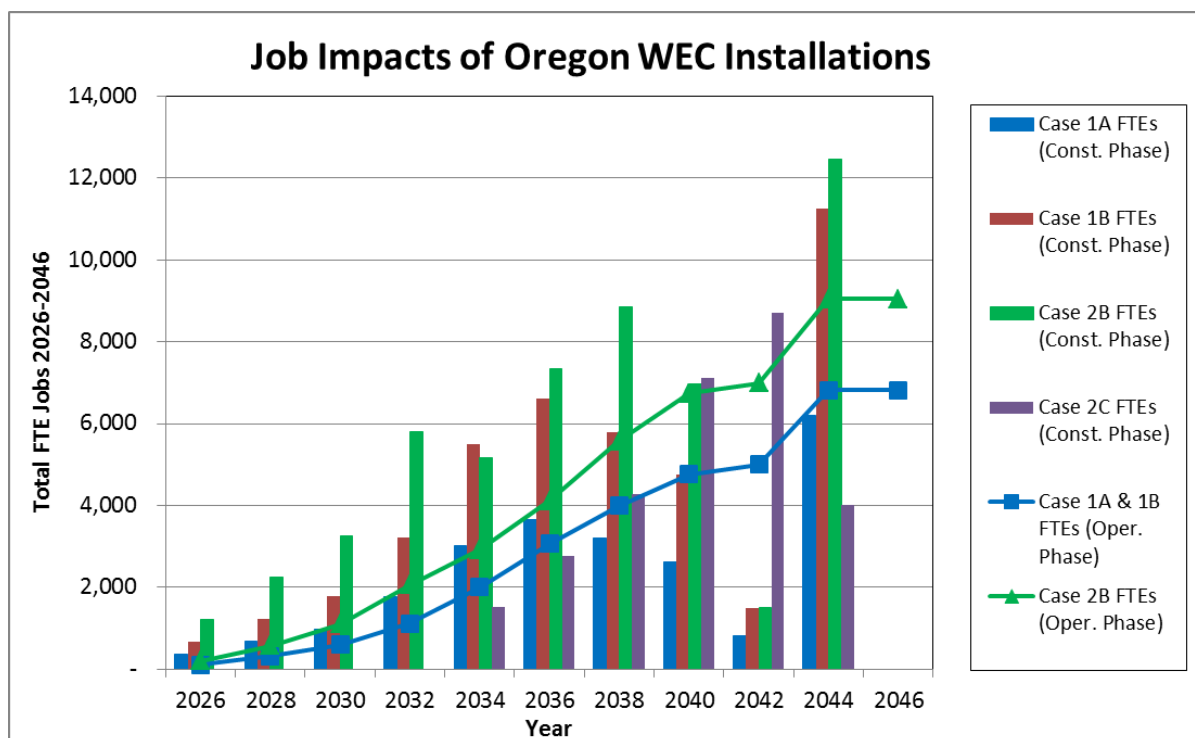


Figure 3-4. Estimated annual employment impacts from WEC deployment in Oregon

<sup>11</sup>By not including earnings from out-of-state workers in the analysis, we minimize the risk of overestimating the impacts in Oregon.

### 3.2.2 Operation and Maintenance Jobs

Over the WEC facility's anticipated 20- to 30-year operating life, long-term employees operate and maintain the facility by replacing components, troubleshooting electrical and mechanical malfunctions, repairing the hydraulic system, conducting diving operations, performing remotely operated vehicle operations, and conducting vessel operations. The analysis assumes that the majority of these positions are filled by Oregonians or by people who relocate to Oregon.

According to the analysis, large-scale WEC deployment in Oregon would result in 6,800 (Cases 1A and 1B) to 9,000 (Case 2B) ongoing jobs by the time 13,000 MW or 18,000 MW is operational (respectively).<sup>12</sup> Of these ongoing jobs, approximately 2,400–2,800 would be on-site positions; 3,100–4,400 would be equipment and supply chain sector jobs; and 1,300–1,900 would be positions in other sectors (e.g., restaurants, hotels, and retail stores) resulting from the induced activity.

### 3.3 State Lease Revenue

Under the assumptions described in Section 2.2.2, 13,000 MW of WEC installations would yield \$7.4 million annually to the government of the State of Oregon and 18,000 MW of WEC installations will give \$10 million annually to the state government. Revenue from leases is often used to fund and improve a state's infrastructure and public services.

## 4 Oregon Manufacturing Sensitivity Analysis

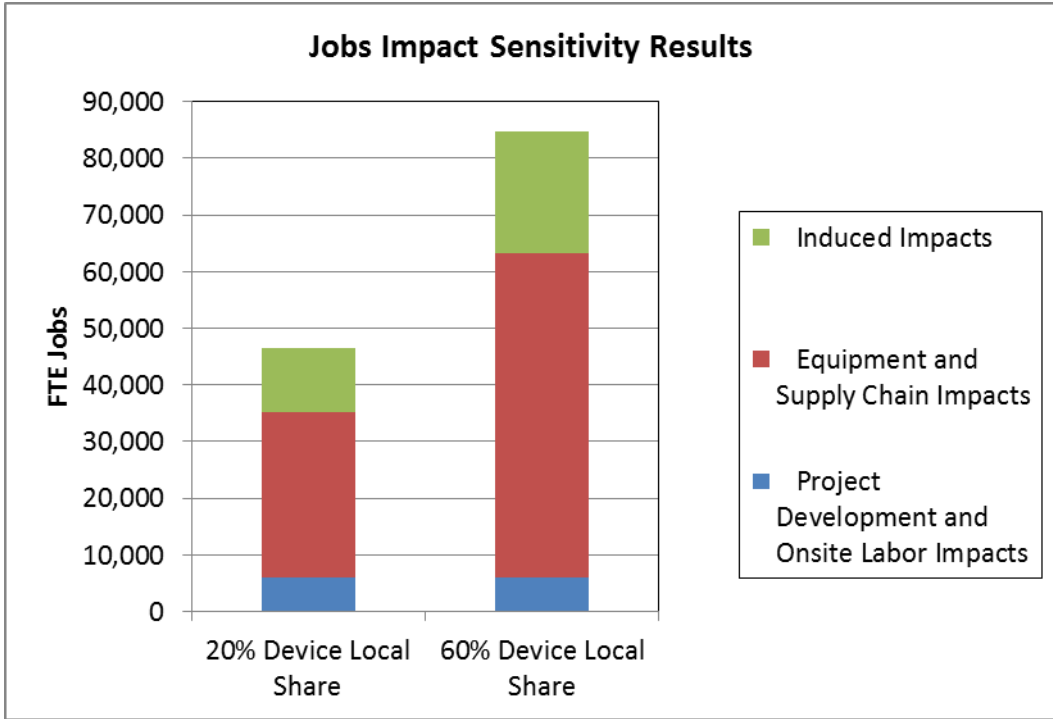
Economic development impacts depend, to a great degree, on the extent to which goods and services are acquired at the local level. WEC device and component manufacturing is anticipated to constitute 70% of the total construction cost of a WEC installation, thereby offering the largest potential source of economic development benefits at the state level. Because of this, Oregon is actively seeking to establish a WEC supply chain to maximize the economic benefits of its significant wave energy resource.<sup>13</sup>

To examine the effects of in-state manufacturing, this study includes a sensitivity analysis that investigates different values for the device local share. Case 1A assumes a 20% value for the device local share, whereas Case 1B assumes a 60% value for the device local share.

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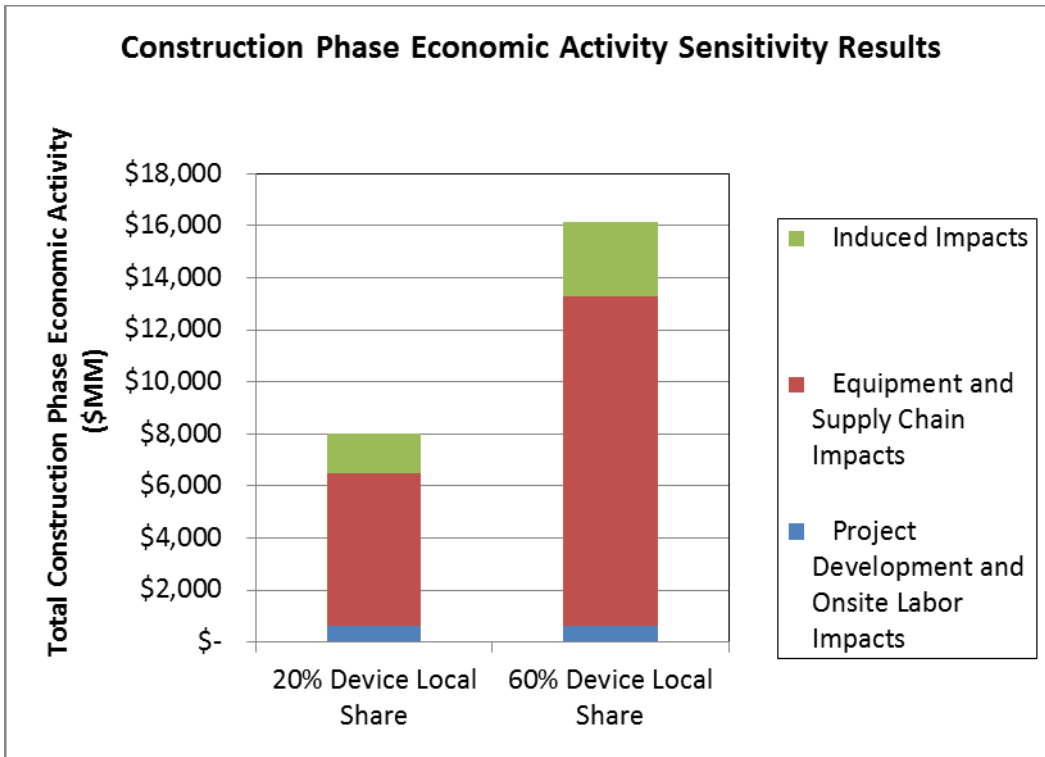
<sup>12</sup> Unlike the construction period, in which temporary workers are hired, during the operation and maintenance period, permanent workers are hired at the state level. Thus, the number of jobs reported during this period remains constant for every year that the WEC facility is operating. In other words, 13,000 MW of wind project development in Oregon would support 6,800 local jobs every year that the WEC facilities are in operation— approximately 20 years or the life of the project.

<sup>13</sup> <http://oregonwave.org/about/>



**Figure 4-1. Manufacturing scenarios and associated job impacts during construction comparing WEC devices with 20% (1A) and 60% (1B) local components**

Figure 4-1 shows the dramatic impact of the device local share on jobs: 13,000 MW of WEC facilities would support roughly 5,900 project development and on-site construction-phase FTE jobs. Figure 4-2, showing construction-phase economic activity for the two scenarios, again shows the supply chain economic activity dwarfing the economic activity related to developing and installing the projects. Establishing an in-state supply chain that captures even a modest portion of WEC installations will dramatically increase the economic impact of large-scale WEC deployment.



**Figure 4-2. Manufacturing scenarios and associated economic impacts during the construction phase with 20% and 60% local share**

## 5 Conclusion

Assuming technological advances and cost reductions in wave energy conversion, large-scale WEC deployment could have a significant impact on Oregon's economy. Over the 20-year analysis period, the ambitious deployment goal of 13,000 MW of WEC facilities (Case 1A) would support over 46,000 construction-phase FTE jobs and 6,800 ongoing jobs at the 13,000-MW deployment level. Gross economic activity for this case totals \$8 billion during the construction phase, \$1 billion by 2045 during the operations phase, and \$1 billion annually after the analysis period. The economic impacts could be even greater if in-state manufacturers capture a larger portion of the Oregon market (Case 1B), there are more installations (Case 2B), or Oregon-based manufacturers capture a portion of the WEC market outside of Oregon (Case 2C).

The analysis shows that WEC device manufacturing appears to be the leading economic development driver in Oregon's potential wave energy industry. The scenario examined here has the potential to support significantly more jobs and associated economic impacts compared to other WEC activities. Specifically, for Case 1A, where in-state manufacturers capture 20% of the state market, the estimated supply chain jobs dwarf the jobs that are directly involved in developing and installing the facilities. Development of a local manufacturing base, as well as use of local labor and materials, could greatly enhance the economic impacts of WEC technology deployment and provide further opportunities for economic diversification and growth. As stated above, this NREL analysis assumed improvements in technology and in the cost of WEC devices. Without these, such high deployment of this generation technology would not be possible.

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## Appendix

Table A-1 shows the jobs in each JEDI category for each year of the scenario. The jobs listed during operating years are not cumulative, so to reach the total number of O&M jobs, the jobs from each year must be summed. For example, in 2026, there are 99 MW of WEC devices installed, and an estimated 111 Oregon jobs to operate and maintain that fleet. Two years later, when there are 199 MW installed, Table A-1 shows 201 jobs. To reach the total O&M jobs supported by projects installed in 2026-2028, we add operating year totals to get 312 Oregon-based operations and maintenance jobs that are ongoing, so they will exist over the life of the energy generation system. This same method of reporting is used in the following tables for operations-period jobs.

**Table A-1. Case 1A Results – FTE Jobs Based on Annual Installations**

<b>JOBS</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	94	171	249	446	765
Construction and Installation Labor	54	97	140	250	428
Construction and Installation Related Services	40	74	109	196	338
Equipment and Supply Chain Impacts	466	847	1,235	2,213	3,802
Induced Impacts	185	335	483	864	1,480
Total Impacts	745	1,353	1,967	3,522	6,047
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	40	72	104	184	315
Local Revenue and Supply Chain Impacts	50	90	130	231	396
Induced Impacts	21	39	56	100	171
<b>JOBS</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	923	808	662	210	1,572
Construction and Installation Labor	514	450	368	117	873
Construction and Installation Related Services	408	358	294	93	699
Equipment and Supply Chain Impacts	4,584	4,015	3,291	1,044	7,815
Induced Impacts	1,780	1,557	1,274	404	3,022
Total Impacts	7,287	6,380	5,228	1,658	12,409
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	381	333	273	86	648
Local Revenue and Supply Chain Impacts	478	417	343	109	814
Induced Impacts	207	181	149	47	354

**Table A-2. Case 1A Results – Earnings Based on Annual Installations**

<b>Earnings [\$MM (2012)]</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 7.15	\$ 12.38	\$ 15.85	\$ 27.53	\$ 45.72
Construction and Installation Labor	\$ 4.21	\$ 7.02	\$ 7.91	\$ 13.26	\$ 21.13
Construction and Installation Related Services	\$ 2.93	\$ 5.37	\$ 7.94	\$ 14.27	\$ 24.60
Equipment and Supply Chain Impacts	\$ 27.75	\$ 50.38	\$ 73.18	\$ 130.97	\$ 224.80
Induced Impacts	\$ 7.89	\$ 14.28	\$ 20.58	\$ 36.77	\$ 62.99
<b>Total Impacts</b>	<b>\$ 42.79</b>	<b>\$ 77.05</b>	<b>\$ 109.60</b>	<b>\$ 195.27</b>	<b>\$ 333.52</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 2.11	\$ 3.80	\$ 5.47	\$ 9.71	\$ 16.64
Local Revenue and Supply Chain Impacts	\$ 2.94	\$ 5.30	\$ 7.63	\$ 13.55	\$ 23.21
Induced Impacts	\$ 0.91	\$ 1.65	\$ 2.39	\$ 4.24	\$ 7.28
<b>Earnings [\$MM (2012)]</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 53.63	\$ 45.98	\$ 36.98	\$ 11.62	\$ 86.21
Construction and Installation Labor	\$ 23.90	\$ 19.88	\$ 15.56	\$ 4.82	\$ 35.25
Construction and Installation Related Services	\$ 29.73	\$ 26.10	\$ 21.42	\$ 6.80	\$ 50.96
Equipment and Supply Chain Impacts	\$ 270.84	\$ 237.11	\$ 194.24	\$ 61.59	\$ 461.04
Induced Impacts	\$ 75.78	\$ 66.27	\$ 54.24	\$ 17.19	\$ 128.62
<b>Total Impacts</b>	<b>\$ 400.25</b>	<b>\$ 349.37</b>	<b>\$ 285.47</b>	<b>\$ 90.40</b>	<b>\$ 675.87</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 20.11	\$ 17.54	\$ 14.40	\$ 4.56	\$ 34.17
Local Revenue and Supply Chain Impacts	\$ 28.06	\$ 24.49	\$ 20.11	\$ 6.38	\$ 47.72
Induced Impacts	\$ 8.82	\$ 7.71	\$ 6.34	\$ 2.01	\$ 15.08

**Table A-3. Case 1A Results – Total Economic Impacts Based on Annual Installations**

<b>Output [\$MM (2012)]</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 11.76	\$ 20.79	\$ 28.19	\$ 49.67	\$ 83.81
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	\$ 94.15	\$ 170.79	\$ 247.49	\$ 442.73	\$ 759.51
Induced Impacts	\$ 24.85	\$ 44.99	\$ 64.83	\$ 115.84	\$ 198.46
Total Impacts	\$ 130.76	\$ 236.57	\$ 340.51	\$ 608.24	\$ 1,041.78
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 2.11	\$ 3.80	\$ 5.47	\$ 9.71	\$ 16.64
Local Revenue and Supply Chain Impacts	\$ 11.35	\$ 20.47	\$ 29.45	\$ 52.28	\$ 89.57
Induced Impacts	\$ 2.88	\$ 5.20	\$ 7.52	\$ 13.37	\$ 22.95
<b>Output [\$MM (2012)]</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 99.60	\$ 86.28	\$ 70.04	\$ 22.11	\$ 164.76
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	\$ 914.66	\$ 800.52	\$ 655.61	\$ 207.85	\$ 1,555.69
Induced Impacts	\$ 238.75	\$ 208.80	\$ 170.88	\$ 54.16	\$ 405.22
Total Impacts	\$ 1,253.01	\$ 1,095.60	\$ 896.53	\$ 284.11	\$ 2,125.67
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 20.11	\$ 17.54	\$ 14.40	\$ 4.56	\$ 34.17
Local Revenue and Supply Chain Impacts	\$ 108.28	\$ 94.48	\$ 77.57	\$ 24.60	\$ 184.12
Induced Impacts	\$ 27.80	\$ 24.30	\$ 19.98	\$ 6.34	\$ 47.51

**Table A-4. Case 1B Results – FTE Jobs Based on Annual Installations**

<b>JOBS</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	94	171	249	446	765
Construction and Installation Labor	54	97	140	250	428
Construction and Installation Related Services	40	74	109	196	338
Equipment and Supply Chain Impacts	923	1,674	2,426	4,339	7,443
Induced Impacts	350	633	912	1,629	2,790
<b>Total Impacts</b>	<b>1,366</b>	<b>2,478</b>	<b>3,586</b>	<b>6,413</b>	<b>10,999</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	40	72	104	184	315
Local Revenue and Supply Chain Impacts	50	90	130	231	396
Induced Impacts	21	39	56	100	171
<b>JOBS</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	923	808	662	210	1,572
Construction and Installation Labor	514	450	368	117	873
Construction and Installation Related Services	408	358	294	93	699
Equipment and Supply Chain Impacts	8,964	7,845	6,425	2,037	15,246
Induced Impacts	3,356	2,935	2,402	761	5,695
<b>Total Impacts</b>	<b>13,242</b>	<b>11,588</b>	<b>9,489</b>	<b>3,008</b>	<b>22,513</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	381	333	273	86	648
Local Revenue and Supply Chain Impacts	478	417	343	109	814
Induced Impacts	207	181	149	47	354

**Table A-5. Case 1B Results – Earnings Based on Annual Installations**

<b>Earnings [\$MM (2012)]</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 7.15	\$ 12.38	\$ 15.85	\$ 27.53	\$ 45.72
Construction and Installation Labor	\$ 4.21	\$ 7.02	\$ 7.91	\$ 13.26	\$ 21.13
Construction and Installation Related Services	\$ 2.93	\$ 5.37	\$ 7.94	\$ 14.27	\$ 24.60
Equipment and Supply Chain Impacts	\$ 56.31	\$ 102.05	\$ 147.55	\$ 263.81	\$ 452.33
Induced Impacts	\$ 14.89	\$ 26.94	\$ 38.80	\$ 69.32	\$ 118.75
<b>Total Impacts</b>	<b>\$ 78.34</b>	<b>\$ 141.37</b>	<b>\$ 202.20</b>	<b>\$ 360.67</b>	<b>\$ 616.81</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 2.11	\$ 3.80	\$ 5.47	\$ 9.71	\$ 16.64
Local Revenue and Supply Chain Impacts	\$ 2.94	\$ 5.30	\$ 7.63	\$ 13.55	\$ 23.21
Induced Impacts	\$ 0.91	\$ 1.65	\$ 2.39	\$ 4.24	\$ 7.28
<b>Earnings [\$MM (2012)]</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 53.63	\$ 45.98	\$ 36.98	\$ 11.62	\$ 86.21
Construction and Installation Labor	\$ 23.90	\$ 19.88	\$ 15.56	\$ 4.82	\$ 35.25
Construction and Installation Related Services	\$ 29.73	\$ 26.10	\$ 21.42	\$ 6.80	\$ 50.96
Equipment and Supply Chain Impacts	\$ 544.50	\$ 476.40	\$ 390.05	\$ 123.64	\$ 925.30
Induced Impacts	\$ 142.85	\$ 124.91	\$ 102.22	\$ 32.40	\$ 242.39
<b>Total Impacts</b>	<b>\$ 740.98</b>	<b>\$ 647.29</b>	<b>\$ 529.26</b>	<b>\$ 167.66</b>	<b>\$ 1,253.91</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 20.11	\$ 17.54	\$ 14.40	\$ 4.56	\$ 34.17
Local Revenue and Supply Chain Impacts	\$ 28.06	\$ 24.49	\$ 20.11	\$ 6.38	\$ 47.72
Induced Impacts	\$ 8.82	\$ 7.71	\$ 6.34	\$ 2.01	\$ 15.08

**Table A-6. Case 1B Results – Total Economic Impacts Based on Annual Installations**

<b>Output [\$MM (2012)]</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 11.76	\$ 20.79	\$ 28.19	\$ 49.67	\$ 83.81
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	\$ 204.96	\$ 371.25	\$ 536.05	\$ 958.16	\$ 1,642.33
Induced Impacts	\$ 46.91	\$ 84.88	\$ 122.25	\$ 218.40	\$ 374.14
Total Impacts	\$ 263.63	\$ 476.93	\$ 686.49	\$ 1,226.23	\$ 2,100.28
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 2.11	\$ 3.80	\$ 5.47	\$ 9.71	\$ 16.64
Local Revenue and Supply Chain Impacts	\$ 11.35	\$ 20.47	\$ 29.45	\$ 52.28	\$ 89.57
Induced Impacts	\$ 2.88	\$ 5.20	\$ 7.52	\$ 13.37	\$ 22.95
<b>Output [\$MM (2012)]</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 99.60	\$ 86.28	\$ 70.04	\$ 22.11	\$ 164.76
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	\$ 1,976.49	\$ 1,728.94	\$ 1,415.34	\$ 448.62	\$ 3,357.02
Induced Impacts	\$ 450.05	\$ 393.55	\$ 322.07	\$ 102.07	\$ 763.68
Total Impacts	\$ 2,526.13	\$ 2,208.77	\$ 1,807.45	\$ 572.79	\$ 4,285.46
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 20.11	\$ 17.54	\$ 14.40	\$ 4.56	\$ 34.17
Local Revenue and Supply Chain Impacts	\$ 108.28	\$ 94.48	\$ 77.57	\$ 24.60	\$ 184.12
Induced Impacts	\$ 27.80	\$ 24.30	\$ 19.98	\$ 6.34	\$ 47.51

**Table A-7. Case 2B Results – FTE Jobs Based on Annual Installations**

<b>JOBS</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	169	309	453	808	719
Construction and Installation Labor	96	175	254	452	401
Construction and Installation Related Services	73	134	199	357	318
Equipment and Supply Chain Impacts	1,657	3,023	4,407	7,861	6,990
Induced Impacts	627	1,140	1,654	2,946	2,616
<b>Total Impacts</b>	<b>2,453</b>	<b>4,472</b>	<b>6,514</b>	<b>11,615</b>	<b>10,326</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	62	114	162	294	260
Local Revenue and Supply Chain Impacts	100	182	259	469	416
Induced Impacts	41	75	108	196	174
<b>JOBS</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	1,025	1,236	976	210	1,743
Construction and Installation Labor	570	687	541	116	966
Construction and Installation Related Services	455	549	434	93	777
Equipment and Supply Chain Impacts	9,948	11,990	9,457	2,032	16,892
Induced Impacts	3,720	4,480	3,531	758	6,304
<b>Total Impacts</b>	<b>14,693</b>	<b>17,706</b>	<b>13,964</b>	<b>3,000</b>	<b>24,940</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	369	445	357	75	626
Local Revenue and Supply Chain Impacts	589	712	572	121	1,002
Induced Impacts	247	299	240	51	422

**Table A-8. Case 2B Results – Earnings Based on Annual Installations**

<b>Earnings [\$MM (2012)]</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 12.26	\$ 21.42	\$ 27.94	\$ 48.17	\$ 41.64
Construction and Installation Labor	\$ 6.95	\$ 11.66	\$ 13.44	\$ 22.19	\$ 18.44
Construction and Installation Related Services	\$ 5.31	\$ 9.76	\$ 14.50	\$ 25.98	\$ 23.20
Equipment and Supply Chain Impacts	\$ 101.03	\$ 184.13	\$ 267.96	\$ 477.65	\$ 424.57
Induced Impacts	\$ 26.67	\$ 48.54	\$ 70.41	\$ 125.39	\$ 111.37
<b>Total Impacts</b>	<b>\$ 139.96</b>	<b>\$ 254.09</b>	<b>\$ 366.31</b>	<b>\$ 651.22</b>	<b>\$ 577.58</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 3.30	\$ 6.00	\$ 8.56	\$ 15.49	\$ 13.72
Local Revenue and Supply Chain Impacts	\$ 5.88	\$ 10.70	\$ 15.26	\$ 27.65	\$ 24.49
Induced Impacts	\$ 1.76	\$ 3.21	\$ 4.60	\$ 8.34	\$ 7.40
<b>Earnings [\$MM (2012)]</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 57.82	\$ 68.42	\$ 53.04	\$ 11.29	\$ 93.45
Construction and Installation Labor	\$ 24.68	\$ 28.39	\$ 21.39	\$ 4.48	\$ 36.83
Construction and Installation Related Services	\$ 33.13	\$ 40.03	\$ 31.65	\$ 6.81	\$ 56.63
Equipment and Supply Chain Impacts	\$ 604.03	\$ 727.79	\$ 573.93	\$ 123.27	\$ 1,024.91
Induced Impacts	\$ 158.34	\$ 190.70	\$ 150.31	\$ 32.28	\$ 268.34
<b>Total Impacts</b>	<b>\$ 820.19</b>	<b>\$ 986.90</b>	<b>\$ 777.27</b>	<b>\$ 166.83</b>	<b>\$ 1,386.70</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 19.45	\$ 23.50	\$ 18.86	\$ 3.98	\$ 33.05
Local Revenue and Supply Chain Impacts	\$ 34.72	\$ 41.96	\$ 33.69	\$ 7.11	\$ 59.03
Induced Impacts	\$ 10.51	\$ 12.72	\$ 10.23	\$ 2.16	\$ 17.96



**Table A-9. Case 2B Results – Total Economic Impacts Based on Annual Installations**

<b>Output [\$MM (2012)]</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 20.59	\$ 36.68	\$ 50.42	\$ 88.40	\$ 77.50
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	\$ 367.52	\$ 669.52	\$ 973.22	\$ 1,734.24	\$ 1,541.08
Induced Impacts	\$ 84.03	\$ 152.93	\$ 221.83	\$ 395.06	\$ 350.88
<b>Total Impacts</b>	<b>\$ 472.14</b>	<b>\$ 859.13</b>	<b>\$ 1,245.47</b>	<b>\$ 2,217.69</b>	<b>\$ 1,969.46</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 3.30	\$ 6.00	\$ 8.56	\$ 15.49	\$ 13.72
Local Revenue and Supply Chain Impacts	\$ 22.75	\$ 41.44	\$ 59.09	\$ 107.04	\$ 94.80
Induced Impacts	\$ 5.54	\$ 10.11	\$ 14.48	\$ 26.28	\$ 23.32
<b>Output [\$MM (2012)]</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ 108.96	\$ 130.15	\$ 101.79	\$ 21.77	\$ 180.64
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	\$ 2,191.98	\$ 2,640.65	\$ 2,082.07	\$ 447.15	\$ 3,717.69
Induced Impacts	\$ 498.88	\$ 600.81	\$ 473.58	\$ 101.69	\$ 845.43
<b>Total Impacts</b>	<b>\$ 2,799.82</b>	<b>\$ 3,371.61</b>	<b>\$ 2,657.44</b>	<b>\$ 570.61</b>	<b>\$ 4,743.76</b>
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	\$ 19.45	\$ 23.50	\$ 18.86	\$ 3.98	\$ 33.05
Local Revenue and Supply Chain Impacts	\$ 134.41	\$ 162.41	\$ 130.40	\$ 27.53	\$ 228.50
Induced Impacts	\$ 33.13	\$ 40.09	\$ 32.24	\$ 6.82	\$ 56.60

**Table A-10. Case 2C Results – FTE Jobs, Earnings, and Total Economic Impacts Based on Annual Installations**

<b>JOBS</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	0	0	0	0	0
Construction and Installation Labor	0	0	0	0	0
Construction and Installation Related Services	0	0	0	0	0
Equipment and Supply Chain Impacts	0	0	0	0	2,216
Induced Impacts	0	0	0	0	797
<b>Total Impacts</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>3,013</b>

<b>JOBS</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	0	0	0	0	0
Construction and Installation Labor	0	0	0	0	0
Construction and Installation Related Services	0	0	0	0	0
Equipment and Supply Chain Impacts	4,086	6,300	10,483	12,823	5,888
Induced Impacts	1,470	2,266	3,771	4,613	2,118
<b>Total Impacts</b>	<b>5,556</b>	<b>8,566</b>	<b>14,253</b>	<b>17,436</b>	<b>8,006</b>

<b>Earnings [\$MM (2012)]</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ -	\$ -	\$ -	\$ -	\$ -
Construction and Installation Labor	\$ -	\$ -	\$ -	\$ -	\$ -
Construction and Installation Related Services	\$ -	\$ -	\$ -	\$ -	\$ -
Equipment and Supply Chain Impacts	\$ 0.16	\$ 0.15	\$ 0.11	\$ 0.10	\$ 138.45
Induced Impacts	\$ 0.04	\$ 0.04	\$ 0.03	\$ 0.02	\$ 33.93
<b>Total Impacts</b>	<b>\$ 0.20</b>	<b>\$ 0.18</b>	<b>\$ 0.13</b>	<b>\$ 0.12</b>	<b>\$ 172.38</b>

<b>Earnings [\$MM (2012)]</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ -	\$ -	\$ -	\$ -	\$ -
Construction and Installation Labor	\$ -	\$ -	\$ -	\$ -	\$ -
Construction and Installation Related Services	\$ -	\$ -	\$ -	\$ -	\$ -
Equipment and Supply Chain Impacts	\$ 255.32	\$ 393.61	\$ 654.94	\$ 801.19	\$ 367.86
Induced Impacts	\$ 62.57	\$ 96.46	\$ 160.50	\$ 196.35	\$ 90.15
<b>Total Impacts</b>	<b>\$ 317.89</b>	<b>\$ 490.07</b>	<b>\$ 815.45</b>	<b>\$ 997.54</b>	<b>\$ 458.01</b>

<b>Output [\$MM (2012)]</b>	<b>2026</b>	<b>2028</b>	<b>2030</b>	<b>2032</b>	<b>2034</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ -	\$ -	\$ -	\$ -	\$ -
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	\$ 0.63	\$ 0.57	\$ 0.41	\$ 0.37	\$ 537.18
Induced Impacts	\$ 0.13	\$ 0.11	\$ 0.08	\$ 0.07	\$ 106.90
<b>Total Impacts</b>	<b>\$ 0.76</b>	<b>\$ 0.68</b>	<b>\$ 0.50</b>	<b>\$ 0.44</b>	<b>\$ 644.08</b>

<b>Output [\$MM (2012)]</b>	<b>2036</b>	<b>2038</b>	<b>2040</b>	<b>2042</b>	<b>2044</b>
During construction and installation period					
Project Development and Onsite Labor Impacts	\$ -	\$ -	\$ -	\$ -	\$ -
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	\$ 990.65	\$ 1,527.22	\$ 2,541.20	\$ 3,108.65	\$ 1,427.30
Induced Impacts	\$ 197.13	\$ 303.91	\$ 505.69	\$ 618.61	\$ 284.03
<b>Total Impacts</b>	<b>\$ 1,187.78</b>	<b>\$ 1,831.13</b>	<b>\$ 3,046.88</b>	<b>\$ 3,727.26</b>	<b>\$ 1,711.32</b>