Land-Based Wind Jobs and Economic Development Impact (JEDI) Model:

Installation and Use Guide for Windows/PC Users

For version released 10/30/2020

This document is a draft designed to accompany the beta version of the land-based wind JEDI model. The model and installation and use guide will be updated throughout the beta testing phase and upon final release of the model.

15013 Denver West Parkway
Golden, CO 80401
Phone 303-275-3000

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Table of Contents

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Land-Based Wind JEDI Model Background Information

The economic impacts from wind energy project development can be significant to both the rural counties and the state in which the project is located. The benefits that are generated by the expenditures, both during the construction and the operations phases of wind plants, depend on the extent to which those expenditures are spent locally, as well as the structure of the local and state economy. The Land-Based Wind Jobs and Economic Development Impact model (LBW JEDI model) is an easy-to-use tool that provides an approximation of the economic impacts to the local county and the state that can be generated from wind project development, during the construction phase of the project and throughout the 20 to 30 year life, or operating years, of the project.

Methodology Behind the Model

Using basic information about a wind project (at minimum the project's state, county, or region; the year of construction; and the size of the facility), the model calculates the project balance-of-plant costs using NREL's LandBOSSE Balance-of-Systems cost model. The model then calculated the number of jobs, income (i.e., wages and salary), and economic activity that will accrue to the state, county, or region being analyzed. To evaluate these impacts, input-output or multiplier analysis is used.

Input-output models were originally developed to trace supply linkages in the economy. For example, they show how purchases of wind turbines not only benefit turbine manufacturers, but also the fabricated metal industries and other businesses supplying inputs to those manufacturers. The benefits that are ultimately generated by expenditures for wind plants depend on the extent to which those expenditures are spent locally and the structure of the local economy. Consistent with the spending pattern and location-specific economic structure (state, county, or region), different expenditures support a different level of employment, income, and output.

Input-output analysis is a method of evaluating and summing the impacts of a series of effects generated by an expenditure (i.e., input). To determine the total effect of developing a wind power plant, three impacts are examined for each expenditure. These include direct effect, indirect effect, and induced effect.

> **Direct effect:** Direct effects are the on-site or immediate effects created by an expenditure. In constructing a wind plant, it refers to the on-site jobs of the contractors and crews hired to construct the plant. It also includes the jobs at the turbine manufacturing plants and the jobs at the tower and blade factories.
>
> **Indirect effect:** Indirect effects 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 to pay others who support their business. For instance, this impact includes the banker who finances the contractor; the accountant who

keeps the contractor's books; and the steel mills and electrical manufacturers and other suppliers that provide the necessary materials.

Induced effect: Induced effects refer to the change in wealth and income that is induced by the spending of those persons directly and indirectly employed by the project. This would include spending on food, clothing, or day care by those directly or indirectly employed by the project, retail services, public transit, utilities, cars, oil, property & income taxes, medical services, and insurance, for example.

The sum of these three effects yields a total effect that results from a single expenditure. To accomplish this analysis at the state level, state-specific multipliers and personal expenditure patterns are used to derive the results. These state-by-state multipliers for employment, wage and salary income and output (economic activity), and personal expenditure patterns were adapted from the IMPLAN Professional model using year 2018 data (to be updated with new data in November 2020). The changes in expenditures from investments in developing wind power plants are matched with their appropriate multipliers for each sector affected by the change in expenditure. The JEDI model user does also have the ability to add in their own IMPLAN data for a specific location using the User Add-In Location sheet within the model.

Consistent with an analysis of this type and scope, the assumptions play an important role in influencing the results. Thus, to accommodate the greatest level of flexibility in user skill level and availability of specific detailed project information, the model is designed to incorporate model default values or new values entered by the user. The default values represent a reasonable expenditure pattern for constructing and operating a wind power plant in the United States and the share of expenditures spent locally. The default expenditure pattern is based on a review of numerous wind resource studies as well as the default values used for NREL's LandBOSSE model simulations.

Currently, not every project will follow this exact "default" pattern for expenditures. Project size, location, financing arrangements, and numerous site-specific factors influence the construction and operating costs. Similarly, the availability of local resources (including skilled labor and materials) and the availability of locally manufactured power plant components will have a significant effect on the costs and the economic benefits that accrue to the state or local region. To the extent the user has and can incorporate project-specific data and the share of spending that is expected to occur locally, the more localized the impact analysis will be.

Entering Data and Running the Model

The JEDI model is designed for all levels of users, requiring no experience with spreadsheets or background in economic modeling. The model includes instructions imbedded within the model in addition to this document which describes the installation process and basic use of the model. The installation of the JEDI model involves also installing NREL's LandBOSSE model through the installer that is included with the JEDI

model when downloaded from the NREL website. This process is described in detail in the Installation and Use section of this guide.

For those users with little or no experience with wind power plants or economic impact analysis, minimal inputs are required, such as the state in which the wind plant will be built, the year the plant will be built, the size of the plant and any available turbine information. The user can then choose to accept all project defaults or review and edit any defaults as desired. Regardless of the number of inputs changed in the model, the user must still proceed through the model and press each button to proceed to the next step to ensure that all calculations in the model are performed correctly.

For those users with more experience with wind power plants and/or economic impact analysis (i.e., those with more project-specific information on costs and expenditures, financing, taxes, and local share of spending, among others), project-specific values can be entered to override the default values.

Interpreting the Results

Regardless of the amount of project-specific data entered by the user, JEDI provides sufficient information to help users better understand the economic impacts associated with the project being analyzed. The model provides basic project information to identify the magnitude of the construction-related spending and ongoing operating and maintenance (O&M) expenditures, as well as the portion of local spending. As noted earlier, these outputs should not be interpreted as precise values. Instead, they should be used as an indication of the magnitude of the potential economic development impacts. The “local share” values – default or user modified – are determined in the model for each of the expenditures. Similarly, the model identifies local spending on debt and equity payments, property taxes and land lease payments.

In addition to the basic project information, the model provides analysis (divided into direct, indirect and induced impacts) of the local jobs, earnings, and output (economic activity) generated as a result of the project. This includes the one-time impacts from the construction phase, as well as the annual or ongoing impacts from the annual operations.

Once the analysis is complete, the user has several options for saving the data and results including printing the results, saving the model (using a different name), or copying the results into a spreadsheet format. The results are divided into separate categories for Construction Impacts and Operating Years Impacts and are broken into 4 categories: jobs, earnings, output, and value added. The Summary sheet of the JEDI model will also display four bar charts showing the results for the wind project being analyzed.

Land-Based Wind JEDI Model Version Release 2020

The Land-Based Wind Jobs and Economic Development Impact (JEDI) Model underwent a series of updates in the 2020 fiscal year. These updates, listed below, aim to keep the model on trend with the current land-based wind industry and increase the model's accuracy when analyzing wind plants throughout various regions of the country. The updates made to the land-based wind JEDI model in 2020 require specific steps to be followed in order for the model to run and for JEDI to calculate accurate costs for your project.

Please follow the steps in this document to correctly install and run the JEDI model.

Key Updates to the Land-Based Wind JEDI Model:

- Integration of the NREL LandBOSSE Balance-of-System Cost Model
  - The LandBOSSE model is a Python-based tool used for modeling the balance-of-system costs for land-based wind plants. This model has been fully integrated into the JEDI Microsoft Excel-based model, allowing the user to calculate and view LandBOSSE outputs through Excel. The integration of this model requires that the JEDI user installs LandBOSSE prior to using the JEDI model. Steps for this installation process are described below.
  - Information on the LandBOSSE Balance of System Cost Model can be found at https://www.nrel.gov/docs/fy19osti/72201.pdf
- Addition of state-specific land lease data
  - Data sourced from American Wind Energy Association WindIQ Database, as well as additional NREL literature review
- Addition of state-specific property tax data
  - Data sourced from American Wind Energy Association WindIQ Database, as well as additional NREL literature review
- Addition of regional, capacity-based curves to determine # of O&M jobs
  - Data from NREL's Workforce and Economic Development Considerations from the Operations and Maintenance of Wind Plants Report (M. Kotarbinski, NREL/TP-5000-76957), was used to develop job curves within JEDI that estimate the number of O&M jobs based on a wind plants region and capacity.
- Redesign of model layout and step-by-step format
  - The latest version of the land-based wind JEDI model includes a redesign of the model layout and function. The model now uses a step-by-step method requiring the user to press the appropriate buttons in Excel to run macros to proceed through the steps and properly run all calculations.

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Installation and Use the Land-Based Wind JEDI Model

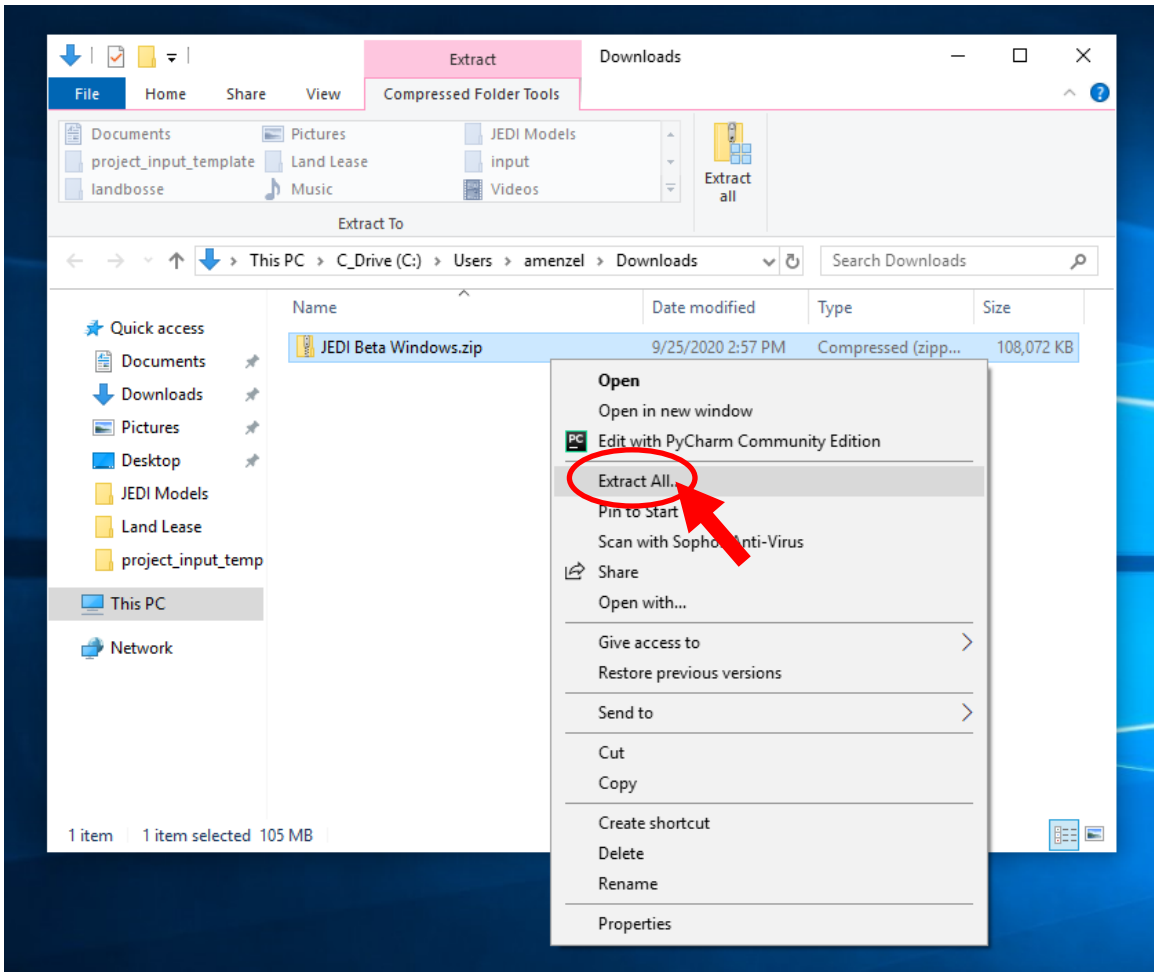
Step 1 - Download the JEDI Model Package

For the latest version of the land-based wind JEDI model, please visit the NREL website at the following link: https://www.nrel.gov/analysis/jedi/wind.html. Click on the Land-Based Wind JEDI Model "Download" button for Windows to download a .zip folder containing the JEDI Model and LandBOSSE installation package titled "JEDI Beta Windows.zip."

Step 2 - Extract and Save the Folder to your Computer

Once the download is complete, you will see the .zip folder in your computer's download folder. Please extract/decompress this folder and save the "unzipped" folder to your computer.

Right click on the .zip folder and click on the option to "Extract All…" This will bring up a new box allowing you to choose the destination where you would like to save this folder. This is the location that you will then go to in order to open the file and run JEDI.



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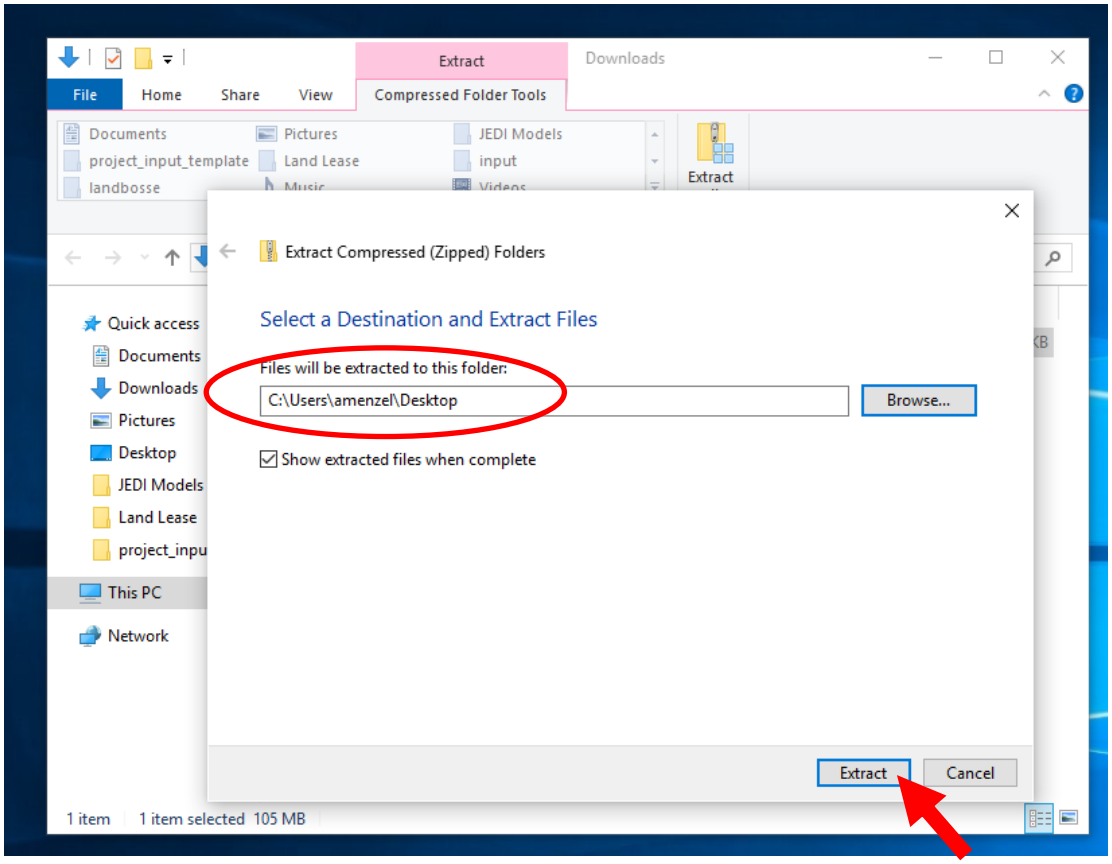
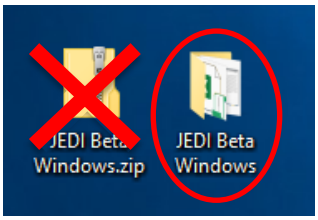


On your desktop (or wherever you chose to save your folders) you may have both the .zip folder and the “unzipped” folder. You can now delete the .zip folder and should keep the other folder titled “JEDI Beta Windows” in one location with all files contained.



Step 3 - Install LandBOSSE

Open the JEDI Beta Windows folder from the location where the folder was saved in Step 2. Double-click on the application titled “landbosse-runtime-0.9.9-x64.exe” to open the installer for LandBOSSE.

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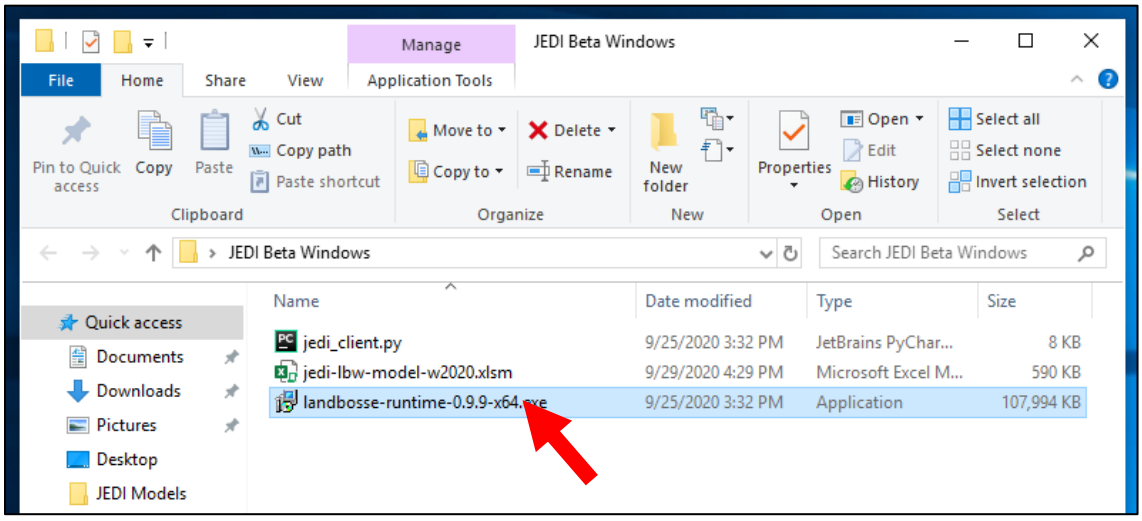
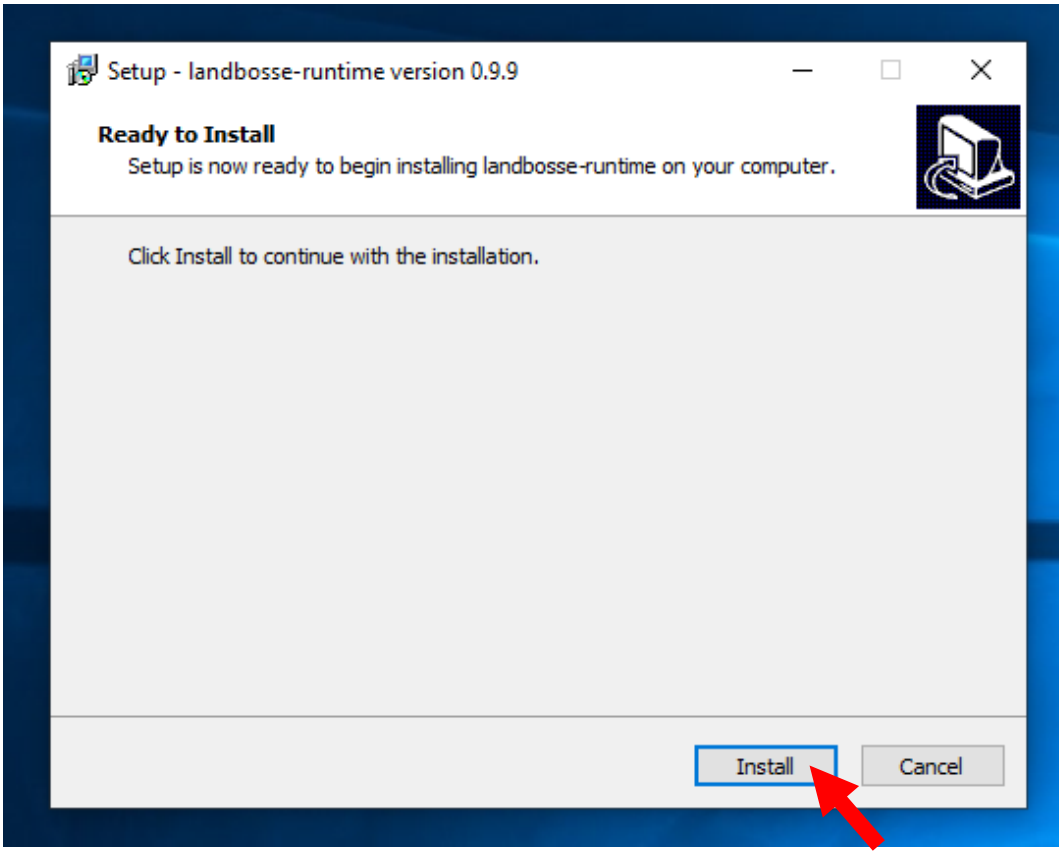


After double clicking on this .exe file, an installer will open. Please follow the steps of the installer to complete the LandBOSSE installation (this can take up to 10 minutes.)



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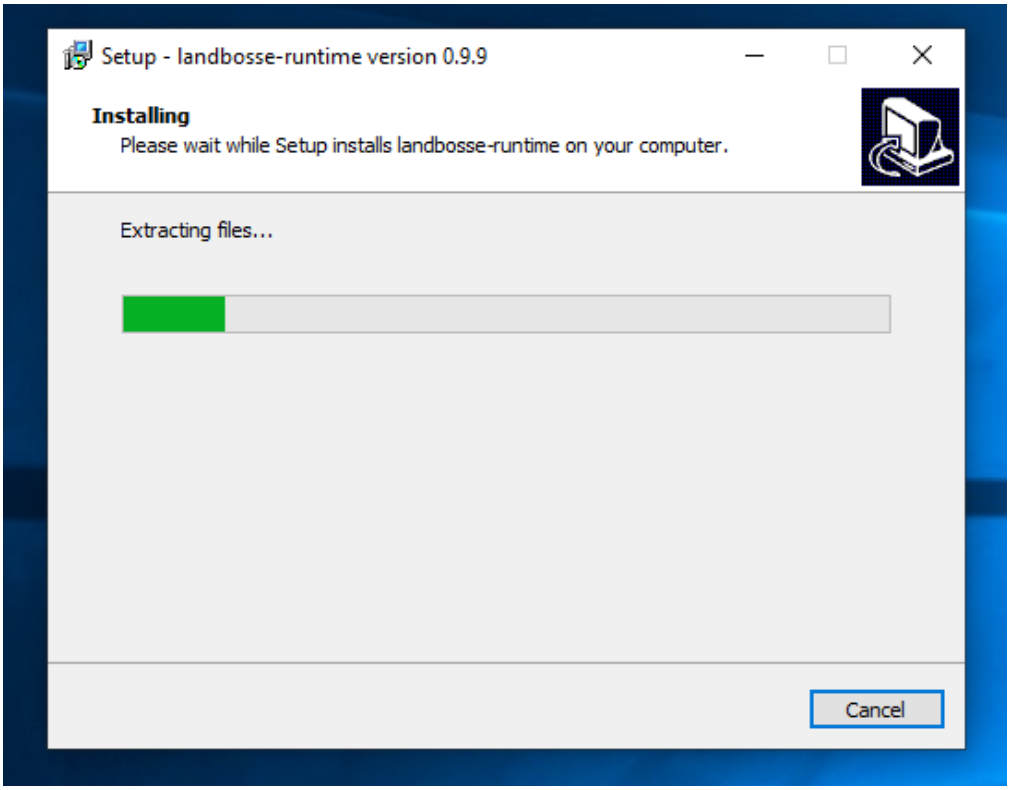

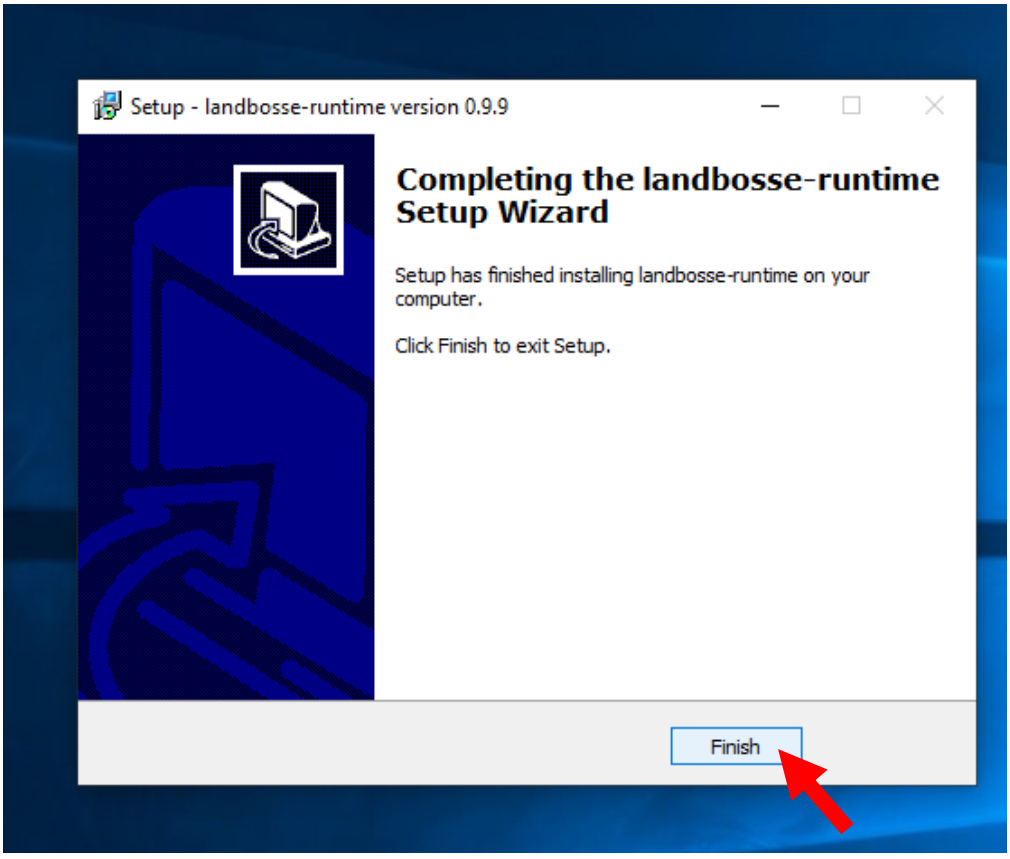

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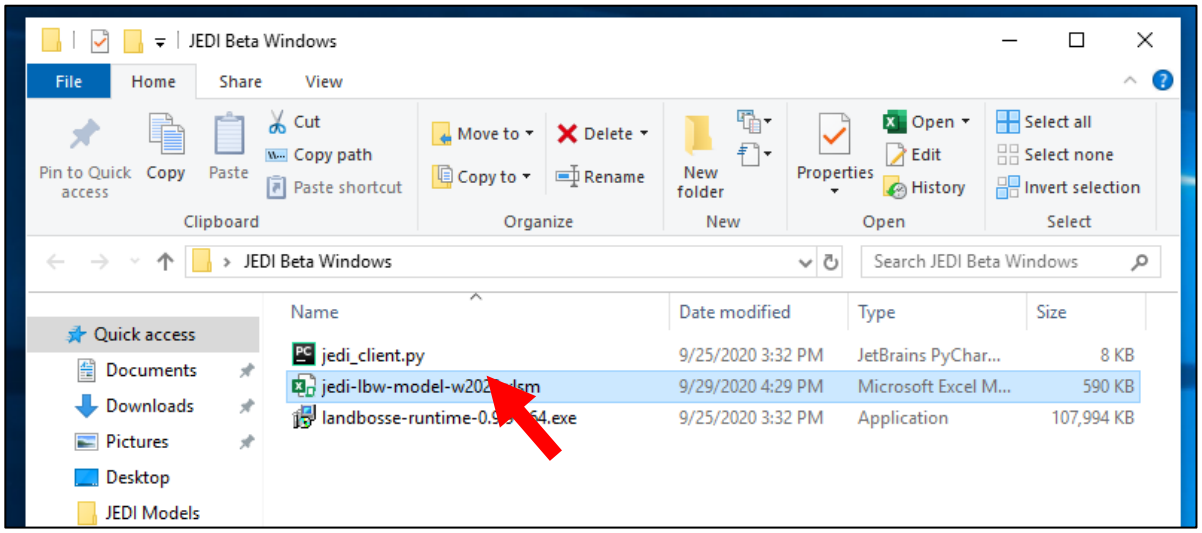
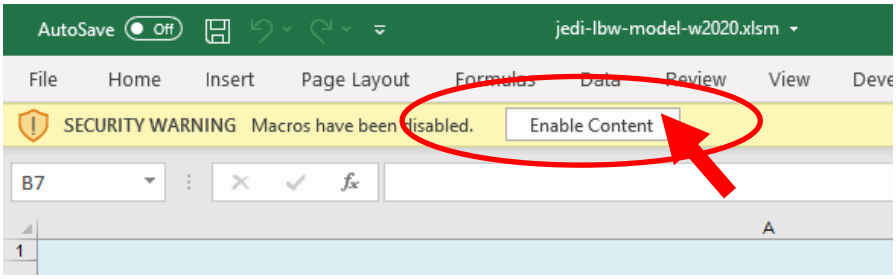
Step 4 – Open the JEDI Model

After the LandBOSSE installation is complete, you can return to the JEDI Beta Windows folder and open the Excel file titled “jedi-lbw-model-w2020.xlsm.” When the file opens, please opt to “Enable Content” to ensure the model runs all calculations.





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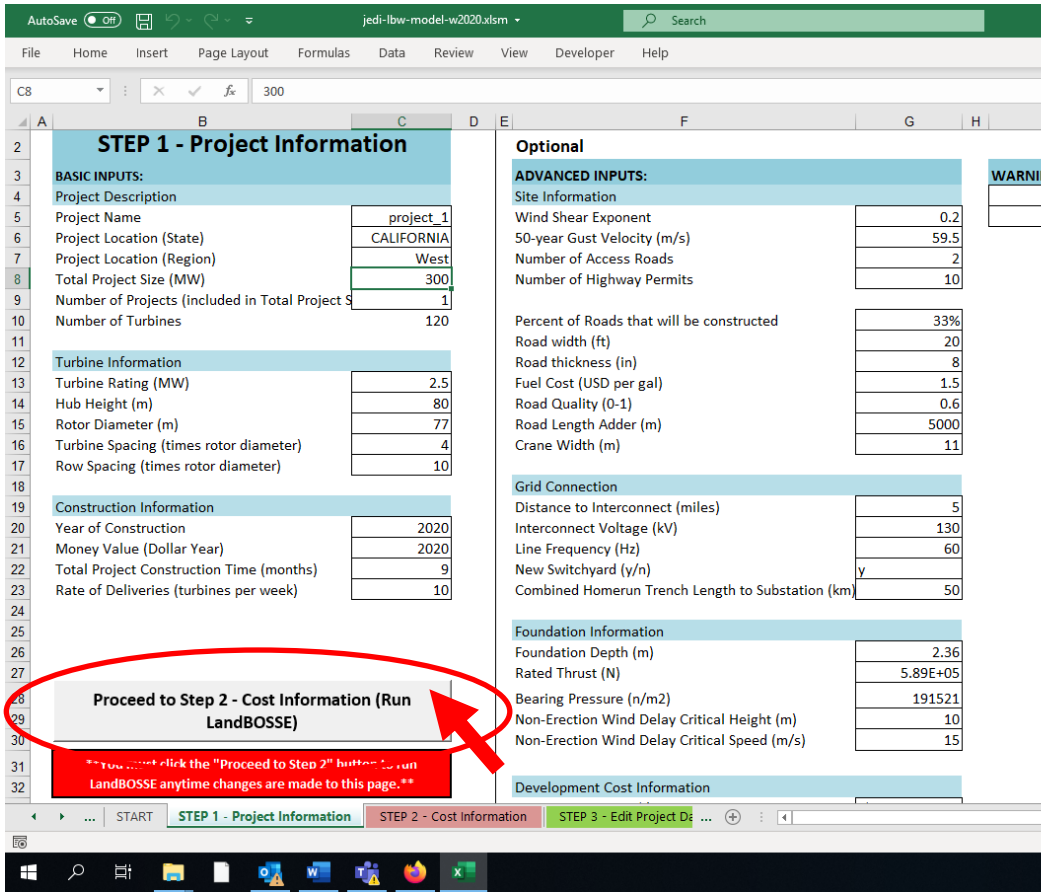
Step 5 – Run the JEDI Model

With the Excel-based model open, start on the tab titled “Step 1 – Project Information.” Here you can change any of the basic and advanced inputs for your project. When you have finished altering your inputs on this page, please click the button “Proceed to Step 2 – Run LandBOSSE.” This button will take your inputs and run a Python code for the LandBOSSE Balance-of-Systems cost model in the background.

You may have to wait a few minutes for the costs on the Step 2 sheet to recalculate.



Note – anytime changes are made to the inputs on the Step 1 page, this button must be clicked to re-run LandBOSSE.

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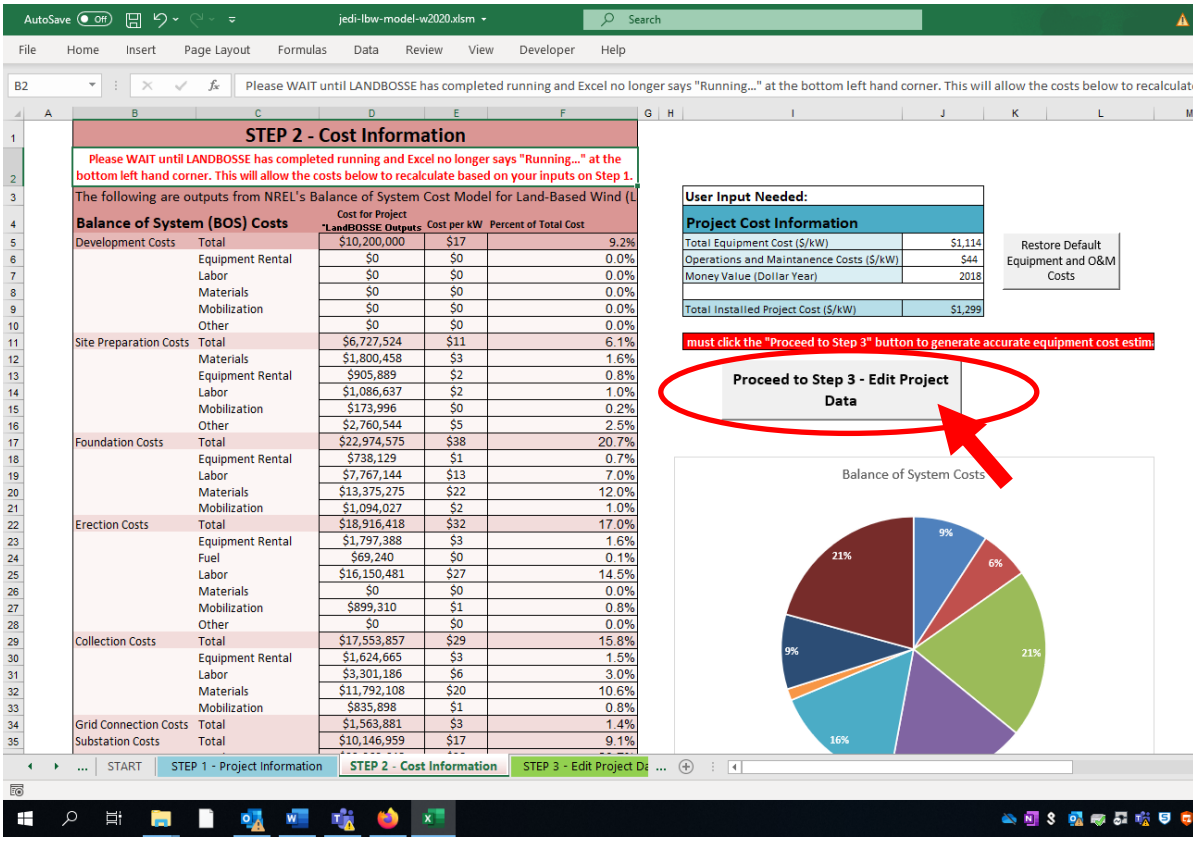
Step 6 – Continue through JEDI Model Steps

After you have clicked the button to Proceed to Step 2 and LandBOSSE has successfully run, you should see new costs populated on the “Step 2 – Cost Information” tab. These costs are the outputs from the LandBOSSE model.



During this step, user inputs to the project cost information can be made for Total Equipment Cost ($/kw), Operations and Maintenance Costs ($/kW), and Money Value (Dollar Year.)

After any changes are made, please click the button to “Proceed to Step 3 – Edit Project Data.” In Step 3, the LandBOSSE outputs are then re-grouped together into the corresponding categories used by JEDI.

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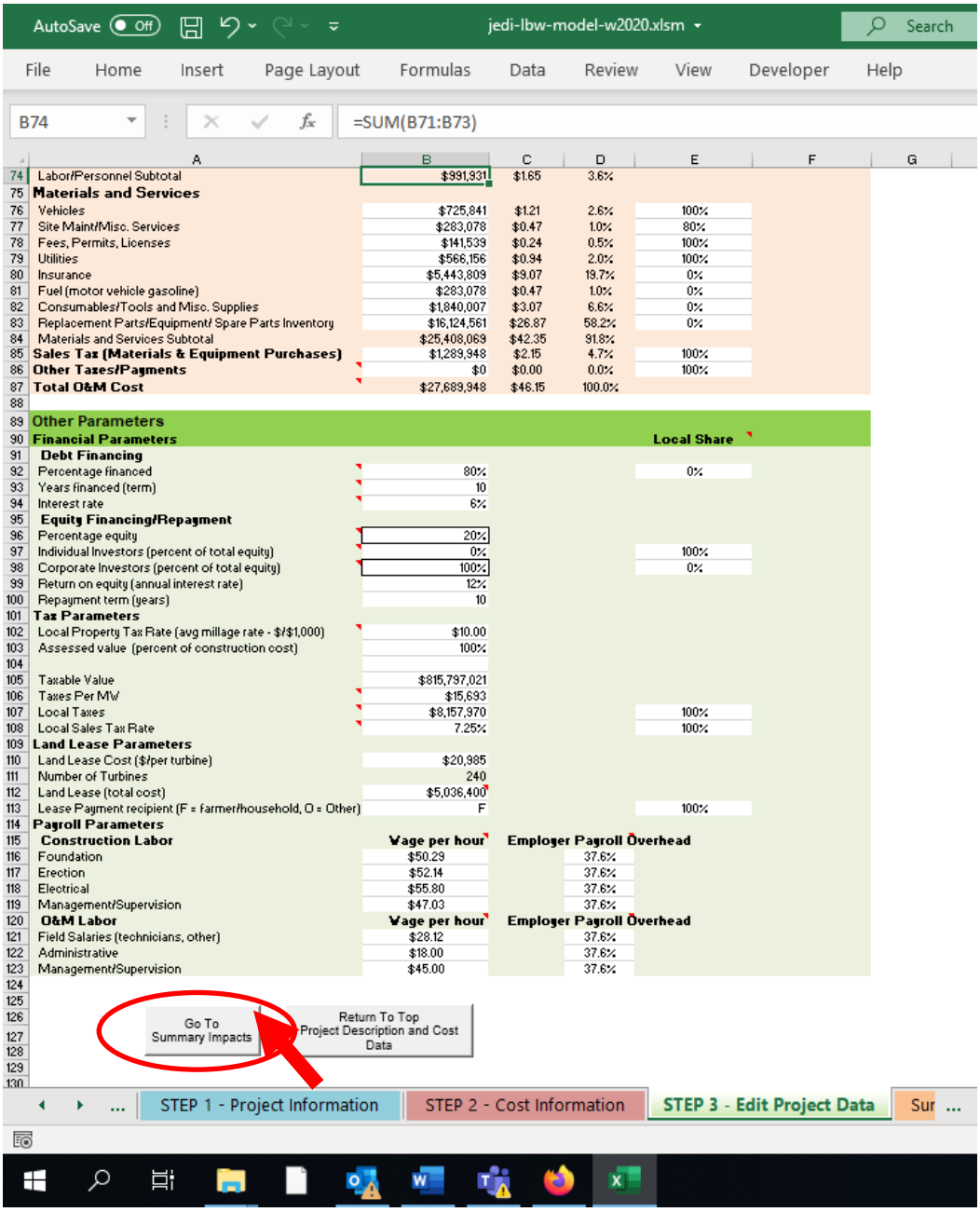

	A	B	C	D	E	F	G
74	Labor/Personnel Subtotal	$991,931	$1.65	3.6%			
75	**Materials and Services**						
76	Vehicles	$725,841	$1.21	2.6%	100%		
77	Site Maint/Misc. Services	$283,078	$0.47	1.0%	80%		
78	Fees, Permits, Licenses	$141,539	$0.24	0.5%	100%		
79	Utilities	$566,156	$0.94	2.0%	100%		
80	Insurance	$5,443,809	$9.07	19.7%	0%		
81	Fuel (motor vehicle gasoline)	$283,078	$0.47	1.0%	0%		
82	Consumables/Tools and Misc. Supplies	$1,840,007	$3.07	6.6%	0%		
83	Replacement Parts/Equipment/ Spare Parts Inventory	$16,124,561	$26.87	58.2%	0%		
84	Materials and Services Subtotal	$25,408,069	$42.35	91.8%			
85	**Sales Tax (Materials & Equipment Purchases)**	$1,289,948	$2.15	4.7%	100%		
86	**Other Taxes/Payments**	$0	$0.00	0.0%	100%		
87	**Total O&M Cost**	$27,689,948	$46.15	100.0%			
88							
89	**Other Parameters**						
90	**Financial Parameters**				**Local Share**		
91	**Debt Financing**						
92	Percentage financed	80%			0%		
93	Years financed (term)	10					
94	Interest rate	6%					
95	**Equity Financing/Repayment**						
96	Percentage equity	20%					
97	Individual Investors (percent of total equity)	0%			100%		
98	Corporate Investors (percent of total equity)	100%			0%		
99	Return on equity (annual interest rate)	12%					
100	Repayment term (years)	10					
101	**Tax Parameters**						
102	Local Property Tax Rate (avg millage rate - $/$1,000)	$10.00					
103	Assessed value (percent of construction cost)	100%					
104							
105	Taxable Value	$815,797,021					
106	Taxes Per MW	$15,693					
107	Local Taxes	$8,157,970			100%		
108	Local Sales Tax Rate	7.25%			100%		
109	**Land Lease Parameters**						
110	Land Lease Cost ($/per turbine)	$20,985					
111	Number of Turbines	240					
112	Land Lease (total cost)	$5,036,400					
113	Lease Payment recipient (F = farmer/household, O = Other)	F			100%		
114	**Payroll Parameters**						
115	**Construction Labor**	**Wage per hour**	**Employer Payroll Overhead**				
116	Foundation	$50.29		37.6%			
117	Erection	$52.14		37.6%			
118	Electrical	$55.80		37.6%			
119	Management/Supervision	$47.03		37.6%			
120	**O&M Labor**	**Wage per hour**	**Employer Payroll Overhead**				
121	Field Salaries (technicians, other)	$28.12		37.6%			
122	Administrative	$18.00		37.6%			
123	Management/Supervision	$45.00		37.6%			
124							
125							
126							
127							
128							
129							
130							

On the Step 3 Edit Project Data page, you will see the balance of plant costs and project information that was inputted during the previous steps. On this sheet, you can edit local share percentages, financial parameters, and O&M costs as needed for your project.

After all inputs are completed, hit the “Go To Summary Impacts” button at the bottom of the sheet to view the summary of economic impacts for your project.

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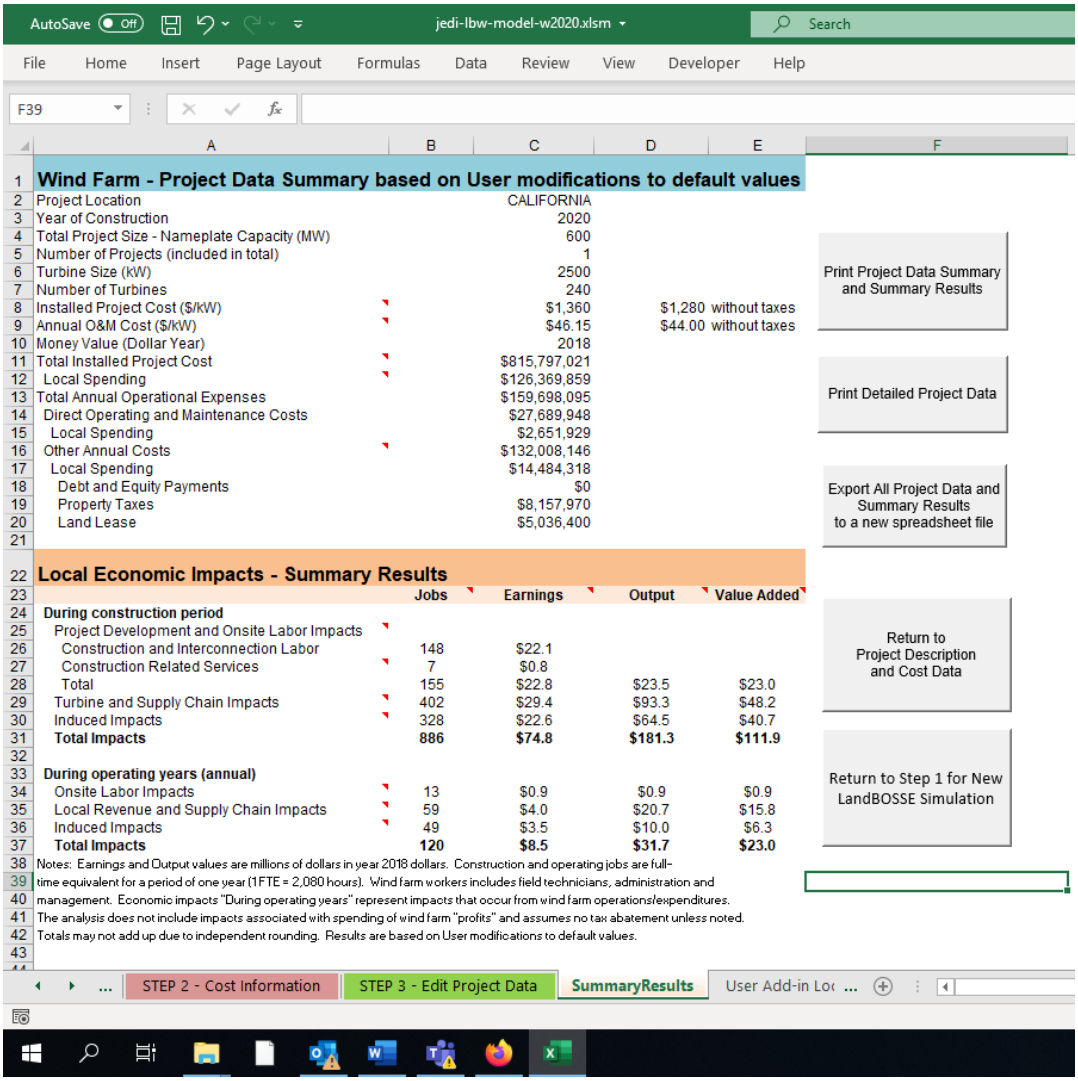

	A	B	C	D	E	F
1	**Wind Farm - Project Data Summary based on User modifications to default values**					
2	Project Location		CALIFORNIA			
3	Year of Construction		2020			
4	Total Project Size - Nameplate Capacity (MW)		600			
5	Number of Projects (included in total)		1			
6	Turbine Size (kW)		2500			
7	Number of Turbines		240			
8	Installed Project Cost ($/kW)		$1,360	$1,280	without taxes	
9	Annual O&M Cost ($/kW)		$46.15	$44.00	without taxes	
10	Money Value (Dollar Year)		2018			
11	Total Installed Project Cost		$815,797,021			
12	Local Spending		$126,369,859			
13	Total Annual Operational Expenses		$159,698,095			
14	Direct Operating and Maintenance Costs		$27,689,948			
15	Local Spending		$2,651,929			
16	Other Annual Costs		$132,008,146			
17	Local Spending		$14,484,318			
18	Debt and Equity Payments		$0			
19	Property Taxes		$8,157,970			
20	Land Lease		$5,036,400			
21						
22	**Local Economic Impacts - Summary Results**					
23		**Jobs**	**Earnings**	**Output**	**Value Added**	
24	**During construction period**					
25	Project Development and Onsite Labor Impacts					
26	Construction and Interconnection Labor	148	$22.1			
27	Construction Related Services	7	$0.8			
28	Total	155	$22.8	$23.5	$23.0	
29	Turbine and Supply Chain Impacts	402	$29.4	$93.3	$48.2	
30	Induced Impacts	328	$22.6	$64.5	$40.7	
31	**Total Impacts**	**886**	**$74.8**	**$181.3**	**$111.9**	
32						
33	**During operating years (annual)**					
34	Onsite Labor Impacts	13	$0.9	$0.9	$0.9	
35	Local Revenue and Supply Chain Impacts	59	$4.0	$20.7	$15.8	
36	Induced Impacts	49	$3.5	$10.0	$6.3	
37	**Total Impacts**	**120**	**$8.5**	**$31.7**	**$23.0**	
38	Notes: Earnings and Output values are millions of dollars in year 2018 dollars. Construction and operating jobs are full-					
39	time equivalent for a period of one year (1 FTE = 2,080 hours). Wind farm workers includes field technicians, administration and					
40	management. Economic impacts "During operating years" represent impacts that occur from wind farm operations/expenditures.					
41	The analysis does not include impacts associated with spending of wind farm "profits" and assumes no tax abatement unless noted.					
42	Totals may not add up due to independent rounding. Results are based on User modifications to default values.					
43						

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Data Sources Used in the LBW JEDI Model - 2020

LandBOSSE

The Land-Based Wind JEDI model was integrated with NREL's LandBOSSE Balance-of-Systems Cost model in 2020. LandBOSSE is NREL's land-based balance of system system's engineering model, which is a tool for modeling the balance of system costs of land-based wind plants. Balance of system costs, which are the costs to perform site preparation, construct foundations, install electrical infrastructure, construct the tower, etc. currently account for approximately 30% of the cost to install a land-based wind plant, so it is extremely important that these costs are accurate within the JEDI model.

Through the integration of LandBOSSE and JEDI, the accuracy of these balance of plant and construction costs is greatly improved, making the JEDI model more accurate and up to date with industry trends. An additional benefit is that the LandBOSSE model, which is typically run by Python, can now be accessed by using the Excel-based JEDI model.

Through this integration, the model takes user inputs and defaults from the JEDI model to run the LandBOSSE model after the user enters any inputs about a project on the Step 1 sheet of the JEDI model. After running LandBOSSE, the user will see all of the outputs from the LandBOSSE model on the Step 2 sheet of the JEDI model. These outputs are split into six modules: development, site preparation, foundation, erection, collection, grid connection, substation, and management. These outputs are then reconfigured to match the four input categories in the JEDI model: equipment costs, materials costs, labor costs, and development or other costs. In addition to LandBOSSE, data from the 2018 NREL cost of wind energy review is also used to calculate the equipment costs. This reconfiguration is done to group all costs together based on the industries that are affected, which ultimately is used in the back end of the JEDI model to run economic multipliers and determine the economic impacts. For a visual flowchart of the integration of these NREL models into the JEDI model, please refer to the Figure 1.

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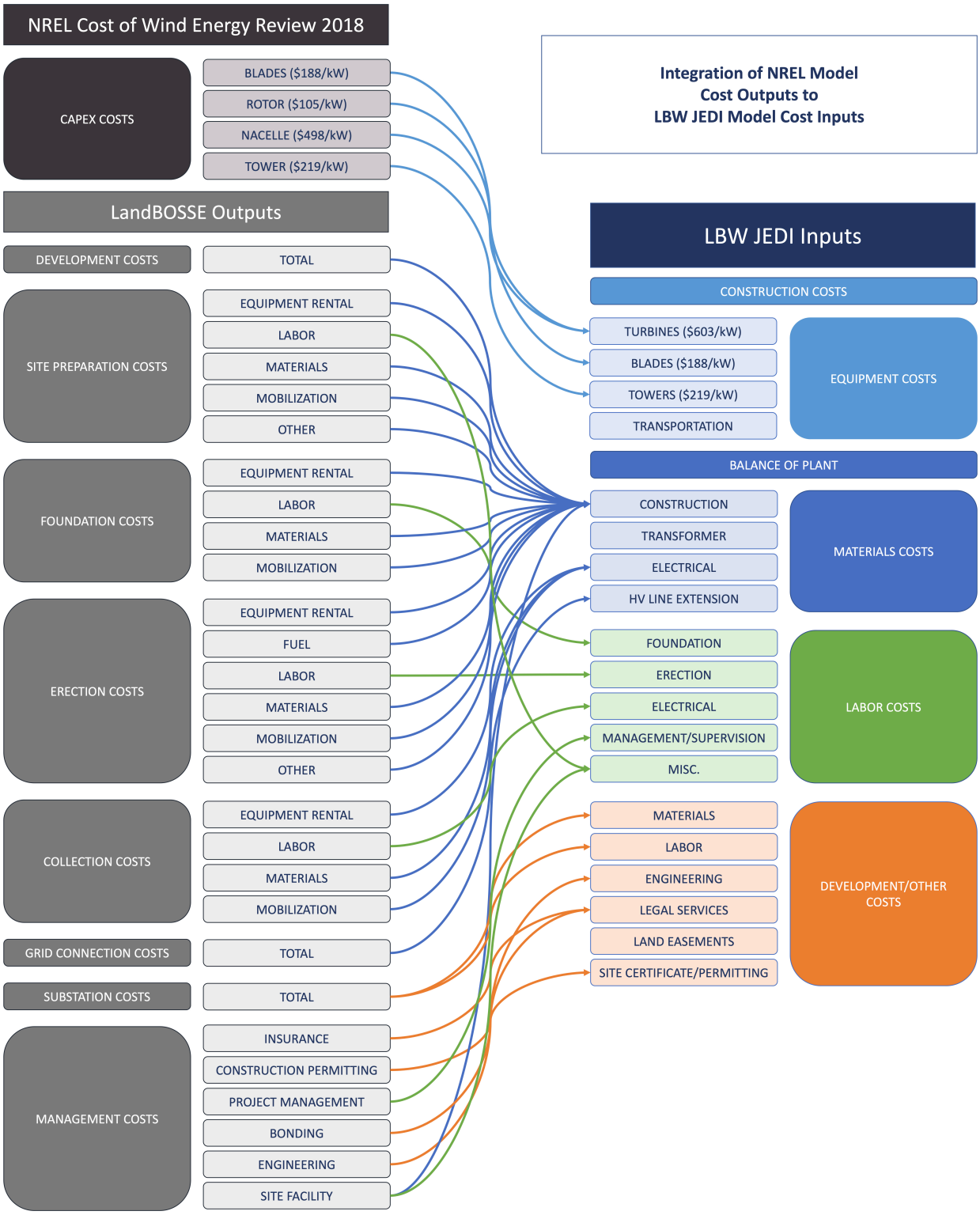
Figure 1. Integration of NREL Model Cost Outputs to LBW JEDI Model Cost Inputs



15013 Denver West Parkway
Golden, CO 80401
Phone 303-275-3000

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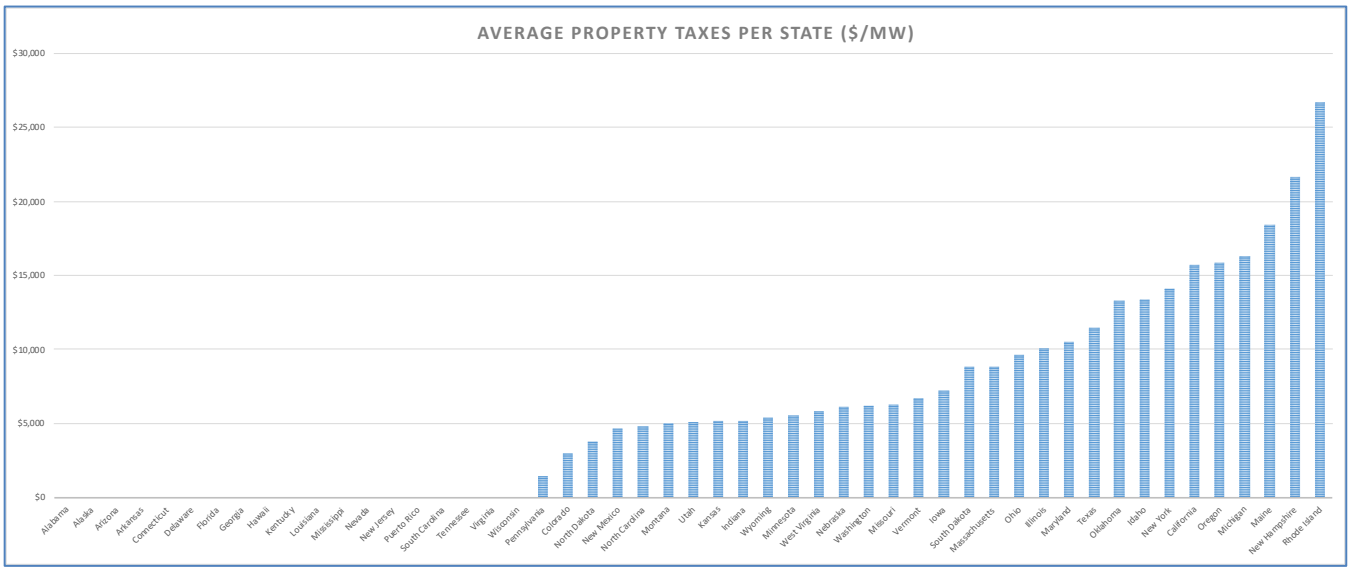
Property Tax Data

In 2020, the Land-Based Wind JEDI model was updated to include state-specific data for property tax payments. This dataset was collected through an NREL literature review, including information from American Wind Energy Association's WindIQ Database and Property Tax Treatment Report and was used to determine tax rate, assessment percentage, and an average value in dollars per megawatt of property taxes for each state. In JEDI property taxes for the wind farm are calculated first using the tax rate and assessment value, or if this information is not available for a particular state, then the model resorts to using the $/MW value for that state. This $/MW dataset is shown in Figure 2. Both of these updates improve the regionality of JEDI and allow the user to generate more accurate results for their state.

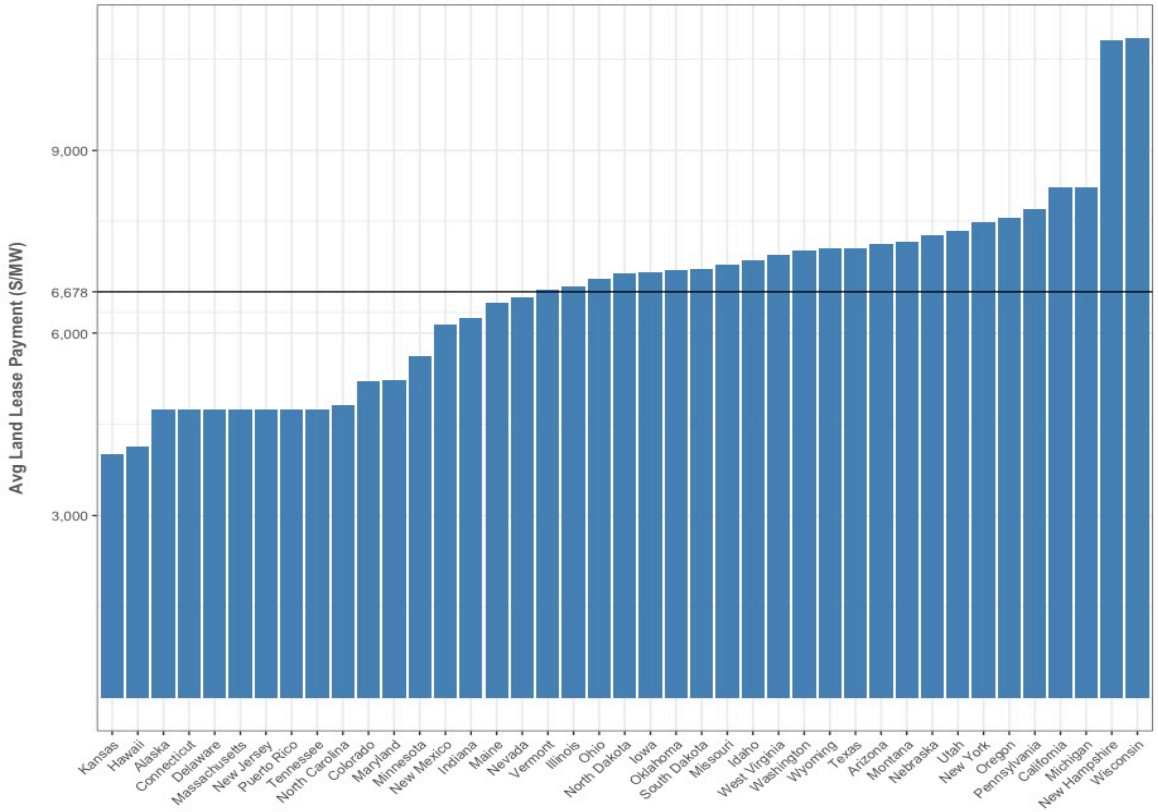
Figure 2. Average Property Taxes per State



Landowner Lease Data

In 2020, the Land-Based Wind JEDI model was updated to include state-specific data for landowner lease payments. This data was collected through an NREL literature review as well as from the American Wind Energy Association's Wind IQ database, to create an average dollar per megawatt value for each state. This value is then multiplied by the total project size to calculate the total cost of the landowner lease payments for the wind project in that state. Figure 3 shows the average value of these landowner lease payments for each state. In the JEDI model, the user is able to change this value if another value is known for the project. The user may also select the type of Lease Payment Recipient.

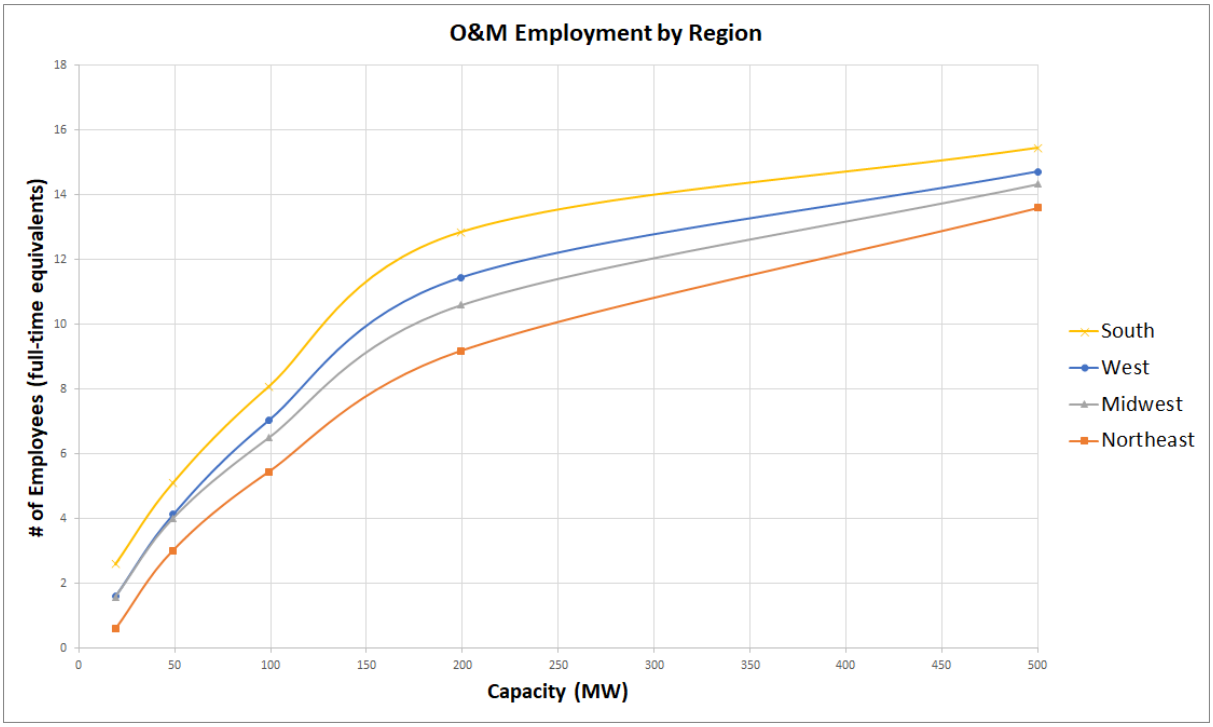
Figure 3. Average Land Lease Payments per State



Operations & Maintenance Data

An update made in 2020 to the Operations & Maintenance section of the Land-Based Wind JEDI model is the addition of regional, capacity-based curves to determine the number of O&M jobs created during the lifetime of a wind project. Data from another NREL report, the Workforce and Economic Development Considerations from the Operations and Maintenance of Wind Plants Report (M. Kotarbinski, NREL/TP-5000-76957) was used to develop these curves to more accurately reflect the difference in number of O&M jobs based on the plant's region and total capacity. This is important because the number of jobs does not increase linearly with the size of the plant. These regional curves can be seen in Figure 4.

Figure 4. Operations and Maintenance Employment by Region



Additional Data

In addition to these datasets and models developed by NREL, economic multiplier data from IMPLAN is also used in the JEDI model. Currently, the model is using 2018 IMPLAN data, but this is set to be updated to the 2020 IMPLAN data as soon as it is released.

JEDI Model Support

For questions about the Land-Based Wind JEDI model or any of the models in the JEDI suite, please email JEDIsupport@nrel.gov. Additionally, more information about the models can be found at https://www.nrel.gov/analysis/jedi/. These models are typically updated every year to reflect current industry data and trends, but feedback about the models and recommendations for improvement are greatly appreciated.

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