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Jobs and Economic Development Impact (JEDI) Model: Offshore Wind User Reference Guide

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Technical Report
NREL/TP-6A20-58389
June 2013

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Summary

The Jobs and Economic Development Impact (JEDI) models, developed through the National Renewable Energy Laboratory (NREL), are user-friendly tools that estimate the economic impacts of constructing and operating power generation projects for a range of conventional and renewable energy technologies. This user reference guide for the offshore wind model was developed to help users understand and apply the model. The guide presents information on the model's underlying methodology, as well as the parameters and references used to develop the cost data contained in the model. This guide also contains basic instruction on model add-in features and model operation, along with a discussion of how the results should be interpreted.

Based on project-specific inputs from the user, the model estimates job creation, earning, and output (total economic activity) for a given power generation project. This includes the direct, indirect, and induced economic impacts on the local economy associated with its construction and operation phases. Project cost and local content data used in the model were gathered from existing offshore wind projects, a literature review, and conversations with industry professionals. Local direct, indirect, and induced jobs and economic impacts are estimated using economic multipliers derived from Impact Analysis for Planning software. By determining the regional economic impacts and job creation for a proposed power facility, the JEDI offshore wind model can be used to answer questions about the impacts of offshore wind power in a given state, region, or local community.

Acronyms and Abbreviations

FTE	full-time equivalent
IMPLAN	Impact Analysis for Planning model
JEDI	Jobs and Economic Development Impact model
kW_e	kilowatt electric
MW	megawatt
MW_e	megawatt electric
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance

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1 Introduction

The Offshore Wind Jobs and Economic Development Impact (JEDI) model is designed to demonstrate the potential economic impacts associated with developing and operating offshore wind power plants in the United States. The primary goal in developing this model is to furnish a tool for offshore wind developers, government officials, decision makers, parties with an interest in renewable energy, and other potential users to identify the possible regional, state, or local economic impacts associated with constructing and operating offshore wind power systems. The model allows users to quickly analyze the economic impacts and job creation potential of offshore wind technologies. Economic impacts are categorized into project development and on-site labor impacts, turbine and supply chain impacts, and induced impacts, as defined in the next section of this report.

Strong emphasis was placed on designing the model in a user-friendly format that can be easily modified, reflecting different levels of project-specific information and user knowledge. This allows inexperienced spreadsheet users, those unfamiliar with economic impact analysis, and more experienced and knowledgeable users to access the tool.

The National Renewable Energy Laboratory (NREL) developed the offshore wind JEDI model with data collection assistance from the Navigant Consortium. The Navigant Consortium is the collective team funded by the U.S. Department of Energy to develop an *Offshore Wind Annual Market Assessment* for the 3-year period from 2012 to 2014) and a one-time *Offshore Wind Supply Chain Study* (2012). Members of the Navigant Consortium include the American Wind Energy Association, the Great Lakes Wind Collaborative, Green Giraffe Energy Bankers, Navigant Consulting Inc., NREL, Ocean and Coastal Consultants, and TetraTech. The consortium is led by Navigant Consulting.

This document describes the general use of the model, explains how to interpret output summaries, and outlines technical assumptions and cost models contained within the model. In general, the model relies on historical cost data from Europe and cost estimates for systems in the United States to develop default values. These data introduce uncertainty because there are many variables associated with offshore development. In addition, when the model was released, there were no U.S. offshore wind projects in operation. As a result, model data represent the best information available to NREL at the time of the model's development and publication. For additional questions about the JEDI models or model updates, please see http://www.nrel.gov/analysis/jedi/.

2 Model Overview

The model offers users the capability to analyze offshore wind projects in the United States. Given basic information about an offshore wind project (minimally, the state in which it is to be located, the year of construction, and the nameplate capacity of the system), users can estimate project capital and operating expenditures as well as the number of jobs, earnings, and economic activity that will accrue to the region of analysis.[1] To evaluate these impacts, input-output analysis, also commonly referred to as multiplier analysis, is used.

Input-output models were originally developed to trace supply linkages in the economy. For example, they show how purchases of offshore wind plant equipment not only affect equipment manufacturers but also the metal industries and other businesses supplying inputs to those manufacturers.

The impacts that are ultimately generated by expenditures for offshore wind systems depend on the extent to which those expenditures are spent locally and the structure of the local economy. Consistent with the local spending pattern and the state-specific economic structure, different expenditures support a different level of employment, income, and output.

Input-output analysis can be thought of as a method for evaluating and summing the gross impacts of a series of effects generated by an expenditure. To determine the total effect of developing an offshore wind project in the form of intuitive results, three separate impacts are examined for each project scenario. These impacts are labeled in the offshore wind JEDI model as follows:

1. **Project development and on-site labor impacts** refer to the on-site or immediate effects created by project expenditures. In constructing an offshore wind power plant, it refers to the on-site jobs of the contractors and crews hired to construct the plant.

2. **Turbine and supply chain impacts** refer to the increase in economic activity that occurs when a contractor, vendor, or manufacturer receives payment for goods or services and in turn is able pay others who support their businesses. For example, this impact includes the banker who finances the contractor who pays the foundation workers and the steel mills and electrical manufacturers along the supply chain that furnishes the necessary materials. This category also includes the manufacturing of offshore wind plant equipment (e.g. offshore wind towers, blades, and nacelles, among others) that are used in the construction of the turbine.

3. **Induced impacts** refer to the effects driven by spending of household earnings from project development and on-site labor impacts as well as turbine and supply chain impacts. Induced results are often associated with increased business at local restaurants, hotels, and retail establishments but also include childcare providers,

[1] Earnings (employee compensation) typically consist of wages, salaries, and benefits such as employer-provided health insurance and retirement. Earnings are not limited to this definition, however. Payments to proprietors (self-employed individuals), for example, might not come in the form of wages or a salary but are still considered earnings if the payments are compensation for work performed.

service providers, and any other entity affected by increased economic activity and spending occurring at the first two tiers.

The sum of these three categories yields the total economic effect that results from a single expenditure. To accomplish this analysis at the state level, state-specific type I and type II multipliers and personal consumption expenditure patterns are used to derive the results.[2] These state-by-state multipliers for employment, wage and salary income and output (economic activity), and personal expenditure patterns were derived from the Impact Analysis for Planning (IMPLAN) Professional Model Version 3.0 using state data.[3] The changes in expenditures from investments in developing offshore wind power plants are matched with their appropriate multipliers for each sector affected by the change in expenditure.

JEDI reports all job figures as full-time equivalent (FTE). One FTE is the equivalent of one person working full time for 1 year (2,080 hours). Two people working half time for 1 year, for example, are the same as one FTE.

JEDI results are calculated and reported for two phases: construction and operating. Construction phase results are cumulative totals over the entire construction period; operating phase results are annual over the operating life of the project. JEDI does not assume a set life span, nor does it consider potential impacts from a project's decommissioning.

Construction phase results are not affected by the duration of the construction period. The results for a project that takes 1 year will be the same as a project that takes 5 years, assuming all costs are consistent. If desired, annual averages can be obtained by dividing construction results by the number of years it takes to build the wind farm. For example, if JEDI produces an estimate of 100 FTE construction jobs supported by a project that takes 2 years to build, the estimate can also be reported as an average of 50 jobs per year (100 / 2 = 50) during the 2-year construction period.

To analyze the local jobs and other economic impacts associated with wind farm worker earnings, the JEDI model allocates operations and maintenance (O&M) labor income according to IMPLAN personal consumption expenditure patterns. These expenditures reflect purchases made by an average household within the region of analysis. For example, for each dollar of earnings a worker receives, a portion is spent on food, housing, insurance, and other necessary or discretionary goods or services. The model allocates this spending to those industries that produce the goods or services and then analyzes the associated direct, indirect, and induced impacts.

JEDI contains default values representative of a "typical" offshore wind project constructed in water with an average depth of 25 meters and no farther than 100 nautical miles from a port. These values allow users with limited knowledge of a specific project or those who simply are

[2] Type I multipliers are used to calculate turbine and supply chain effects and type II multipliers are used to calculate induced effects.

[3] IMPLAN is a social accounting and impact analysis tool developed by the Minnesota IMPLAN Group (see www.IMPLAN.com for more information). The initial version of the offshore wind JEDI model contains multipliers and personal consumption expenditure patterns for 2010, the most current year available when the model was released for public use. NREL updates default multipliers and expenditure patterns approximately every 2 years.

interested in a theoretical scenario to estimate potential economic impacts from a general project. These default values represent a reasonable expenditure pattern for constructing and operating an offshore wind project in the United States. Admittedly, not every project will follow this exact default pattern for expenditures. Resource characteristics, project size, location, financing arrangements, and numerous site-specific factors influence the installation and operating costs.

Similarly, the availability of local resources, including labor and materials, and the availability of locally manufactured components can have a significant effect on the costs and the economic impacts that accrue to the state or local region.

3 Entering Data and Running the Model

The JEDI model is designed for all levels of users. It requires minimal experience with spreadsheets and no background in economic modeling. The model contains instructions for entering data for analysis and informative comments meant to help users understand the type of data required in specific cells. The user can view the comments by pointing the cursor to the red triangle located in the corner of select cells.

User-modified data can be entered and saved with JEDI. These changes can be undone by clicking on Restore Default Values. JEDI defaults and model formulas are protected—project scenario data can be changed but default data cannot.

3.1 Getting Started

The offshore wind JEDI model is based on Microsoft Excel. To begin using it, simply open the offshore wind JEDI Excel file. The JEDI model opens to the Start tab, which briefly explains what the model is used for and outlines the steps for completing an economic impact analysis (see Figure 1).To learn more about the model version and history, click on the About JEDI tab. To begin a JEDI analysis, either click on the Start tab and click on Start Economic Impact Analysis or go to the Project Data tab.

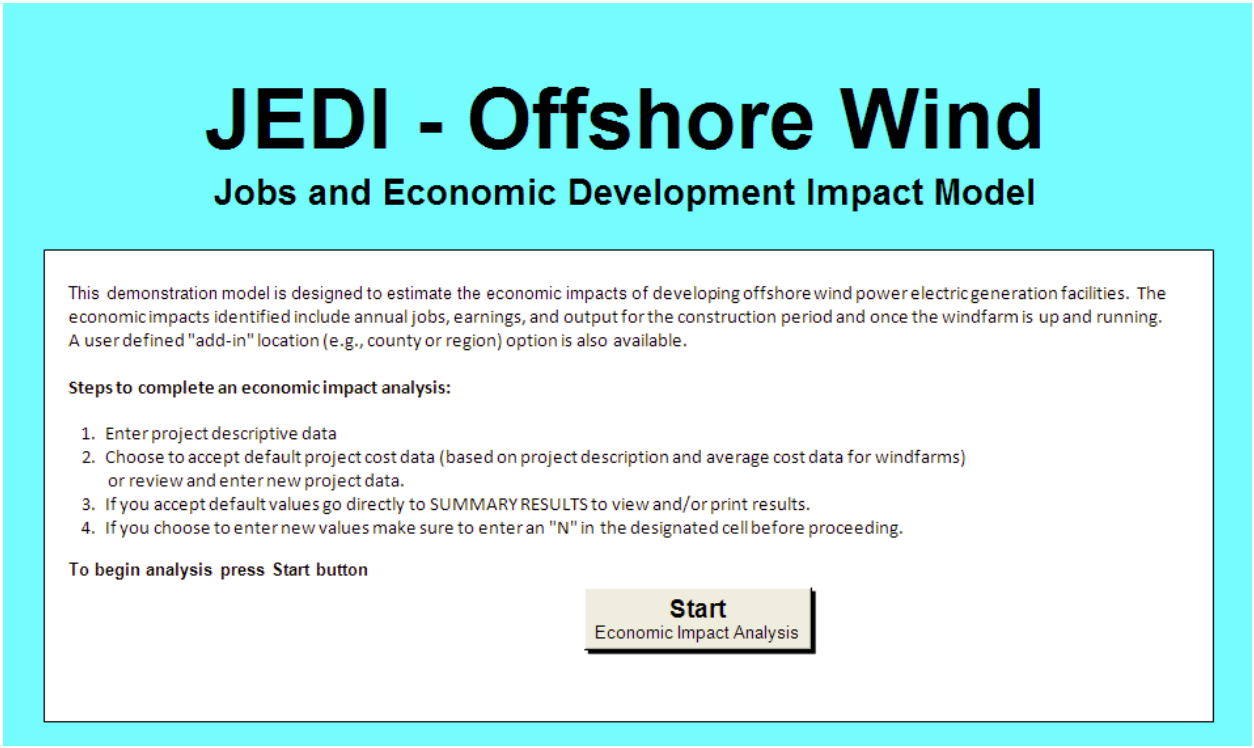

Figure 1. JEDI model Start page

3.2 Entering Data into the Model

Two modeling options are employed to accommodate a broad user base with a wide range of knowledge about offshore wind projects. A simple or advanced input option allows a user to choose the number and detail of user inputs that are accessible for the model (see Figure 2).

3.2.1 Simple Input Option

For users with limited experience with offshore wind power plants or economic impact analysis, the simple option requires minimal inputs such as the year in which construction starts, the state or region in which the plant will be located, and the nameplate capacity of the power plant. In addition, the simple input option allows the user to specify the money value (dollar year) of model results. This adjusts metrics reported by JEDI for expected inflation.[4] If the user has additional information about the offshore wind project, such as detail about the turbine size, that can be entered it as well. The simple option uses default project cost data in the analysis. To use the simple input option, choose "Y" (Utilize Project Cost Data default values) in cell B30 on the "Project Data" page.

3.2.2 Advanced Input Option

An advanced model is available for users with more information or knowledge of offshore wind projects. This model allows users to enter project-specific details. The primary differences between the simple model and advanced model options are the user's ability to view and edit detailed model input data. The simple model uses default cost data and does not allow for user changes to any of the detailed default cost data. The advanced model uses the same detailed model input data but allows users to override default inputs for all phases of the offshore wind project and use their own values. To use the advanced input option, choose "N" in cell B30 on the Project Data page.

If advanced input is selected, JEDI does not use the Money Value (Dollar Year) entry. In this case it is assumed that values entered by the model user are already adjusted for inflation.

[4] The inflation index is derived from the U.S. Office of Management and Budget (2012), Table 10.1, Gross Domestic Product and Deflators Used in the Historical Tables 1940–2016. Deflators for 2016–2031 assume an average annual inflation rate of 2.0%.

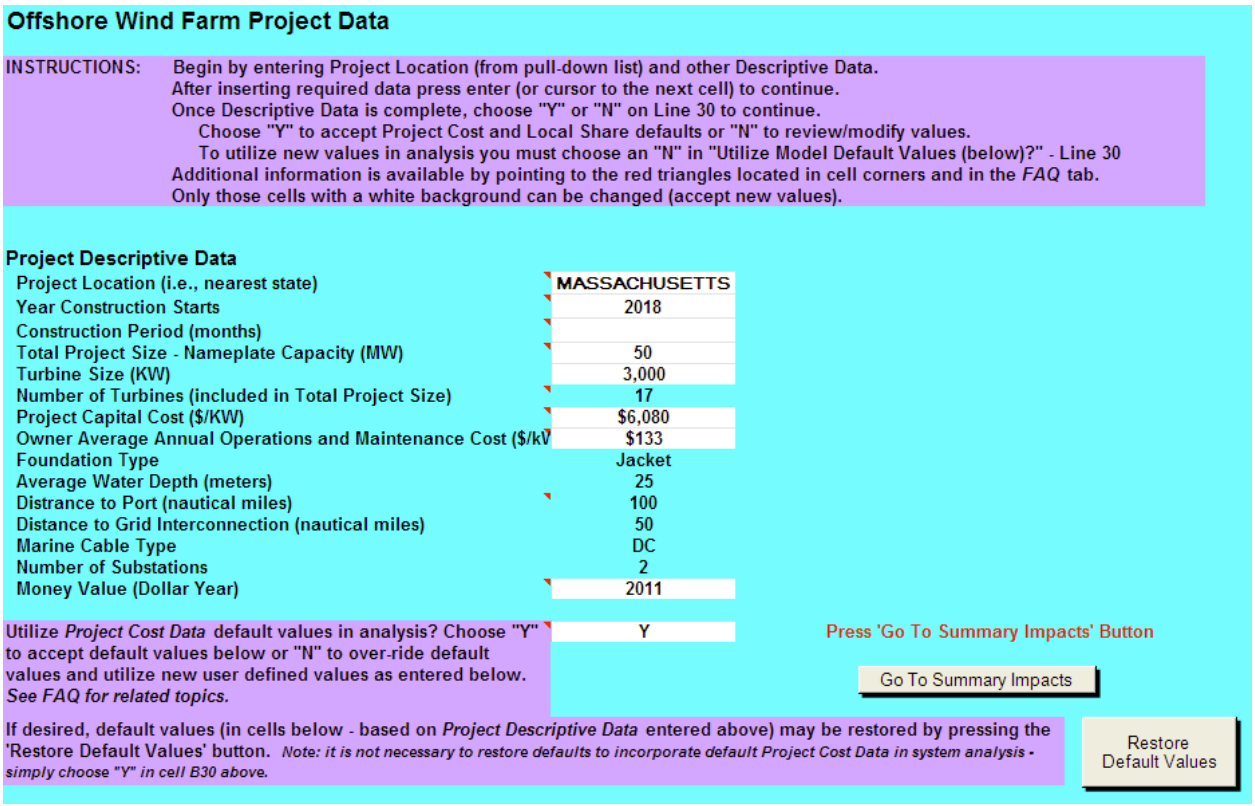

Figure 2. JEDI model Project Data page

Once project descriptive data input is complete, click on the Go To Summary Impacts button or simply navigate to the Summary Results tab. The model estimates the number of jobs and other economic impacts supported throughout the construction/development and annual operating phases. The model only estimates the impacts that accrue to the state or region being analyzed. These economic impact and job creation values are estimates for constructing and operating a hypothetical offshore wind power plant; they should not be interpreted as precise values.

3.3 Viewing and Saving Results

Once the analysis is complete, users have several options for saving the data and results. To print hard copies, click on Print Project Data Summary and Summary Results to print the summary data and results contained on the summary page, or click on Print Detailed Project Data to print a detailed version of all cost and expenditure data used in the analysis. Clicking the Export button exports the data and results to a separate Excel file. To save the entire model (with the user-modified data) for future use or reference, choose Save As from the Excel menu, rename the model, and choose a directory. Users with Excel 2007 or newer should save the file with a macro-enabled ".xlsm" extension because the file uses macros. Changing the name ensures that the original model (with model defaults) is kept intact for future analysis. The option to simply copy and paste any desired cells to another spreadsheet or document is always available.

3.4 Accessing and Viewing Model Work Areas

To help ensure that the JEDI model is as user-friendly as possible, calculations, deflators, and default data are contained within their own worksheets. If desired, these can be viewed (but not

edited) by clicking on the respective worksheet and scrolling to the right. Viewing the worksheets will not affect the operation of the model.

Multipliers, household expenditures, and two calculation work areas specific to offshore wind are also contained within their own worksheets. To adhere to licensing agreements that cover proprietary data, these worksheets are hidden, locked, and cannot be viewed. Multiplier and household expenditure data can be changed; this is covered in Section 5 of this guide.

4 Interpreting the Results

JEDI results contain information to help users better understand the magnitude of the economic impacts associated with the scenario being analyzed. The model provides basic project information to help users identify construction-related spending levels and ongoing O&M expenditures. The model also displays the portion of the spending assumed to occur locally (determined by the Local Share values—default or user-modified—used in the model for each of the expenditures). Similarly, the model displays local spending on debt and equity payments, property taxes, and land lease payments, if applicable.

4.1 Examining Economic Impacts and Jobs

In addition to the basic system information and costs, the model analyzes and reports the local jobs, earnings, and gross output (economic activity) supported by the project for the construction phase and for the ongoing operations phase. For the construction phase, the impacts are broken out by project development and on-site labor impacts, including construction labor and construction-related services, turbine and supply chain impacts, and induced impacts. Operating phase impacts are broken out by on-site, local revenue and supply chain, and induced.

For example, users interested in understanding the potential economic impacts from installing a 50-MW_e offshore wind plant off the coast of Massachusetts, built in 2015, can easily and quickly find the answers by using the JEDI model.

Figure 3 shows the job and economic impact summary for a 50-MW_e offshore wind plant (simple model option) constructed in 2015. By incorporating capacity, capital cost, and O&M cost inputs and accepting the rest of the model defaults, a user can obtain summary results. The project data summary and local economic impacts summary result from the model run are also shown. The results from this estimate show that 316 FTE jobs are supported, generating more than $24 million in earnings and more than $61 million in total economic activity during project development and construction. These results include a total of 83 FTE jobs[5] from project development (40 construction and 42 construction services), 122 from the turbine and supply chain, and 111 from induced impacts. Once the project is producing power, the user finds that 3 full-time O&M jobs are created and sustained for the life of the facility, with another 27 supporting jobs through supply chain and induced impacts, for a total of 30 full-time jobs associated with plant operations.

[5] Because of the allowance of partial FTEs and rounding, total jobs reported may not equal the sum of FTEs listed in subsets of the summary table.

Offshore Wind Farm - Project Data Summary based on model default values

Project Location	MASSACHUSETTS
Year Construction Starts	2015
Construction Period (months)	
Total Project Size - Nameplate Capacity (MW)	50
Turbine Size (KW)	3000
Number of Turbines	17
Project Capital Cost ($/KW)	$6,080
Owners Average Annual Operations and Maintenance Cost ($/kW)	$133
Average Water Depth	25
Distrance to Port (nautical miles)	100
Distance to Grid Interconnection (nalutical miles)	50
Marine Cable Type (AC or DC)	DC
Number of Substations	2
Money Value (Dollar Year)	2011
Installed Project Cost	$310,440,715
Local Spending	$36,977,598
Total Annual Operational Expenses	$37,057,668
Direct Operating and Maintenance Costs	$6,650,000
Local Spending	$3,165,330
Other Annual Costs	$30,407,668
Local Spending	$0
Debt and Equity Payments	$0
Property Taxes	$0

Print Project Data Summary and Summary Results

Print Detailed Project Data

Export All Project Data and Summary Results to a new spreadsheet file

Return to Project Description and Cost Data

Local Economic Impacts - Summary Results

	Jobs	Earnings	Output
During construction period			
Project Development and Onsite Labor Impacts	83	$11.0	$24.6
Construction and Interconnection Labor	40	$5.7	
Construction Related Services	42	$5.4	
Turbine and Supply Chain Impacts	122	$7.4	$20.7
Induced Impacts	111	$5.7	$15.8
Total Impacts	**316**	**$24.2**	**$61.1**
During operating years (annual)			
Onsite Labor Impacts	3	$0.3	$0.3
Local Revenue and Supply Chain Impacts	18	$1.3	$3.9
Induced Impacts	9	$0.5	$1.3
Total Impacts	**30**	**$2.0**	**$5.5**

Notes: Earnings and Output values are millions of dollars in year 2011 dollars. Construction and operating jobs are full-time equivalent for a period of one year (1 FTE = 2,080 hours). Wind farm workers includes field technicians, administration and management. Economic impacts "During operating years" represent impacts that occur from wind farm operations/expenditures. The analysis does not include impacts associated with spending of wind farm "profits" and assumes no tax abatement unless noted. Totals may not add up due to independent rounding. Results are based on model default values.

Note: Because of continuous updates and improvements to the JEDI model, it may not be possible to exactly reproduce the results of this model run.

Figure 3. Project data summary and local economic impacts summary results from offshore wind JEDI run

4.2 Comparing Results Among JEDI Models

Capacity factor and energy generation should be considered when comparing the economic development impacts from different power generation technologies. When comparing results from JEDI models for different power technologies (i.e. solar, wind, or fossil), it is recommended that users compare facilities with equivalent energy generation instead of comparing facilities with a similar nameplate capacity (e.g., compare jobs per kilowatt-hours generated per year, not jobs per kilowatts installed).

4.3 Understanding the Caveats

Several important caveats should be noted:

The intent of the offshore wind JEDI model is to construct a reasonable profile of expenditures (i.e., development services, materials and equipment costs, construction labor, and operating costs) and demonstrate the magnitude of the gross economic impacts that could result,[6] assuming a project is built and operates during the stated period of analysis. Given the unique nature of offshore wind resources and the changing nature of the industry, including expected changes as development activity in the United States increases and offshore wind technologies mature, the analysis is not intended to precisely project expected impacts. Instead, the analysis should be viewed as an estimate of the overall magnitude of the impacts.

JEDI is a static model. As such, it relies on inter-industry relationships and personal consumption patterns existing in the year of the multipliers. The model does not account for shifts in industry inputs or changes in consumption patterns that could result from changes in prices. Model results assume that all inputs—such as industry, materials, labor, and capital, among others—necessary to complete a project will be available. The model assumes that local resources and production and service capabilities are adequate to meet the level of local demand identified in the modeling assumptions. Similarly, the model does not automatically take into account industry productivity improvements that may occur over time or changes that may occur in the construction or operations processes (e.g., production recipe for labor, materials, and service cost ratios) for new offshore wind plants. Should users wish to examine the impacts as the wind industry changes or matures (e.g., lower costs in the future), such inputs must be developed external to the model and incorporated in the requisite model input locations.

The model was not designed to project cash flow or to be used as a cash flow analysis tool. NREL offers financing models and tools that address cash flows in detail.[7]

The analysis assumes that the output from the offshore wind system and the specific terms of a power purchase agreement generate sufficient revenues to accommodate the equity and debt repayment and annual operating expenditures. To the extent that additional revenues (i.e., profits and tax advantages above actual costs) accrue to the project owner, there will be added impacts, but these are not included in JEDI analysis.

JEDI results are gross as opposed to net. JEDI does not incorporate potentially far-reaching impacts that may arise as a result of a project such as greenhouse gas emissions, changes in utility rates, property values, or displaced investment.

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[6] The JEDI models do not estimate the displaced energy or associated jobs, earnings, and output related to existing or planned energy generation resources (e.g., jobs lost in the operation of natural gas or coal plants because of diminished need for electricity production from these plants, given increased generation from wind) or increases or decreases in jobs related to changes in electric utility revenues and consumer energy bills, among other impacts. As a result, the estimates represent gross rather than net impacts.

[7] The Cost of Renewable Spreadsheet Tool (CREST) is available for download at http://financere.nrel.gov/finance/content/crest-model.

5 User Add-in Location Feature

The initial design of the JEDI models provided only for state-level impact analysis. It was apparent, however, that many potential users might wish to perform a similar level of analysis for different levels of geography. To accommodate these users, the User Add-in Location feature allows JEDI to be used with multipliers from sources other than IMPLAN (such as the U.S. Bureau of Economic Analysis).

This feature allows users with the capability to derive or obtain the necessary data to complete analysis for a specific region of interest. There are several necessary inputs. The number of direct, indirect, and induced jobs, earnings, and output per million dollar change in final demand must be supplied. In addition, consumer expenditures must be specified. These expenditures reflect the percent of total expenditures that households spend on output from each industry. The sum of all consumer expenditures is 100%. All data – multipliers and expenditures – need to be specified for each industry. Users have the choice to either use 14 aggregated industries or the 432 IMPLAN industry sectors. The aggregated industries follow:

1. Agriculture
2. Construction
3. Electrical equipment
4. Fabricated metals
5. Finance, insurance, and real estate
6. Government
7. Machinery
8. Mining
9. Other manufacturing
10. Other services
11. Professional services
12. Retail trade
13. Transportation, communication, and public utilities
14. Wholesale trade.

For IMPLAN users, gathering the necessary data will require several steps:

1. Purchase the desired county or state-level data files.
2. Using IMPLAN Version 3 software or the most current available, create a new model with the desired region (one county, a group of counties, or a group of states).
3. Construct the model.
4. Export all industry multipliers for employment, employee compensation, and output to spreadsheet files.

5. Format data contained in each of these files to input (i.e., cut and paste) into the disaggregated portion of the respective location (My County for a single county or My Region for a group of counties or states) in the User Add-in Location worksheet in JEDI.
6. Aggregate the model, which requires creating a new 14-industry aggregation scheme. The JEDI template used to aggregate the state multipliers into the 14 industries listed previously is available by request from NREL.[8]
7. Reconstruct the model.
8. Export household local commodity demand (personal consumption expenditures) and multipliers for employment, employee compensation, and output to spreadsheet files.
9. Format data contained in each of these files to input (i.e., cut and paste) into the respective location (My County for a single county or My Region for a group of counties or states) in the User Add-in Location worksheet in JEDI.

Once the user data are entered into the JEDI model, the user need only identify the location of the offshore wind system (in the project description section of the Project Data worksheet) as My County or My Region, depending upon the type of data and where the data are entered, and proceed with the analysis.

For non-IMPLAN users or those unfamiliar with input-output modeling, there are several options for gathering the necessary data to perform specific county or regional analysis[9]. These include:

1. Follow a similar process as that noted above to derive the aggregated and disaggregated multipliers and consumer expenditure data (aggregated) from another input-output modeling tool.
2. Purchase the necessary data (aggregated and disaggregated multiplier and consumer commodity demand—see description above) from an input-output data provider.
3. Obtain desired updates from the model developer or some other person or organization skilled in input-output modeling.

[8] Contact NREL at JEDISupport@nrel.gov.
[9] As a federally funded research and development center, NREL cannot recommend or endorse particular products or services.

6 Creating the Model: Data and Cost Categories

Analyzing the economic impacts of constructing and operating offshore wind plants requires a large amount of project- and location-specific data. These include project capital costs, labor rates, state- (or region-) specific input-output multipliers, personal expenditure patterns, and price deflators.

Before formal model development began, a representative project was defined. This is critical, particularly for offshore wind because plant components (e.g., substructure type) and expenditures are highly sensitive to project parameters. For this first iteration of the offshore wind JEDI model, a representative project was derived based on a review of the multiple project proposals and concepts under consideration at the time of the model's development. The representative project was developed principally to align with a hypothetical project expected to come online in the latter half of this decade and to be indicative of project parameters associated with a second round of North American projects (i.e., not a first-of-a-kind commercial-scale or pilot project). Table 1 summarizes the representative project parameters on which the current offshore wind JEDI model is based. If projects considered in future model analysis differ from the project parameters listed in the table, revisions to the default model inputs and potentially to the model structure itself may be necessary.

Table 1. Basic Project Parameters for the Representative Offshore Wind Project That Underlies Offshore Wind JEDI

Installed Capacity	500 MW
Turbine Size	5 MW
Water Depth	25 meters
Substructure Type	Jacket
Distance to Staging Port	100 miles
Distance to Point of Interconnection	50 miles
Distance to Servicing Port	<30 miles
Site Location	North Atlantic
Approximate Commercial Operation Date	2018

Building on these basic parameters, the model contains default values for all inputs necessary to perform an analysis. Project costs, including plant construction and O&M, were derived from a variety of sources, including communications with offshore wind industry professionals, renewable energy studies, and project-related case studies. These sources helped to establish a baseline for analysis.

6.1 Disaggregating Project Expenditures

Offshore wind is not a unique sector within the standard North American Industry Classification System (NAICS) or IMPLAN industry sectors specific to offshore wind. The absence of an explicit offshore wind sector in the IMPLAN data means that developing a JEDI model requires total project costs or expenditures to be disaggregated into individual line items that can be aligned with the existing IMPLAN sectors. This allows individual expenditures to be evaluated

for their impact within their respective sectors and then summed to estimate the total impact of building and operating the plant. Functionally, an offshore wind project must be broken down into its constituent industries including, for example, rolled steel production, steel fabrication, fiberglass assembly and manufacturing, marine services, and commercial construction. Labor expenditures are also isolated from capital or equipment expenditures wherever possible.

Having previously defined a representative project, the first step in developing the offshore wind JEDI model was to develop a detailed list of line item expenditures with high enough resolution that a given expenditure could be assigned to its respective IMPLAN sector. At the same time, the resolution needed to be low enough that the input data were known or could be estimated. To accomplish this, NREL developed an initial set of line items that were circulated among the various members of the Navigant Consortium. Feedback was obtained and incorporated. This process resulted in the detailed line items for project costs in the model's Project Data worksheet. Both construction and operating costs are broken into their constituent elements and labor expenditures are isolated from capital expenditures in many cases. The project specific data inputs include the following:

1. Turbine costs (e.g., nacelle, blades, and towers)
2. Materials and equipment costs (e.g., basic construction materials, foundation, substructure, collection system, high-voltage cable, converter stations, and substations)
3. Labor costs (e.g., foundation, substructure, and management/supervision)
4. Insurance
5. Development costs (e.g., engineering, legal, ports and staging, and marine transportation)
6. Annual operational labor costs
7. Annual materials and services costs
8. Other parameters (e.g., financial—debt and equity and taxes and payroll).

As explained previously, projects that deviate significantly from this set of expenditure types, potentially including projects that rely on substructures other than jackets, may not lend themselves to modeling in offshore wind JEDI without revisions in inputs or in the underlying model structure.

6.2 Developing Detailed Project Cost Data

With the requisite project expenditure disaggregation in place, the next step was to identify the detailed costs associated with each expenditure item. In a mature industry, such data could be derived from reports and studies documenting costs based on years of industry experience with developing, constructing, and operating plants. The relative nascence of the offshore industry, though, required a different approach. In addition, the level of resolution required by the JEDI model goes well beyond the data that are typically available in the public domain. To develop the cost input data, NREL and the Navigant Consortium estimated the costs associated with individual line items (for the representative project described previously) independently. This bottom-up approach to documenting and developing appropriate cost estimates used various methods, including the following:

- Estimates derived from international experience (e.g., financing and development costs)
- Market data (e.g., turbine prices and O&M costs)
- Component-level cost models within NREL and other industry partners (e.g., turbine towers, blades, and nacelle)
- Calculated labor requirements and assumed wage rates (e.g., project management)
- Contractor bids for fabrication and assembly work associated with hypothetical designs (e.g., jackets and electrical infrastructure).

Once individual expenditures were estimated, subsystem costs and totals were compared—after adjusting for differences in project parameters—with estimates derived elsewhere in the literature (Tegen et al. 2012; BVG Associates 2011; Deloitte 2011; Douglas-Westwood 2010). Next, the estimates were refined.

6.3 Estimating Local Content

In developing the offshore wind JEDI model, it was necessary to estimate a local share percentage for each expenditure. The local share allows the model to analyze the economic impact that accrues to the local area (state or geographic area). In this way, monetary leakages (spending on goods and services outside the local area) are not included in calculating local impacts. With no significant offshore wind industry or development activity in the United States today to draw on, but recognizing that many industries can easily support an offshore market in the future, NREL and the Navigant Consortium developed local content for each expenditure. Table 2 summarizes the initial construction period local content estimates. These estimates suggest that, for projects slated to come online by 2020 (the time frame of the representative project described previously), total construction period local content is likely to be relatively low, on the order of 10% of total construction period costs. In addition, the vast majority of local expenditures will be for development-related activities and construction services. These include environmental and engineering studies, port upgrades and staging, air and marine transportation to and from the project site, and potentially turbine transport and installation. Project management and basic construction materials (e.g., gravel, concrete, and basic hardware) are also expected to be procured locally.

Table 2. Summary of JEDI Construction Period Local Content Values

Summary Project Line Item	Aggregate Estimated Local Content (%)
Turbine and Electrical Infrastructure	2
Labor	2
Development and Construction Services	63
Other	0
Total Construction Period Local Content	**10**

Generally, operations period activities are expected to be somewhat more dependent on local sources of goods and services (Table 3). Aggregate local content is estimated to be approximately 45% of operations period total annual expenditures. Current estimates assume that technicians and administrative support are based locally and that management is situated elsewhere. Other than replacement parts, all general materials and services (e.g., transport, subcontractors, and equipment) are assumed to be procured locally.

Table 3. Summary of JEDI Operations Period Local Content Values

Summary Project Line Item	**Aggregate Estimated Local Content** (%)
Labor	54
Materials and Services	44
Total Annual Operations Period Local Content	**45**

Even though these estimates were developed with the intention of being broadly representative, they are also based on subjective estimates of existing industries and the ability of their distribution networks to support future offshore wind construction and operations activity. The existing industry structures in North America for land-based wind, and in Europe for offshore wind, were also considered. For example, because basic raw materials such as concrete and gravel are generally accessible locally and are costly to transport, the incentive to acquire these goods locally is strong. In contrast, because offshore turbine equipment tends to be larger and more difficult to transport over land, the existing land-based wind manufacturing industry is not expected to support near-term offshore wind projects. Instead, this equipment, at least in the early stages of the industry, is assumed to be imported from existing European offshore wind manufacturers. Ultimately, the estimates are based on what might be reasonable for initial projects, assuming current levels of workforce specialization and capabilities.

The default local content estimates may or may not reflect actual project specific expenditure patterns. In fact, even in the existing land-based wind industry, project expenditures vary widely. Moreover, with many states and local jurisdictions considering net economic impact tests in their approval process, project developers may be required to procure more goods and services locally. Under such conditions, local content may be much higher than envisioned here. Where better estimates of local or regional content are available, it is strongly recommended that users incorporate them in their analyses.

7 Validating JEDI Results

The offshore wind JEDI model has undergone both peer review and internal testing. Core data described previously (project line items, costs, and local content) were reviewed both internally by NREL and the Navigant Consortium and externally by members of the academic community and the offshore wind industry. In addition, model inputs and preliminary results were presented in public on at least three different occasions. In each instance, feedback on both the inputs and preliminary results was solicited and incorporated into the publicly released version of the model.

NREL also conducted an internal benchmarking effort where the results from the offshore wind JEDI model were analyzed in relation to those reported elsewhere in the literature. In addition to comparing results, JEDI model inputs were adapted to reflect many of the same inputs and data applied in other studies and results were compared again. Table 4 shows how the offshore wind JEDI model construction period results compared with other estimates when inputs were adjusted to reflect changes in the local content in accord with estimates elsewhere in the literature. These data indicate that the JEDI model is generally capable of replicating the broad range of impacts reported by others, assuming variability in local content ranging from 7% to 100%. This analysis reveals that much of the variability in estimated impacts is a function of different assumptions around key variables such as installed capital cost and local content.

Table 4. Comparison of Construction Period Analysis

Study	**Estimated Total Construction Period** (FTE/MW)
Global Insight (2003)	1.4–2.4
Flynn and Carey (2007)	2.0–3.7
Coad and Antunes (2010)	25–29
Hagerman et al. (2010)	39
Bloomberg New Energy Finance (Global Direct)(2012)	17
Offshore JEDI	5–25–40

Note: Construction period JEDI results are based on the estimated impacts for local content of 7%, 45%, and 100%.

Results differ from JEDI estimates due to a combination of factors. Different modeling techniques, capital costs, and local content assumptions all contribute to differences. The lowest end of the literature range, though, was below that reported by JEDI. This apparent discrepancy is the result of much lower capital costs assumed by analysts in the early 2000s. Estimates from other more recent studies fall within the range of results produced by JEDI.

During operations, impacts estimated by JEDI and throughout the literature are less substantial in terms of FTE/MW (Table 5), because expenditures required to maintain and operate a facility are much lower than those required to develop and construct a plant. These estimates, however, are also generally more consistent across studies. In addition, operations period FTEs represent long-term jobs. The relatively lower variability among operations period estimates is related to the lower level of expenditures as well as greater consistency in terms of estimated local content. During operations, much of the basic labor and services can be procured locally, but specialized

parts and equipment will not be locally available in most cases. Accordingly, estimating local content across projects is a somewhat more straightforward task.

The largest differences between JEDI estimates and the literature estimates often result from the fact that some studies focus exclusively on on-site technicians (direct) estimates. Although there is consistency between JEDI calculated impacts and the literature relative to the construction period, JEDI operations period estimates appear to be marginally higher than those found elsewhere in the literature. This is largely the result of two factors: (1) higher O&M and replacement costs in JEDI because the representative project (described previously) is located farther from shore than is typical of the international industry to date; and (2) slightly higher operations period costs in general. These cost estimates have edged upward as the offshore wind industry has developed and more operational experience has been gained.

Table 5. Comparison of Operations Period Analysis

Study	**Estimated Total Operations Period** (FTE/MW)
Global Insight (2003)	0.37
Flynn and Carey (2007)	0.20–0.33
Coad and Antunes (2010)	0.3
Oxford Economics (2010)	0.28–0.43
Boettcher et al. (2008/2010)	0.34
Carbon Trust (2008)	0.27–0.36
Goulden and Isola (2009)	0.12 (Direct)
Global Wind Energy Council (GWEC; 2008)	0.33
Ladenburg et al. 2005 (Horns Rev)	0.31
Ladenburg et al. 2005 (Nysted)	0.11
Cambridge Econometrics; University of Warwick Institute for Employment Research; IFF Research (2011)	0.34–0.38
Bloomberg New Energy Finance	0.13–0.17 (Direct)
Offshore JEDI	0.4–0.6–1.1*

Note: Operations Period JEDI results are based on impacts for local content of 35%, 60%, and 100%.

8 Resources

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