



Jobs and Economic Development Impact (JEDI) User Reference Guide: Fast Pyrolysis Biorefinery Model

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Executive Summary

The Jobs and Economic Development Impact (JEDI) models, developed through the National Renewable Energy Laboratory (NREL), are user-friendly tools that can be used to estimate the local economic impacts of constructing and operating a fuel and power generation project for a range of conventional and renewable energy technologies. This guide -the JEDI Fast Pyrolysis Biorefinery Model User Reference Guide - was developed to assist users in operating and understanding the JEDI Fast Pyrolysis Biorefinery Model. The guide provides information on the model's underlying methodology, as well as the parameters and data sources used to develop the cost data utilized in the model. This guide also provides basic instruction on model add-in features and a discussion of how the results should be interpreted.

Based on project-specific inputs from the user, the JEDI Fast Pyrolysis Biorefinery Model estimates local (e.g., county- or state-level) job creation, earnings, and output from total economic activity for a given fast pyrolysis biorefinery. These estimates include the direct, indirect and induced economic impacts to the local economy associated with the construction and operation phases of biorefinery projects. Project cost and job data used in the model were derived from the current cost estimations in a design case developed by Pacific Northwest National Laboratory (PNNL) and NREL (Jones et al. 2013). Local revenue and supply chain impacts as well as induced impacts are estimated using economic multipliers derived from the IMPLAN software program. By determining the local economic impacts and job creation for a proposed biorefinery, the JEDI Fast Pyrolysis Biorefinery Model can be used to field questions about the added value biorefineries might bring to a local community.

It is important to note that economic impacts estimated by JEDI - including job creation- are estimates for constructing and operating a hypothetical biorefinery using the fast pyrolysis pathway described in Jones et al. (2013); they should not be interpreted as precise values. It is also worth noting that estimates from the JEDI Fast Pyrolysis Model represent gross economic impacts. The model does not take into account market-driven feedback effects, and it is not meant to estimate the net economic impacts of a biorefinery project.

List of Acronyms

BETO	Bioenergy Technologies Office
DOE	U.S. Department of Energy
FTE	Full-time equivalent
gpm	gallons per minute
GNP	Gross National Product
INL	Idaho National Laboratory
JEDI	Jobs and Economic Development Impact Model
NREL	National Renewable Energy Laboratory
PNNL	Pacific Northwest National Laboratory

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1 Introduction

The Jobs and Economic Development Impact (JEDI) Fast Pyrolysis Biorefinery Model (hereafter referred to as “the model”) is designed to demonstrate the economic impacts associated with developing and operating a stand-alone biorefinery via fast pyrolysis followed by hydroprocessing of the condensed pyrolysis oil to infrastructure-compatible transportation fuels (gasoline blendstock and diesel blendstock) (Jones et al. 2013) in the United States. The model is primarily intended to provide a tool for biorefinery investors and developers, decision makers, policymakers, researchers, and others to identify and understand the potential local economic impacts associated with constructing and operating biorefineries that employ the fast pyrolysis technology pathway. The model allows users to quickly analyze the gross economic impacts and job creation potential of biorefinery construction and ongoing annual operations. The economic impacts are categorized into project development and onsite labor impacts, local revenue and supply chain impacts, and induced impacts, as defined in Section 2. The model does not take into account other market-driven feedback effects. For this reason, the model is not meant to estimate net economic effects of a specific biorefinery project.

This guide describes the general use of the model, details how to interpret output summaries, and outlines technical assumptions and cost inputs used within the model as the default values. While the data incorporates significant uncertainties, in part due to many assumptions used to develop default values, we believe the information presented in the model represents the most detailed and current information available at this time. For questions regarding the JEDI models or model updates, please refer to the Jobs and Economic Development (JEDI) Models home page at <http://www.nrel.gov/analysis/jedi/>.

Strong emphasis was placed on designing the model in a user-friendly format that can be easily modified based on different levels of availability of project-specific information and users’ skills. This format ensures the greatest flexibility for inexperienced users of JEDI models, those unfamiliar with economic impact analysis, as well as more experienced and knowledgeable users who need this specific type of analysis.

2 Model Overview

The model offers users the capability to analyze the economic impacts of a fast pyrolysis biorefinery based on the plant's feedstock rate and production capacity. Given basic information about a fast pyrolysis biorefinery project (minimally, the state in which it is located, the feedstock rate and the production capacity), users can estimate project capital and operating expenditures as well as the number of jobs, income (wages and salary), and economic activity that will accrue locally¹ from the project. To evaluate these impacts, input-output analysis, also commonly referred to as multiplier analysis, is used.

In economics, an input-output model, originally developed by Leontief (1986), is a quantitative economic technique that represents the interdependencies of different branches of a national economy or different regional economies. The structure of the input-output model has been incorporated into national accounting in many developed countries (e.g., United States, and France), and has been used to calculate important measures such as national GDP. Input-output analysis can be thought of as a method of evaluating and summing the impacts of a series of effects generated by an expenditure (i.e., an input). For example, equipment purchases made by a new biorefinery result in increases in output from metal industries, equipment manufacturers, and other industries. The impacts that are ultimately supported by expenditures of a biorefinery depend upon the extent to which those expenditures are spent locally and the structure of the local economy. Consistent with local spending patterns and economic structure, different expenditures support different levels of employment, income, earnings, and output.

To determine the total effect of developing a biorefinery, three separate impacts are examined for each expenditure. Often these effects are referred to as project development and on-site labor impacts (or direct impacts), local revenue and supply chain impacts (or indirect impacts), and induced effects.

- **Project development and on-site labor impacts (or direct impacts)** refer to the on-site or immediate effects created by an expenditure. For example, during construction of a biorefinery, these impacts refer to the on-site contractors and crews hired to construct the plant.
- **Local revenue and supply chain impacts (or indirect impacts)** are the economic activities resulting from expenditures by the project to receive outside products or services. For example, these impacts include the impacts brought about by the bankers who finance the project, and the steel mills and electrical manufacturers that provide the necessary materials to the biorefinery. The indirect economic effect would also apply to the manufacturing of equipment (e.g., vessels, tanks, and heat exchangers) used in the biorefinery.
- **Induced impacts** refer to the effects driven by spending of household earnings by direct and indirect beneficiaries. Induced results are often associated with increased business at local restaurants, hotels, and retail establishments, but also include childcare providers,

¹ Although the model is designed to provide state or national-level analysis, it includes a “User Add-in Location” feature that allows users to import specific county or region-level multipliers and personal expenditure patterns to localize an analysis to a smaller or larger region than the state level. For details about this procedure, refer to Section 5.

service providers and any other entity affected by increased economic activity and spending occurring at the first two tiers (i.e., direct and indirect impacts).

The sum of these three effects yields the *gross* economic effect that results from a single expenditure. No other market-driven feedback effects are taken into account in the model. For this reason, the model is not meant to estimate net economic effects from a specific project.

To accomplish an analysis, economic sectors, whose products/services are demanded by the biorefinery (during construction as well as ongoing operations), were identified for each expenditure, and the appropriate local (e.g., state-level) multipliers were derived for use in constructing the JEDI model.² For example, the state-by-state multipliers for employment, earnings (wage and salary), output (economic activity), and personal expenditure patterns were derived from the IMPLAN Professional model Version 3.0 (IMPLAN 2014) using IMPLAN state data³. The initial version of the model relies on multipliers for the year 2012 for inter-industry relationships and personal consumption patterns. When the project data costs are reported in a dollar year other than the year of the multipliers, such as the default cost data in the model, which is reported in year 2011 dollars, the model automatically adjusts (i.e., inflates or deflates as appropriate) the costs during the internal calculations to insure costs are consistent with the multipliers.⁴ The model results (i.e., for earnings and output) are then automatically readjusted (deflated or inflated) and reported in the same year dollars as the project data costs.

To accommodate the variability in user skill level and availability of project-specific information, the model uses default values representative of a “typical” stand-alone fast pyrolysis biorefinery project that can be changed by the user. The default values represent a reasonable expenditure pattern for constructing and operating a fast pyrolysis biorefinery in the United States based on the design case described in Jones et al. (2013) (a target for 2017) because there is no commercial-scale biorefinery using this technology pathway currently operating in the United States. Admittedly, given the complexity and number of variables associated with constructing and operating biorefineries, it is likely very few projects will follow this exact “default” pattern for expenditures. Many factors influence the installation and operating costs, including: the type(s) of feedstock used, feedstock rate, production capacity, on-stream factor⁵, project location, environmental regulations, financing arrangements, and numerous site-specific factors. Similarly, the availability of local resources, including labor and materials, and the availability of locally manufactured components can significantly affect the costs and the economic impacts that accrue to the state or local region. If the user has and can incorporate project-specific data and the share of spending that is expected to occur locally, the impact analysis will be more localized.

² Multipliers quantify the total production requirements of all industries within a study area necessary to meet industry and household demands resulting from consumption of goods and services from a specified industry.

³ The initial version of the JEDI Biorefinery Model contains multipliers and personal expenditure patterns for 2012, the most current year available at the time the model was released for public use. Default multipliers and expenditure patterns are updated approximately every two years.

⁴ Inflators and deflators utilized in the model are derived from “Table 10.1 - Gross Domestic Product and Deflators Used in the Historical Tables 1940-2017” in *Budget of the United States* (U.S. GPO 2013). Deflators for 2016-2031 assume an average annual inflation rate of 2.0%.

⁵ On-stream factor refers to the amount of time the plant is actually on-line and operating during the year.

3 Inputting Data and Running the Model

The model is designed for all levels of users, requiring minimal experience with biorefineries and background in economic modeling. It includes online instructions explaining how to enter data for analysis as well as informative “comments” that help users understand the type of data required in specific cells. A comment can be viewed by pointing the cursor to the triangle located in the corner of the spreadsheet cell.

The model formulas and default data are locked and protected and user-modified data apply to only the specific analysis a user performs while the model is open. If unwanted changes are made, click on the “Restore Default Values” button on the Project Data page or simply close the model and reopen it to start over with the initial model default values.

3.1 Getting Started

The model is an Excel-based model. To begin using it, simply open the Biorefinery JEDI Excel file.⁶ The JEDI Model opens to the “Start” tab, which briefly explains the model’s applications and outlines the required steps to complete an economic impact analysis (see Figure 1):

- To learn more about the model version and a brief background on the development of the model, click on the “About JEDI” tab.
- To begin a JEDI analysis, either click on the “Start Economic Impact Analysis” button on the “Start” tab (Figure 1) or go to the “Project Data” tab.

⁶ The JEDI model utilizes macros to assist users with navigating throughout the spreadsheet and between worksheets, and to perform specific tasks using control buttons. Depending upon your computer’s security settings, upon opening the model, you may be prompted to “enable macros” to allow you to use the control buttons. If you choose not to, the model will still function and provide analytical results, but the buttons will not function.

JEDI - Biorefinery

Fast Pyrolysis and Upgrading Plants

Jobs and Economic Development Impact Model

This demonstration model is designed to estimate the statewide economic impacts associated with developing and operating biorefineries using fast pyrolysis and upgrading (hydrotreating and hydrocracking) to produce diesel and gasoline fuels in the United States. The economic impacts identified include jobs, earnings, and output for the construction period and annually once the refinery is up and running. A user defined "add-in" location (e.g., county or region) option is also available.

Steps to complete an economic impact analysis:

1. Enter project descriptive data
2. Choose to perform a simple analysis, to accept default project cost data (based on project descriptive data entered), or an advanced analysis, to review and enter new project data.
3. If you choose simple analysis, after entering project descriptive data, go directly to SUMMARY RESULTS to view, save and/or print results.
4. If you choose advanced analysis, after entering project descriptive data, review and edit detailed project cost data before going to SUMMARY RESULTS.

To begin analysis press Start button

Start
Economic Impact Analysis

Figure 1. Starting page of the JEDI Fast Pyrolysis Biorefinery Model.

3.2 Entering Model Inputs

To accommodate a broad user base with a wide range of knowledge about biorefinery projects, two input options are available: a “simple” and “advanced” input option. Using either option, a user can choose the number and detail of user inputs accessible in the model (see Figure 2):

- **Simple Input Option:** For users with little or no experience with biorefineries or economic impact analysis, the simple option requires minimal inputs such as the state in which the biorefinery will be located, the year in which construction starts, feedstock input rate, and production capacity. If additional information about a specific biorefinery project – such as the on-stream factor, feedstock type(s) and local availability, and delivered feedstock prices – is available, users are allowed to enter the details as well. Because such details significantly impact the costs of developing and/or operating a biorefinery, the user is encouraged to enter as much detail as possible about the project.
- **Advanced Input Option:** An advanced input option is available for users with more experience and knowledge of a specific biorefinery project allowing them to provide additional project details. The primary difference between the simple model and advanced input options involves the user’s ability to edit detailed model input data. The simple model uses a set of cost estimates based on the design case documented in Jones et al. (2013) and does not allow changes to any of the detailed default cost data. The advanced option allows the user to override default inputs for all equipment and cost components of the biorefinery development.

Fast Pyrolysis and Upgrading Plant (Stand-Alone) Project Data

Please read instructions before getting started

INSTRUCTIONS:

1. Begin by entering Project Descriptive Data. Choose Project *Location* (from pull-down list) and other parameters relevant to your project.
2. Once Project parameters are entered (lines 15-33), you may choose to perform a "Simple" analysis or an "Advanced" analysis.
Choosing "Simple" Analysis indicates use of Model defaults, no editing of detailed cost data and other inputs.
Choosing "Advanced" Analysis allows user to review and edit detailed cost data and other inputs.
3. Once Descriptive Data is complete, if Simple Analysis is chosen, go to Summary Results; if Advanced Analysis is chosen, cursor down to review/edit detailed cost data and inputs below.

NOTE: Additional information is available by pointing to the red triangles located in cell corners. Only those cells with a white background can accept new values.

Project Descriptive Data

Project Location	Iowa				
Year Construction Starts	2015				
Construction Period (Months)	36				
Plant Feedstock Rate (U.S. Tons/Day)	2,205				
Plant Production Capacity (Mil. Gal./Year)	60.6				
On-Stream Factor	90%				
Operating Hours per Year	7,884				
Fuel Produced (Type)	Gasoline Blendstocks				
Feedstock (Type)	Pulpwood	Logging Residue	Switchgrass	C&D Waste	Total
Percent of Total	45.0%	32.0%	3.0%	20.0%	100%
Cost of Dry Feedstock (\$/Ton Delivered)	\$99.49	\$67.51	\$66.68	\$58.12	\$80.00
Feedstock Required (Annual Dry U.S. Tons)	325,954	231,790	21,730	144,869	724,343
Feedstock Delivered Cost	\$32,429,176	\$15,648,116	\$1,448,975	\$8,419,757	\$57,946,024
Produced Locally (Percent)	100%	100%	100%	100%	
New Production (Percent)	100%	100%	100%	100%	
Money Value (Dollar Year)	2011				

Figure 2. Project Data page of the model.

Model updates are incorporated in the analysis instantaneously as the user inputs are entered. Once project descriptive data input is complete, the user can go to the "Summary Results" page to view the results of the analysis by clicking on the "Go To Summary Impacts" button. The model calculates the total project cost and estimates the number of jobs and other economic impacts supported throughout the construction/development and annual operating phase. The model estimates only the impacts that accrue to the state or defined region being analyzed. These economic impacts and job creation values are estimates for constructing and operating a hypothetical biorefinery; 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. If a hard copy is desired, users can 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 (see Figure 3). Alternately, users can export the data and results to a separate Excel file by clicking the "Export" button. Users that wish to save the entire model (with the user-modified data) for future use or reference should choose "Save As" from the Excel menu, rename the model, and choose a directory. Changing the file name ensures the original model (with model defaults) is kept intact for future analysis. Users always have the option to simply "select" and "copy" any desired cells to another spreadsheet or document.

Fast Pyrolysis and Upgrading Plant - Project Data Summary based on Advanced Analysis - User Revised Data

Project Location	Iowa		
Year Construction Starts	2015		
Construction Period (Months)	36		
Print Project Data Summary and Summary Results			
Plant Feedstock Rate (U.S. Tons/Day)	2,205		
Plant Production Capacity (Mil. Gal./Year)	60.6		
On-Stream Factor	90%		
Fuel Produced (Type)	Diesel and Gasoline Blendstocks		
Feedstock (Type)	Pulpwood Logging Residue Switchgrass C&D Waste		
Feedstock Required (Annual Dry U.S. Tons)	724,343		
Cost of Dry Feedstock	\$57,946,024	\$80 per ton	
Money Value (Dollar Year)	2011		
Print Detailed Project Data			
Project Construction Cost	\$714,697,508		
Local Spending	\$468,753,524		
Total Annual Operational Expenses	\$234,142,398		
Direct Operating and Maintenance Costs	\$127,631,394		
Local Spending	\$100,101,346		
Other Annual Costs	\$106,511,004		
Local Spending	\$0		
Debt and Equity Payments	\$0		
Property Taxes	\$0		
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 (Millions)	Output (Millions)
During construction period			
Project Development and Onsite Labor	2,454	\$274.7	\$367.2
Other Onsite Construction Related Services	702	\$28.5	\$66.5
Subtotal	3,156	\$303.3	\$433.7
Local Revenue and Supply Chain Impacts	1,172	\$59.9	\$170.9
Induced Impacts	1,218	\$50.5	\$152.6
Total Impacts	5,546	\$413.8	\$757.1
During operating years (annual)			
Onsite Labor Impacts	83	\$4.8	\$4.8
Local Revenue and Supply Chain Impacts	132	\$8.1	\$38.8
Induced Impacts	76	\$3.3	\$9.8
Total Impacts	291	\$16.1	\$53.4

Notes: Earnings and Output values are millions of dollars in year 2011 dollars. Construction period related jobs are full-time equivalent and represent the total number of jobs for the 36 month construction period. Plant workers includes operators, maintenance, lab techs, administration and management. Economic impacts "During operating years" represent impacts that occur from plant operations/expenditures. The analysis does not include impacts associated with spending of plant "profits" and assumes no tax abatement unless noted. Totals may not add up due to independent rounding.

Figure 3. Project data summary and summary of local economic impacts⁷ from a model run for an Iowa biorefinery.

3.4 Accessing and Viewing Model Work Areas

To help ensure the JEDI model is as user-friendly as possible and to adhere to strict licensing restrictions on proprietary data contained in the model, several of the intermediate work areas have been hidden from view. These areas include: default data, calculations, deflators, household expenditures, multipliers and the specific cost calculation work areas. If desired, all intermediate work areas, with the exception of the multipliers and household expenditures (derived from IMPLAN), can be viewed by clicking on the respective worksheet and scrolling to the right. Viewing the worksheets will not affect the operation of the model. *Please note: The data and formulas contained in all work areas are locked and protected (except those specifically designed to accept user input) and should not be modified. Modifying any of the data or formulas could seriously impact the accuracy or usability of the model.*

⁷ Due to continuous updates and improvements to the JEDI model, it may not be possible to exactly reproduce the results of the model run shown here.

4 Interpreting the Results

Regardless of whether or not project-specific data is entered by the users, JEDI provides sufficient information to help users better understand the magnitude of the economic impacts associated with the project being analyzed. The model results summarize basic project information such as the magnitude of the construction-related spending and ongoing annual O&M expenditures. The model results also identify the portion of the construction spending that occurs locally (determined by the “local share” values—default or user-modified—used in the model for each of the expenditures). Similarly, the model results show local spending on debt and equity payments, and property and sales tax if applicable.

4.1 Economic Impacts and Job Creation

In addition to the basic project information and costs, the model analyzes and reports the local jobs, earnings and output (economic activity) supported as a result of 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, local revenue and supply chain impacts, and induced impacts.

For example, users interested in understanding the job and economic impacts from developing a biorefinery with an annual capacity of 60.6 million gallons of transportation fuels (28.9 million gallons of gasoline blendstock and 31.7 million gallons of diesel blendstock) per year in Iowa, built in the year 2015, can quickly obtain the results by using the JEDI model. The feedstocks included in the JEDI model are pulpwood, logging residues, switchgrass, and a subset of construction and demolish waste. For example, Figure 3 shows a jobs and economic impact summary for a 60.6 million gallon refinery (simple model option) constructed in 2015 in Iowa. The results indicate that during the construction period (36 months), the project supports 3,156 direct full-time equivalent (FTE)⁸ jobs (associated with project development and all onsite field services), and 1,172 indirect FTE jobs (associated with local revenue and supply chain) throughout the state of Iowa. In addition, the construction of the project is expected to generate 1,218 induced FTE jobs due to the increased economic activities and demands by direct and indirect workers. In all, project construction is estimated to generate over \$417 million in total earnings and \$762 million in total economic activity (both in 2011 dollars).

Once the biorefinery is up and running, 83 full-time plant operations and maintenance jobs (or direct jobs) are estimated to be supported by the annual operation over the entire economic life of the facility [30 years per the design case by Jones et al. (2013)]. 132 indirect jobs are expected to be supported through local revenue and supply chain activity and additional 76 induced jobs are supported through induced impacts. A total of 291 FTE jobs are estimated to be supported **annually** by the biorefinery during the 30 year economic life of the facility.

4.2 Comparing Results Among JEDI Models for Different Technologies

The suite of JEDI models can be used to compare job and economic impacts of constructing and operating several transportation fuel refineries, including dry mills, which produce ethanol from

⁸ Job calculations are based on a full time equivalent (FTE) basis for a year. One FTE job = 2080 hours worked in a year by one person full time or several persons part-time.

corn, cellulosic ethanol biorefineries using biochemical or thermochemical technology pathways, and petroleum refineries, which produce conventional diesel and gasoline.

When comparing the economic development impacts for different technologies using their respective JEDI models (e.g., JEDI Corn Ethanol Model and JEDI Petroleum Refinery Model), it is best to compare between facilities with equivalent production capabilities (e.g., annual production capacity) rather than merely comparing two facilities. For example, it is more reasonable to compare jobs per million gallons of gasoline equivalent for final products from either a petroleum refinery or a biorefinery, rather than jobs per refinery.

4.3 Caveats

Several important caveats should be noted at this point. First, the intent of the JEDI Fast Pyrolysis Biorefinery Model is to provide a reasonable profile of expenditures associated with the construction and operation of a biorefinery and demonstrate the magnitude of the gross economic impacts⁹ that would likely result, assuming a project occurs during the stated period of analysis. Given the unique nature of each biorefinery and the changing nature of the industry, the cost data used in the model is not intended to replace project-specific engineering estimates. Consistent with this approach, the analysis is not intended to provide a precise forecast of expected impacts. Rather, the analysis should be viewed as an **estimate** of the overall magnitude of the impacts.

Second, the JEDI Fast Pyrolysis Biorefinery Model is considered 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 feedback through demand increases or reductions that could result from price changes. Similarly, the model does not account for feedback from inflation, or potential constraints on labor, goods, or money supplies. The model assumes there are adequate local resources and production and service capabilities 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 and maintenance processes (e.g., requirement for labor and materials) for new biorefineries.

Third, the JEDI Fast Pyrolysis Biorefinery Model was not designed to provide cash flow projections or for use as a cash flow analysis tool.

Fourth, the analysis assumes the outputs from the biorefinery operations and the revenues generated from these outputs are sufficient to accommodate the equity and debt repayment and annual operating expenditures. To the extent additional revenues (i.e., sale of by-products or profits and tax advantages above actual costs) accrue to the project owner, there will be added benefits. These benefits are not included in the analysis.

⁹ The JEDI models do not estimate the displaced jobs, earnings, and output related to alternative investments or increases or decreases in jobs related to changes in prices of refinery products, associated revenues or consumer energy bills, among other impacts. Therefore, the estimates represent gross rather than net impacts.

5 User Add-in Location Feature

The initial design of the JEDI model provided for state-level impact analysis. However, it was apparent that many potential users might wish to perform a similar level of analysis for a smaller or more localized region (e.g., an individual county or group of counties) or for a larger region (e.g., Midwestern region) to better capture the regional benefits. Unfortunately, the high cost of including multiplier and expenditure data in the model for every county in the United States and the complexities associated with designing the model to analyze the endless number of possibilities for combining counties and states made this impractical.

To accommodate users who desire to do this level of analysis, a User Add-in Location feature is provided in the model. This feature allows users with the capability to derive or obtain the necessary data to complete analysis for a specific region of interest other than the state level included with the base model. The necessary inputs include direct, indirect, and induced multipliers for employment, earnings and output (per million dollars change in final demand), and personal consumption expenditure patterns (i.e., average consumer expenditures on goods and services—calculated as a percentage for each industry) for the aggregated¹⁰ industries and the 432 IMPLAN unaggregated industry sectors (IMPLAN 2014).¹¹ The aggregated industries include:

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 the following steps:

¹⁰ Aggregated multipliers are used when the expenditures being analyzed do not clearly fit into a specific industry or multipliers for the specific industry are unavailable. When the expenditure clearly fits into a specific industry where the multipliers are available, the unaggregated multipliers for the target industry are used.

¹¹ For more detail on the IMPLAN industry sectoring, see the IMPLAN documentation available on the IMPLAN website at http://implan.com/index.php?option=com_content&view=article&id=633:633&catid=241:KB23.

1. Purchase the desired county- or regional-level data files
2. Using IMPLAN Version 3 software or the most current available, create a new model for the desired county or region (e.g., a group of counties or states)
3. Construct the model¹²
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 unaggregated portion of the respective location (MyCounty for a single county or MyRegion for a group of counties or states) in the User Add-in Location worksheet in the JEDI
6. Aggregate the model. This step requires the user to create a new 14-industry aggregation scheme to aggregate the new model. The JEDI aggregation template used to aggregate the state multipliers into the 14 industries noted above is available by request from NREL¹³
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 aggregated portion of the respective location (MyCounty for a single county or MyRegion for a group of counties or states) in the User Add-in Location worksheet in JEDI.

Once data is entered into the JEDI model, the user needs to identify the location of the biorefinery (in the project description section of the ProjectData worksheet) as MyCounty or MyRegion, depending upon the type of data and where the data is entered, and then 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. These include:

1. Follow a similar process as that noted above to derive the aggregated and unaggregated multipliers and consumer expenditure data (aggregated) from another input-output modeling tool.
2. Purchase the necessary data (aggregated and unaggregated multiplier and consumer commodity demand—see description above) from the IMPLAN Group, Inc. (IMPLAN 2014).
3. Purchase the necessary data (aggregated and unaggregated multiplier and consumer commodity demand—see description above) from MRG & Associates, one of the JEDI model developers.

¹² See the IMPLAN software online reference manual for more detail on constructing models (IMPLAN 2014).

¹³ Contact NREL at JEDISupport@nrel.gov.

6 Data Sources and Cost Categories

Analyzing the economic impacts of constructing and operating biorefineries requires a large amount of project-specific data as well as economic data. The data includes feedstock rate, types of biomass feedstock, share of each feedstock and its cost, detailed project capital costs, labor rates, location specific input-output multipliers and personal expenditure patterns, and price deflators to insure consistency of project costs with industry multipliers used in the analysis,¹⁴ among others. Project-specific differences such as feedstock rate, types and costs of feedstock, production capacity, on-stream factor, and availability of equipment and specialized labor can significantly impact costs. Similarly, the year in which the costs are reported in the analysis (e.g., equipment costs from year 2008, in 2008 dollars, versus equipment costs from 2011, reported in 2011 dollars) can have a significant impact on analyzing the economic impacts. As a result, it is not possible to identify a “one size fits all” scenario. As of the writing of this report, no commercial-scale fast pyrolysis biorefineries had been built in the United States and developers generally consider project financial data proprietary due to competitive forces in the marketplace. The limited availability of detailed project cost data makes efforts to analyze the economic impacts even more difficult. Given the complex nature of developing cost estimates for biorefineries, and the lack of detailed cost data publicly available, the default cost data for various cost categories was derived primarily from the design case described in Jones et al. (2013) along with other references (Davis et al. 2013, Peters et al. 2013), which document design cases for biorefineries using advanced yet developing biofuel technology pathways or present economic principles as applied in chemical engineering processes and operations.

Building on the construction and operations and maintenance parameters and associated costs derived from these references, the JEDI model provides default values for all inputs necessary to perform an analysis for a fast pyrolysis biorefinery with a feedstock rate of 2,000 metric tons per day of dry biomass. The following defines some key parameters and model inputs used throughout the JEDI model, and provides a brief description of approaches employed to estimate these parameters.

6.1 Feedstock Rate

Plant feedstock rate (f_r) refers to the input or feed processing capacity of the biorefinery. The feedstock rate varies by biorefinery design and strategic decisions related to projected fuel demand, resource availability and costs among other factors. The default feedstock rate used in the model is 2,205 dry short tons per day (2,000 dry metric tons per day). Although fast pyrolysis of biomass is being commercialized, upgrading the pyrolysis oil to transportation fuels (blendstocks) is still an emerging technology (Jones et al. 2013). As a result, there is no standard or typical capacity for a fast pyrolysis biorefinery of this type. Users are required to input a feedstock rate or accept the default value. In addition to being the key factor for calculating the amount of feedstock required annually and the overall refinery production capacity, the feedstock rate provides the basis for scaling of process equipment costs.

6.2 Production

Production (p) refers to the amount (e.g., volume) of products that can be generated by a biorefinery in a year. Based on the feedstock rate noted above, and estimated biofuel yields, the

¹⁴ For a summary of how the model adjusts for cost differences see section 3.2 Model Overview, in this Guide.

default production for the plant is calculated to be 60.6 million gallons per year of combined gasoline and diesel blendstocks, which include 28.9 million gallons of gasoline blendstock and 31.7 million gallons of diesel blendstock.¹⁵ It is estimated that the fast pyrolysis process yields 39.9 gallons of gasoline blendstock and 43.7 gallons of diesel blendstock from each dry ton of biomass feedstock (Jones et al. 2013). Production is calculated as:

$$p = (39.9 * fr * 365 * os) + (43.7 * fr * 365 * os)$$

Where;

feedstock rate (*fr*) = 2,205 tons per day

on-stream factor (*os*) = 0.90

Users are required to input a production capacity or accept the default value if desired.

6.3 On-stream Factor

On-stream factor (*os*) refers to the actual time during a year a plant is operating. The factor is expressed as a percentage in the JEDI model, with 100% implying the plant is operating 24 hours per day 365 days per year. The default on-stream factor used in the JEDI model is 90% (Jones et al. 2013), indicating the plant operating time (*ot*) is 7,884 hours per year. Plant operating time is calculated as:

$$ot = 365 * 24 * os$$

Users are required to input an on-stream factor or accept the default value.

6.4 Feedstock Costs and Specifications

Feedstock costs and specifications refer to the aggregate delivered cost (\$/dry ton) for all biomass feedstocks utilized in the biorefinery. Table 1 provides the detailed cost categories for each stage involved in harvesting, processing and transportation for each of the default feedstock types incorporated within the JEDI model (Cafferty et al. 2014).¹⁶ In addition, the table indicates the default share (i.e., percentage of total) for each feedstock. The values in the table are used to allocate the feedstock costs among different economic sectors within the analysis.

¹⁵ The default total production value (60.6 million gallons) differs slightly from that reported in Jones et al. 2013 (60.5 million gallons) due to independent rounding of values.

¹⁶ The feedstocks types, costs and share of total for the default analysis are based on the latest 2017 Idaho National Laboratory design case (Jacobson et al. 2014), updated from the blend described in Cafferty et al. 2014 and Jones et al. 2013.

Table 1. Cost Categories for Biomass Feedstocks Delivered to the Biorefinery (Default Values)

Cost Category	Pulpwood	Logging Residues	Switchgrass	Construction and Demolition Waste (C&D)	Blend
Grower/Provider payment	\$25.00	\$26.35	\$19.67	\$8.15	\$21.90
Harvest and collection	\$22.24	\$0.00	\$15.41	-	\$10.47
Landing Preprocessing/Sorting	\$12.17	\$8.73	\$0.00	\$9.85	\$10.24
Transportation	\$10.98	\$3.33	\$4.50	\$6.87	\$7.52
Preprocessing	\$23.97	\$23.97	\$19.70	\$28.12	\$24.67
Storage	\$3.23	\$3.23	\$5.50	\$3.23	\$3.30
Handling	\$1.90	\$1.90	\$1.90	\$1.90	\$1.90
Total Delivered Cost	\$99.49	\$67.51	\$66.68	\$58.12	\$80.00
<i>Percent of Total</i>	<i>45%</i>	<i>32%</i>	<i>3%</i>	<i>20%</i>	<i>100%</i>

Note: All costs are in dollars per dry short ton. Logging residues costs do not include costs associated with harvest and collection; these are attributed to the merchantable portion of the tree. Cost estimates are derived from Jacobson et al. (2014), BETO (2014) and Cafferty (2015).

Users are required to input (or accept the default values of) the delivered cost (dollars per dry short ton) and the share (percentage) each feedstock (*fs*) type contributes to the feedstock blend (see Figure 4). The annual amount of feedstock is based on the biorefinery feedstock rate. Figure 4 shows an example for model inputs used to estimate feedstock costs delivered to the biorefinery.

The total annual amount of feedstock (*af*) required (in dry short tons) is calculated as:

$$af = fr * 365 \text{ days per year} * os$$

The annual cost of feedstock (*afc*) for each feedstock type is calculated as:

$$afc = af * fs$$

Users must also input (or accept default values) the amount of each feedstock that is produced locally (i.e., in the area being analyzed) and the portion of that locally produced share that is new production. New production of biomass feedstock refers to new plantings that do not reduce plantings of other crops or offset existing uses or revenues (i.e., not surplus or crops being sold elsewhere). For the subset of construction and demolition (C&D) waste, new production refers to waste not already being sold for other uses.

Feedstock (Type)	Pulpwood	Logging Residue	Switchgrass	C&D Waste	Total
Percent of Total	45%	32%	3%	20%	100%
Cost of Dry Feedstock (\$/Ton Delivered)	\$99.49	\$67.51	\$66.68	\$58.12	\$80.00
Feedstock Required (Annual Dry U.S. Tons)	325,954	231,790	21,730	144,869	724,343
Feedstock Delivered Cost	\$32,429,176	\$15,648,116	\$1,448,975	\$8,419,757	\$57,946,024
Produced Locally (Percent)	100%	100%	100%	100%	
New Production (Percent)	100%	100%	100%	100%	

Figure 4. JEDI model feedstock data input section from Project Data page.

6.5 Construction and Operations and Maintenance Costs

In addition to the biorefinery project descriptive data noted above, the model includes a bill of goods (e.g., detailed costs associated with actual construction of the facility, roads, storage tanks, costs for equipment and other services required), annual operating and maintenance costs, data on the portion of expenditures spent locally, financing terms and tax rates, and a location adjustment factor, among others.

A location adjustment factor, specific to the state where the biorefinery is built, is automatically applied to all construction expenditures within the model to account for differences in labor costs due to variations in state construction sector earnings.¹⁷ Both the simple and advanced model options incorporate the location adjustment factor in the analysis; however, if the user has more localized or current information on plant equipment or other costs in the state or region being analyzed, the detailed cost can be changed by choosing the advanced option.

More specifically, the model incorporates the following key project-specific inputs:

1. Site development costs
2. Process unit costs
3. Infrastructure costs
4. Labor costs
5. Other costs
6. Sales tax
7. Annual operating and maintenance costs (fixed – labor, maintenance and other materials and services, and variable – disposal, chemicals and catalysts, utilities, and feedstocks)
8. Local shares.

6.5.1 Site Development Costs

Site development costs (*sdc*) include civil engineering and other construction-related activities not included in the process unit installation or infrastructure. Among others, the site development costs include: fencing, curbing, roads, parking lots, drainage, rail system (if applicable), and general paving. Site development costs are calculated as a fixed percentage of the total installed equipment (process units) cost (*tiec*) (Jones et al. 2013).

$$sdc = tiec * 0.10$$

Users may override the default site development costs in the advanced model option and input their own cost if desired.

¹⁷ The location adjustment factor is based on analysis of average construction sector earnings per job in each state and the base default cost data. The earnings data is derived from the IMPLAN state construction sector multiplier data developed for the JEDI model.

6.5.2 Process Unit Costs

Process unit costs refer to the process units (i.e., equipment) only and do not include installation-related costs, which are accounted for in labor costs. Equipment costs are based on a baseline cost and scaling factor. The basis for scaling is typically some characteristic of the equipment related to production capacity (f) such as flow or heat duty (Davis et al. 2013). As facility capacity and flow change, equipment costs (ec) are adjusted using appropriate scaling factors (b) and the baseline costs (a) obtained from vendor quotes. The JEDI model includes adjusted equipment costs for different production capacities based on scaling factors and baseline costs presented in Jones et al. (2013). Scaling factors range from 0.34 to 0.79, with most equipment scaling factors between 0.6 and 0.7. The cost for a new piece of equipment is calculated as:

$$ec = a * (f_i/f)^b$$

Where;

ec = cost of new equipment

a = baseline cost

f_i = size of new equipment

f = size of baseline equipment

Adding up the equipment costs within a process unit yields the process unit costs. Users may override the process unit costs (default values) in the advanced model option and input their own unit costs if desired.

6.5.3 Infrastructure Costs

Infrastructure costs (ic) include costs for general infrastructure and buildings, and additional piping. Each of the infrastructure costs is calculated as a fixed percentage of the total equipment (process unit) costs (tec) (data are derived from Jones et al. 2013). The infrastructure cost for general infrastructure and buildings (ic_b) is calculated as:

$$ic_b = tec * 0.04$$

The infrastructure cost for additional piping (ic_p) is calculated as:

$$ic_p = tec * 0.045$$

Users may override the infrastructure cost defaults in the advanced model option and input their own system costs if desired.

6.5.4 Labor Costs

Labor costs (lc) include the labor portion of the total installed costs for each process unit, and encompass both skilled and general labor, as well as the associated employer costs (social security, workers compensation, benefits, etc.). Labor costs are calculated as a function of the equipment (process unit) cost (ec), the installation factor (if) and the location adjustment factor (la). Installation factors vary from as low as 1.09 for some compressors to as high as 9.73 for a steam generator (Jones et al. 2013). The labor costs are calculated as:

$$lc = (ec*if*la)-ec$$

Users may override the labor cost defaults in the advanced model option and input their own labor costs if desired.

6.5.5 Other Costs

Other costs (oc) include field expenses, home office and miscellaneous construction expenses, other expenses (e.g., permits and fees), insurance and land. The JEDI model assumes other costs plus site development costs represent added direct costs and are approximately 81% of the combined cost of total installed equipment costs (*tiec*) and infrastructure costs (*ic*) (Jones et al. 2013). Field expenses (*fe*), home office and construction expenses (*hoe*), and other expenses (*oe*) are assumed to have a ratio of 1:2:1 (Davis et al. 2013). These other costs are calculated as a function of the total direct costs (*tdc*) minus site development costs (*sd*), insurance expense (*ine*) and land expense (*le*), and the ratio (expressed as a percentage of the total) for each of the individual cost categories. Insurance costs are calculated as a fixed percentage of the sum of total installed equipment costs and infrastructure costs; land expenses are calculated as a fixed percentage of the total equipment (process unit) costs (*tec*) (Jones et al. 2013).

Insurance expense is calculated as:

$$ine = (tiec+ic)*0.004$$

Land expense is calculated as:

$$le = tec*0.005$$

The field expenses are calculated as:

$$fe = ((tiec+ic)*.81-(sd+ie+le))*fer$$

Where;

$$\text{field expense ratio } (fer) = 1/(1+2+1)$$

The home office and construction expenses are calculated as:

$$hoe = ((tiec+ic)*.81-(sd+ie+le))*hoer.$$

Where;

$$\text{home office and construction expense ratio } (hoer) = 2/(1+2+1)$$

The other expenses are calculated as:

$$oe = (tiec+ic)*.81-(sd+ie+le))*oer.$$

Where;

$$\text{other expense ratio } (oer) = 1/(1+2+1)$$

Users may override the defaults for any other costs in the advanced model option and input their own costs (in dollars) for any of the cost categories.

6.5.6 Sales Tax

The model assumes sales tax is paid on all materials and equipment purchases made during construction and annual ongoing operations. The default sales tax rate is calculated based on the state in which the biorefinery will be located. Similarly, the model incorporates a sales tax exemption if applicable.¹⁸ Both values are set within other parameters under tax parameters on the Project Data page in the JEDI model.

Users may override the sales tax and exemption default values in the advanced model option and input their own values (in percentages) for both categories.

6.5.7 Annual Operation and Maintenance Costs

Once a biorefinery is operational, there are annual fixed and variable operation and maintenance costs.

6.5.7.1 Fixed Costs

Fixed costs are costs that are independent of output, including labor, basic maintenance materials, services, and insurance and taxes.

Labor Costs

Labor cost includes salaries and employer costs for all staff employed on-site to operate and maintain the facility. Figure 5 provides the default labor parameters used to determine total staffing costs and the number of positions/staff required, assuming the biorefinery will be located in Iowa. The on-site position and staff requirements are derived from Jones et al. (2013).

¹⁸ Sales tax rates are derived from state Department of Finance websites as of January 2014. Sales and property tax exemptions are based on the Database of State Incentives for Renewables & Efficiency (DSIRE) (<http://www.dsireusa.org/>).

Labor Rates and Positions	Annual Salary	Number of Positions Required
Manager	\$156,983	1.0
Engineer	\$74,698	1.0
Maintenance Supervisor	\$60,887	1.0
Maintenance Technician	\$42,698	16.0
Lab Manager	\$59,817	1.0
Lab Technician	\$42,698	3.0
Shift Supervisor	\$51,258	5.0
Shift Operators	\$51,258	40.0
Yard Employees	\$29,860	12.0
Clerical and Secretaries	\$38,419	3.0
Total		83.0

Figure 5. Default values for the number of positions required and labor rates for Iowa (on the Project Data page of the JEDI model).

Labor costs are based on annual salaries (s) for each position (adjusted for location), employer labor-related overhead, and the number of positions required (p). The default labor multiplier (o) is 1.28, accounting for a labor overhead of 28% (Bureau of Labor Statistics 2014). A scaling factor (b), which varies depending upon whether the number of a particular position is affected by the production capacity of the biorefinery, is applied to all positions (Peters et al. 2003). The labor expense for each position (lcp) is calculated as:

$$lcp = s * la * o * (p * (c_1/c)^b)$$

Where;

$$Lcp = \text{labor expense}$$

$$s = \text{annual salary for each position}$$

$$la = \text{location adjustment}$$

$$c_1 = \text{production capacity of a new biorefinery (million gallons per year)}$$

$$c = 60.6 \text{ million gallons per year (default baseline production capacity)}$$

$$b = 0.225 \text{ for positions, including maintenance technicians, lab technicians, shift operators and yard employees}$$

$$b = 0 \text{ for positions other than those, for which } b = 0.225$$

Users may override the default annual salary and number of positions required in the advanced model option and input their own costs (in dollars) for any of the positions if desired.

All on-site operation and maintenance jobs estimated in the results summary of the JEDI model are considered **annual** full-time equivalent (FTE) jobs, sustaining for the entire economic life of the biorefinery. It should be noted that a biorefinery may use part-time employees and the optimal staff size may vary by location and refinery configuration.

Maintenance Costs

Maintenance cost (m) includes materials only; maintenance labor is accounted for under labor costs. The maintenance cost is calculated as a fixed percentage of total fixed capital investment (fci) (Jones et al. 2013).¹⁹ Maintenance cost is calculated as:

$$m = fci * .03$$

Service Costs

Service costs are included as a cost category in the JEDI model, however, there is no specific default value for this cost category in the model. Users may input their own service cost (in dollars) if the costs are not included elsewhere within another category.

Insurance and Taxes

Insurance and taxes (it) are calculated together as a fixed percentage of total fixed capital investment (Jones et al. 2013). Insurance and taxes are calculated as:

$$it = fci * .007$$

6.5.7.2 Variable Costs

Variable costs are costs that vary with output. Variable costs include disposal of ash, water and solid waste, as well as expenditures for chemicals and catalysts, utilities, and feedstocks. The cost for each of these inputs (vci) is calculated based on the respective usage rate (u), cost factor (cf) and the appropriate annual output (e.g., gallons per year) or operating hours (hours per year).

For example, in calculating ash disposal costs, where the disposal rate is 6,704 pounds per hour (lb/hr), the cost factor is \$18 per ton of ash, and the annual operating hours are 7,884 hours (taking into account a 90% on-stream time). The disposal costs for ash are estimated as:

$$6,704 * 18 * 7,884 / 2000 = \$475,689 \text{ per year}$$

Figure 6 provides the default values on usage rates and cost factors for each of the respective input types (Jones et al. 2013). The annual costs are automatically calculated based on the usage rate and cost factor data (default or user revised). Alternately, users may enter the Annual Cost rather than the usage rate and cost factor (necessary for the automatic calculation).

Feedstock costs are also considered a variable cost. As noted in the Feedstock Costs and Specifications section (Section 6.4), the annual costs are calculated based on feedstock data (default or user revised) contained in the Project Descriptive data area.

¹⁹ Fixed Capital Investment refers to all construction costs, including site development, process units, infrastructure, labor and other costs (field expenses, home office and construction, other (permits, fees, etc.), insurance and land). It does not include costs associated with contingency.

Other Resource Inputs	Usage Rate	Cost Factor	Annual Cost
	lb/hr	\$/ton	
Ash Disposal	6,704	\$18.00	\$475,685
Solid Waste Disposal	17	\$18.00	\$1,205
	cuft/hr	\$/100 cuft	
Wastewater Disposal	142	\$2.07	\$23,110
	lb/hr	\$/lb	
Chemicals and Catalysts			
Stabilizer Catalyst	14.0	\$60.00	\$6,604,233
1st Bed Catalyst	14.0	\$60.00	\$6,604,233
2nd Bed Hydrotreating Catalyst	50.3	\$15.50	\$6,141,656
Hydrocracking Catalyst	0.8	\$15.50	\$102,865
	scf/hr	\$/1000 scf H ₂	
Hydrogen Plant Catalysts	18,526	\$3.60	\$525,811
	lb/hr	\$/lb	
Sulfiding Agent	0.00	\$0.80	\$0
Cooling Tower Chemicals	0.24	\$1.98	\$3,756
Boiler Feed Water Chemicals	2.20	\$2.78	\$48,198
Chemicals and Catalysts Subtotal			\$20,030,752
Utilities	kWh/gal.	\$/kWh	
Purchased Electricity	1.3	\$0.07	\$5,298,747
	gpm	\$/1000 gals	
Water			
Boiler Feed Water Makeup	162.0	\$1.0008	\$76,694
Cooling Tower Water Makeup	29.0	\$1.0008	\$13,729
Water Subtotal			90,422.9
	scf/gal.	\$/1000 scf	
Natural Gas	20	\$5.10	\$6,176,613
Utilities Subtotal			\$11,656,206

Figure 6. Default values for the Other Resource Inputs (on the Project Data page of the JEDI model).

6.6 Local Share

A local share (percentage) is required to determine the economic impact that will accrue to the state or geographic area being analyzed over the project lifetime. If a service or material is available in the state or geographic area, in which the project is located, then a percentage is assigned based on the availability of that service or material. For example, site development during the biorefinery construction phase will likely be sourced locally. As such, a 100% local share can be assumed for the costs associated with site development. Conversely, a state or geographic area being analyzed may not have an engineering firm familiar with pipeline techniques. Therefore, a 0% local share may be assigned to the costs associated with piping.

In general, JEDI assumes that activities that do not require specialized skills, such as construction and general labor, are locally sourced. The same is true for materials that are widely available such as cement and water. States that have an established track record of oil and gas or biorefinery operations, such as Texas or California, typically offer many of the services, equipment, and materials required in a biorefinery project. If one of these states is chosen as the

project location, then a higher local impact will be likely be realized compared to a project located in a state without an established refinery industry.²⁰

Although the model contains default local share values, more project specific local values may be obtained from a variety of sources. Among others, these include: knowledgeable persons in the area, contacting local business and contractor organizations, refinery organizations, and/or the local chamber of commerce, among others.

²⁰ Default local share values were derived by the author in December 2012 based on a review of states with existing petroleum refineries and associated industry equipment and service providers. The data was updated in 2013 and 2014 based on conversations with NREL staff regarding biorefinery manufacturers and suppliers.

7 Concluding Notes

The JEDI Fast Pyrolysis Biorefinery Model is a tool, which can be used to estimate local (e.g., county- or state-level) job creation, earnings, and output from total economic activity for a given fast pyrolysis biorefinery project. These estimates include the direct, indirect and induced economic impacts to the local economy associated with biorefinery construction and operation phases. Local revenue and supply chain impacts as well as induced impacts are estimated using economic multipliers derived from the IMPLAN software program.

The JEDI model is considered a static model. The current version of the model is built on 2012 multipliers for inter-industry relationships and personal consumption patterns. When the prices of raw materials and other parameters (e.g., inter-industry relationships and spending patterns) are significantly different than those in 2012, the model might over- or under-estimate the number of jobs.

It should be emphasized that the JEDI model does not estimate net jobs created by a fast pyrolysis biorefinery because the model does not take into account the extent to which the biorefinery project might displace other jobs. For example, increased biofuel production from the biorefinery project might reduce demand for conventional fuels, and therefore likely result in changes in jobs in conventional fuel industries if total demand for transportation fuels remains unchanged.

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