Petroleum Refinery Jobs and Economic Development Impact (JEDI) Model User Reference Guide

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NREL/SR-6A20-60657
December 2013

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Summary

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

Based on project-specific inputs from the user, the model estimates local-level job creation, earning and output (total economic activity) for a given petroleum refinery. This includes the direct, indirect and induced economic impacts to the local economy associated with the refinery's construction and operation phases. Project cost and job data used in the model are derived from the most current cost estimations available. Local direct and indirect economic impacts are estimated using economic multipliers derived from IMPLAN software. By determining the regional economic impacts and job creation for a proposed refinery, the JEDI Petroleum Refinery model can be used to field questions about the added value refineries may bring to the local community.

List of Acronyms and Abbreviations

BPCD	Barrels per Calendar Day
BPSD	Barrels per Stream Day
DOE	U.S. Department of Energy
FTE	Full-time Equivalent
JEDI	Jobs and Economic Development Impact Model
NREL	National Renewable Energy Laboratory
O&GJ	Oil & Gas Journal

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1 Introduction

The Petroleum Refinery Jobs and Economic Development Impact Model (JEDI) is designed to estimate the economic impacts associated with developing and operating petroleum refineries in the United States. The primary goal in developing this model is to provide a tool for refinery developers, renewable energy advocates, government officials, decision makers, and other potential users to easily identify the potential local economic impacts associated with constructing and operating petroleum refineries. The petroleum refinery JEDI model allows users to quickly analyze the local-level economic impacts of and potential jobs supported by refinery construction and ongoing operations. The economic impacts are categorized into project development and on-site labor impacts, local revenue and supply chain impacts and induced impacts, as defined in the next section of this report.

Strong emphasis was placed on designing the model in a user-friendly format that can be easily modified, reflecting different levels of project-specific information. This design ensures flexibility for inexperienced spreadsheet users, those unfamiliar with economic impact analysis, and more experienced and knowledgeable users who have a need for this specific type of analysis. The model is designed to analyze a refinery producing motor gasoline, jet fuel, diesel, fuel oil or other products.

This document describes general use of the model, how to interpret output summaries, and outlines technical assumptions and cost inputs used within the model. In general, the model relies on historical cost estimation data to develop default values. While the data incorporates significant uncertainties, in part due to the many variables associated with developing petroleum refineries, we believe the information presented in this model represents the most detailed, current and accurate information available at this time. For questions regarding the JEDI models or model updates, please refer to the *Jobs and Economic Development Impacts (JEDI) Models* home page at http://www.nrel.gov/analysis/jedi/.

2 Model Overview

The model offers users the capability to analyze the local-level economic impacts of a petroleum refinery based on the distillation capacity, entered in either barrels per calendar day[1] or barrels per stream day.[2] Given basic information about a petroleum refinery project (minimally, the state in which it is located, the year of construction and the distillation 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 to the state[3] from the project. To evaluate these impacts, input-output analysis, also commonly referred to as multiplier analysis, is used.

Input-output models were originally developed to trace supply linkages in the economy. For example, they show how output increases in equipment manufacturers, metal industries, and other industries that supply inputs as a result of purchases of refinery plant equipment. The impacts that are ultimately supported by expenditures for petroleum refineries depend upon the extent to which those expenditures are spent locally and the structure of the local economy. Consistent with the spending pattern and state-specific economic structure, different expenditures support a different level of employment, income, and output.

Input-output analysis can be thought of as a method 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 petroleum refinery, three separate impacts are examined for each expenditure. Often these impacts are referred to as direct, indirect, or induced. To provide results that are more intuitive, these impacts are labeled in the Petroleum Refinery JEDI model as follows:

- Direct: project development and on-site labor impacts are the on-site or immediate effects created by an expenditure. In constructing a petroleum refinery, they refer to the on-site jobs of the contractors and crews hired to construct the plant.

- Indirect: local revenue and supply chain impacts are the economic activity that occurs outside the site when contractors, vendors, or manufacturers receive payments for goods or services and in turn are able to pay their workers. For example, this impact includes the banker who finances the contractor who pays the engineer; and the steel mills and electrical manufacturers along the supply chain that provide the necessary materials. The indirect economic effect would also apply to the manufacturing of refinery plant equipment. For example, piping, condensers, heat exchangers, vessels, tanks, etc. that are used in the construction of the plant may be included.

- Induced: these impacts are 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

[1] Barrels per calendar day refers to the average flow rate under usual operating conditions.
[2] Barrels per stream day refers to the flow rate when running at full capacity.
[3] Although the JEDI model is designed to provide state-level analysis, the model also includes a "User Add-in Location" feature. This feature allows users to import specific county or region-level multipliers and personal expenditure patterns to localize the analysis to a smaller or larger region than the state level. For more detail on this procedure, refer to the User Add-in Location section description in this document.

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

The sum of these three effects yields the total local economic 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, personal expenditure patterns, and wage and salary income and output (economic activity)were derived from the IMPLAN Professional model Version 3.0 using IMPLAN state data.[4] The changes in expenditures from investments in developing petroleum refineries are matched with their appropriate multipliers for each sector affected by the change in expenditure.

To accommodate the availability of project-specific information, the model uses default values representative of a "typical" petroleum refinery project that can be changed by the user. The default values represent a reasonable expenditure pattern for constructing and operating petroleum refineries in the United States. Given the complexity and number of variables associated with constructing and operating refineries, there is really no typical refinery and few projects will follow this exact "default" pattern for expenditures. Type of feedstock, desired finished products, distillation capacities (also referred to as crude oil charge rates), storage capacities, project location, environmental regulations, financing arrangements and numerous site-specific factors influence the installation and operating costs. Similarly, the availability of local resources, including labor and materials, and the availability of locally manufactured components can have a significant effect on the costs and the economic impacts that accrue to the state or local region. The more 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.

[4] IMPLAN (Impact Analysis for Planning) is a social accounting and impact analysis tool(www.IMPLAN.com). The version of the JEDI Petroleum Refinery model highlighted in this document contains multipliers and personal expenditure patterns for 2010, the most current year available at the time the model was developed. Default multipliers and expenditure patterns are updated approximately every two years.

3 Inputting Data and Running the Model

The JEDI model is designed for all levels of users, requiring minimal experience with spreadsheets and no background in economic modeling. The model includes online instructions explaining how to proceed with entering data for analysis and informative “comments” assisting users to understand the type of data required in specific cells. The comments are viewed by pointing the cursor to the triangle located in the corner of the cell.

The model formulas and default data are protected, and user-modified data are only applicable to the specific analysis users are performing 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 Petroleum Refinery JEDI model is an Excel™-based model. To begin using it, simply open the Petroleum Refinery JEDI Excel™ file. The JEDI model opens to the “Start” tab, which briefly explains what the model is used for and outlines the steps for completing an economic impact analysis (see Figure 1):

- To learn more about the model version and 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 (see Figure 1 below) or go to the “Project Data” tab.

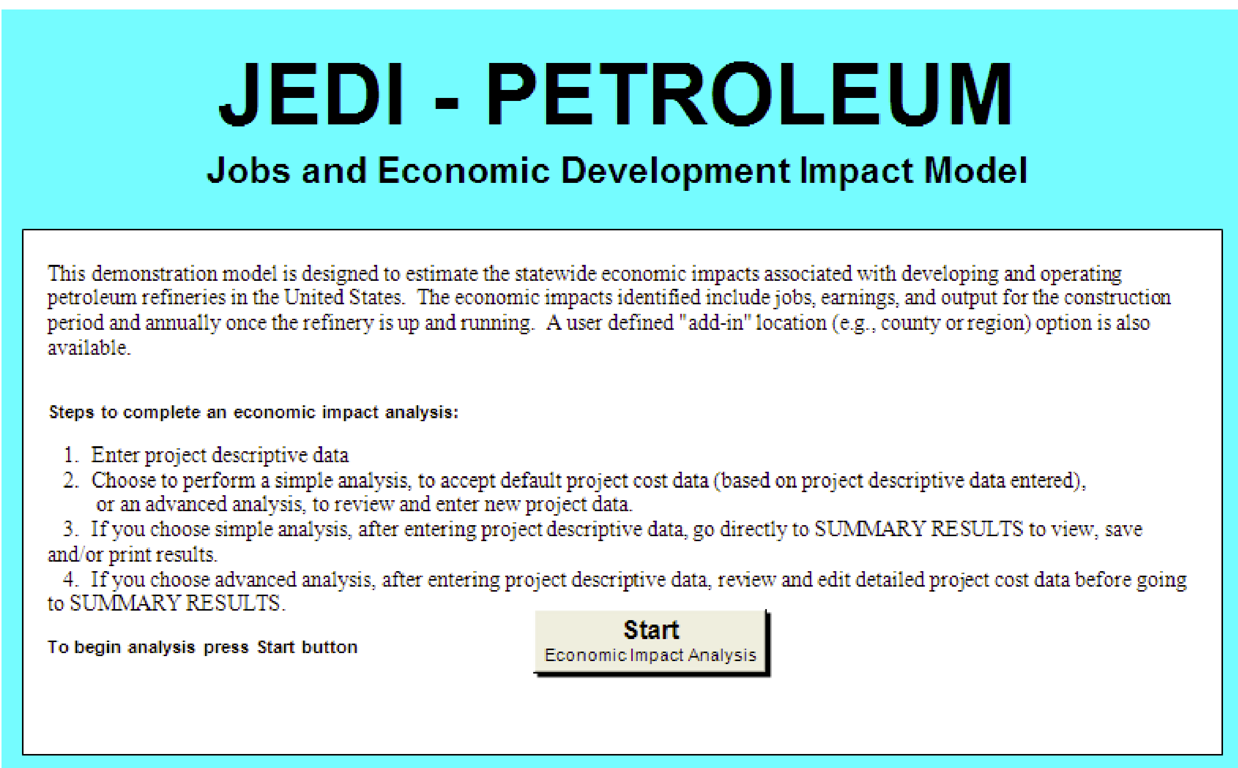
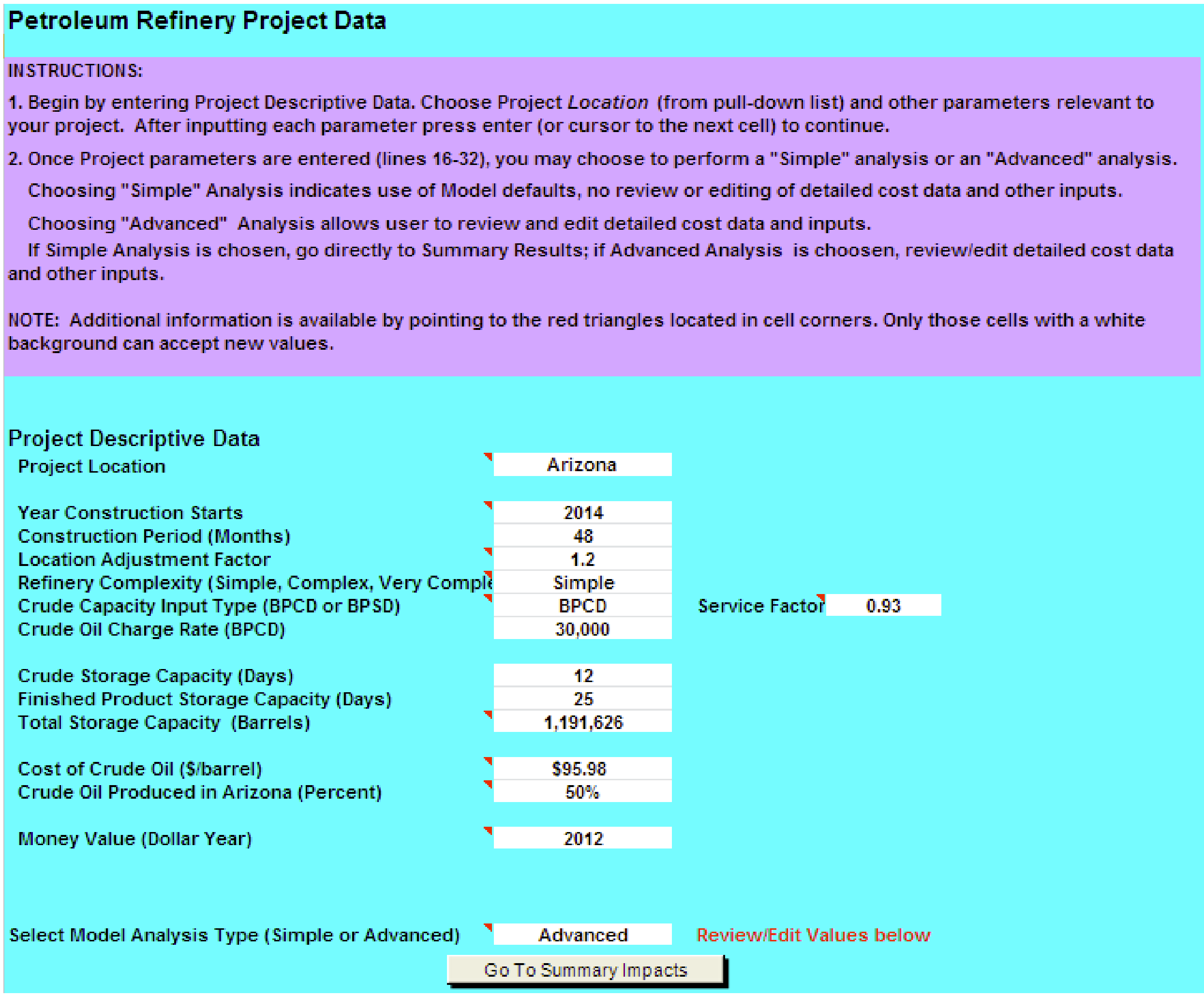


Figure 1. JEDI model Start page

3.2 Model Input

Two modeling options were employed to accommodate a broad user base with a wide range of knowledge about petroleum refinery projects. A “simple” or “advanced” input option allows a user to choose the number and detail of user inputs accessible in the model (see Figure 2):

- **Simple Input Option:** For those users with little or no experience with petroleum refineries or economic impact analysis, the simple option requires minimal inputs: the state in which the refinery will be located, the year in which construction starts, complexity of the refinery, and the crude oil capacity. If the user has additional information about the refinery project, such as details about the crude and finished product storage capacities or crude prices, they can enter them as well. Since these details have a significant impact on the costs of developing and operating a petroleum refinery, the user is encouraged to enter as much detail as possible about the project.
- **Advanced Input Option:** An advanced model is available for users with more experience and knowledge of petroleum refinery projects, allowing them to provide specific project details. The primary differences between the simple model and advanced model options are the user’s ability to view and edit detailed model input data. The simple model uses a set of cost estimates based on process cost functions and does not allow for user 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 petroleum refinery development.


Petroleum Refinery Project Data

INSTRUCTIONS:

1. Begin by entering Project Descriptive Data. Choose Project *Location* (from pull-down list) and other parameters relevant to your project. After inputting each parameter press enter (or cursor to the next cell) to continue.

2. Once Project parameters are entered (lines 16-32), you may choose to perform a "Simple" analysis or an "Advanced" analysis.

Choosing "Simple" Analysis indicates use of Model defaults, no review or editing of detailed cost data and other inputs.

Choosing "Advanced" Analysis allows user to review and edit detailed cost data and inputs.

If Simple Analysis is chosen, go directly to Summary Results; if Advanced Analysis is choosen, review/edit detailed cost data and other inputs.

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	Arizona		
Year Construction Starts	2014		
Construction Period (Months)	48		
Location Adjustment Factor	1.2		
Refinery Complexity (Simple, Complex, Very Comple	Simple		
Crude Capacity Input Type (BPCD or BPSD)	BPCD	Service Factor	0.93
Crude Oil Charge Rate (BPCD)	30,000		
Crude Storage Capacity (Days)	12		
Finished Product Storage Capacity (Days)	25		
Total Storage Capacity (Barrels)	1,191,626		
Cost of Crude Oil ($/barrel)	$95.98		
Crude Oil Produced in Arizona (Percent)	50%		
Money Value (Dollar Year)	2012		
Select Model Analysis Type (Simple or Advanced)	Advanced	Review/Edit Values below	

Go To Summary Impacts

Figure 2. JEDI model Project Data page

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 phases. The model only estimates 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 petroleum refinery; 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. If users wish to save the entire model (with the user-modified data) for future use or reference, choose "Save As" from the Excel™ menu, rename the model, and choose a directory. Changing the 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.

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 calculations. 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. *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.*

4 Interpreting the Results

Regardless of how many project-specific data are entered by the user, JEDI provides sufficient information to help users better understand the magnitude of the economic impacts associated with the project being analyzed. The model provides basic project information to help users identify the magnitude of the construction-related spending and ongoing operations and maintenance (O&M) expenditures. The model also identifies the portion of the 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 identifies local spending on debt and equity payments, property taxes, and land purchase payments, if applicable.

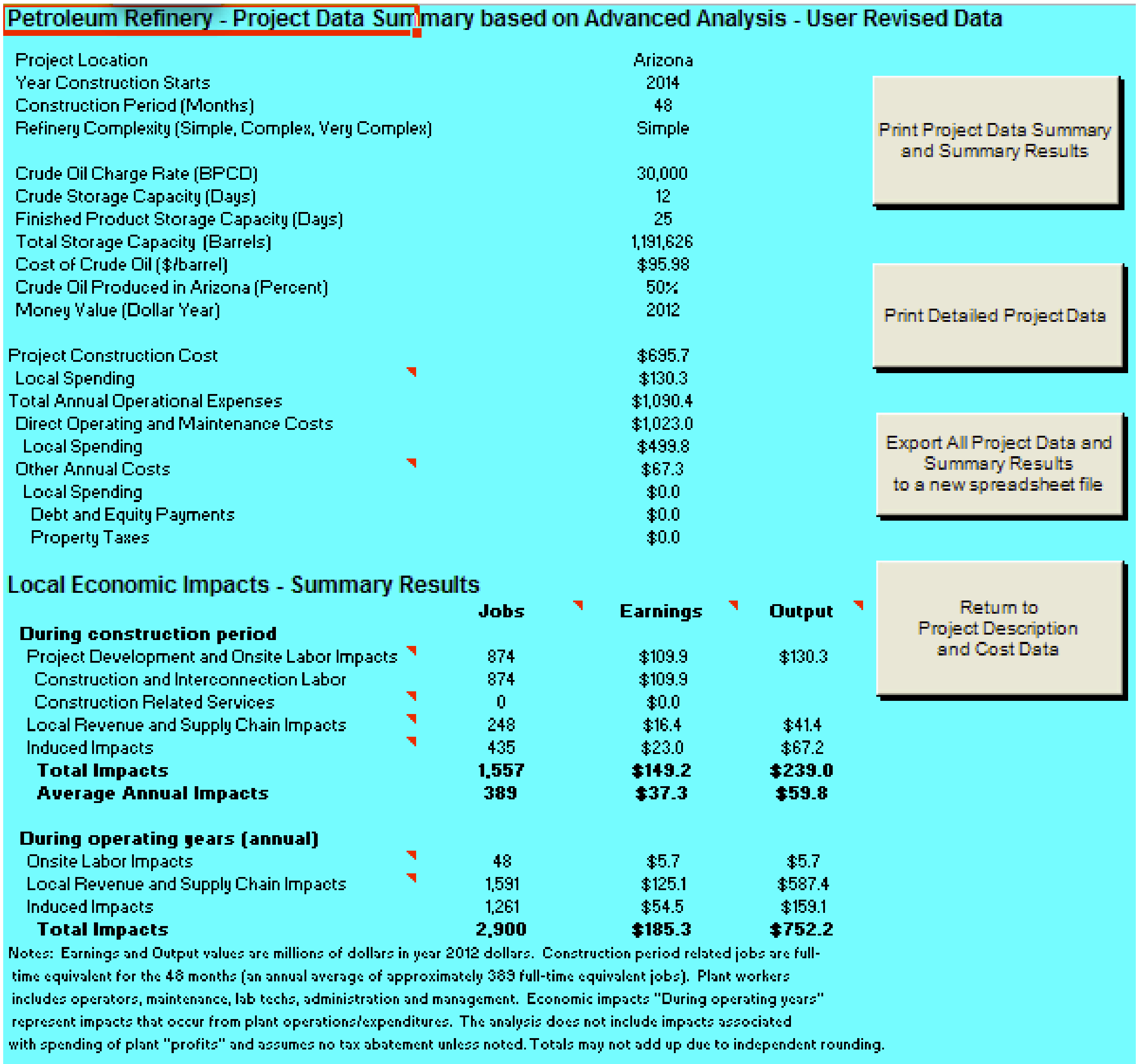
4.1 Economic Impacts and Job Creation

In addition to the basic project information and costs, the model analyzes and reports the local jobs, earnings, and gross 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 creation and economic impacts from developing a petroleum refinery with a crude distillation capacity of 30,000 barrels per calendar day in Arizona, built in the year 2014, can easily and quickly find the answers by using the JEDI model. Figure 3 shows a job and economic impact summary for a 30,000 barrel per calendar day refinery (simple model option) constructed in 2014. By incorporating a few user inputs and accepting the rest of the model defaults, a user obtains the project data summary and local economic impacts summary results. The results from this particular scenario show that 1,557 full-time equivalent (FTE)[5] jobs (an annual average of 389 FTE jobs) are supported, generating over $149 million in earnings and $239 million in total economic activity during project development and construction, including a total of 874 FTE jobs[6] from project development (874 construction and 0 construction services), 248 from the local revenue and supply chain, and 435 from induced impacts. Once the refinery is up and running, the user finds that 48 full-time operations and maintenance jobs are created and sustained each year for the life of the facility. Another 1,591 jobs are support through local revenue and supply chain activity and 1,261 from induced impacts, for a total of 2,900 FTE jobs associated with O&M operations.

[5] Job calculations are based on a full time equivalent (FTE) basis for a year. One FTE job = 2,080 hours worked in a year.

[6] Due to the allowance of partial FTEs and independent rounding, total jobs reported may not equal the sum of FTEs listed in subsets of the summary table.


Petroleum Refinery - Project Data Summary based on Advanced Analysis - User Revised Data

Project Location	Arizona
Year Construction Starts	2014
Construction Period (Months)	48
Refinery Complexity (Simple, Complex, Very Complex)	Simple
Crude Oil Charge Rate (BPCD)	30,000
Crude Storage Capacity (Days)	12
Finished Product Storage Capacity (Days)	25
Total Storage Capacity (Barrels)	1,191,626
Cost of Crude Oil ($/barrel)	$95.98
Crude Oil Produced in Arizona (Percent)	50%
Money Value (Dollar Year)	2012
Project Construction Cost	$695.7
Local Spending	$130.3
Total Annual Operational Expenses	$1,090.4
Direct Operating and Maintenance Costs	$1,023.0
Local Spending	$499.8
Other Annual Costs	$67.3
Local Spending	$0.0
Debt and Equity Payments	$0.0
Property Taxes	$0.0

Print Project Data Summary and Summary Results

Print Detailed Project Data

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

Return to Project Description and Cost Data

Local Economic Impacts - Summary Results

	Jobs	Earnings	Output
During construction period			
Project Development and Onsite Labor Impacts	874	$109.9	$130.3
Construction and Interconnection Labor	874	$109.9	
Construction Related Services	0	$0.0	
Local Revenue and Supply Chain Impacts	248	$16.4	$41.4
Induced Impacts	435	$23.0	$67.2
Total Impacts	**1,557**	**$149.2**	**$239.0**
Average Annual Impacts	**389**	**$37.3**	**$59.8**
During operating years (annual)			
Onsite Labor Impacts	48	$5.7	$5.7
Local Revenue and Supply Chain Impacts	1,591	$125.1	$587.4
Induced Impacts	1,261	$54.5	$159.1
Total Impacts	**2,900**	**$185.3**	**$752.2**

Notes: Earnings and Output values are millions of dollars in year 2012 dollars. Construction period related jobs are full-time equivalent for the 48 months (an annual average of approximately 389 full-time equivalent jobs). 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 local economic impacts summary results[7] from Petroleum Refinery JEDI run for a 30,000 barrel per calendar day refinery in Arizona built in 2014

4.2 Comparing Results Among JEDI Models for Different Fuel Production Technologies

When comparing the economic development impacts (results) or results for different technologies (i.e., corn ethanol, cellulosic ethanol, etc.) from the JEDI Petroleum Refinery model runs with other JEDI models, it is best to compare between facilities with equivalent production capabilities (e.g., annual distillation capacity) rather than merely comparing two facilities (e.g.,

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

compare jobs per million gallons of motor gasoline equivalent for final products from either a petroleum refinery or a biorefinery, not jobs per refinery).

4.3 Caveats

Several important caveats should be noted at this point. First, the intent of the petroleum refinery impact model is to construct a reasonable profile of expenditures (i.e., refinery plant construction and operating costs) and demonstrate the magnitude of the gross economic impacts that would likely result,[8] assuming a project occurs during the stated period of analysis. Given the unique nature of each refinery and the changing nature of the industry, the cost data used in the model are not intended to replace site-specific project 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 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 final 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 O&M processes (e.g., production recipe for labor, materials, and service cost ratios) for new refineries.

Third, the 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 refinery 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., 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.

The Petroleum JEDI is freely available to the public. The National Renewable Energy Laboratory (NREL) is not responsible for how the Petroleum JEDI model is used or its results interpreted.

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[8] 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 (such as an individual county or group of counties) or for a larger region (such as a group of states) 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 extension 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. There are two categories of necessary inputs (1) direct, indirect, and induced multipliers for employment, earnings and output (per million dollars change in final demand) and (2) personal consumption expenditure patterns (i.e., average consumer expenditures on goods and services—calculated as a percentage, entered in decimal format, for each industry, totaling 100% combined) for the aggregated industries and the IMPLAN 432 (disaggregated) industry sectors. 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 several steps:

1. Purchase the desired county or state-level data files.
2. Using the most recent version of IMPLAN software, create a new JEDI model with the desired region (one county, group of counties, or group of states).

3. Construct the model.
4. Export all industry multipliers for employment, employee compensation, and output to spreadsheet files.
5. Format data contained in each of these files to input (i.e., cut and paste) into the non-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 the JEDI model.
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 NREL.[9]
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 the user data are entered into the JEDI model, the user need only identify the location of the refinery (in the project description section of the ProjectData worksheet) as MyCounty or MyRegion, depending upon the type of data and where the data are entered, and proceed with the analysis.

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

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

[9] Contact NREL at JEDISupport@nrel.gov.

6 Data Sources and Cost Categories

Analyzing the economic impacts of constructing and operating petroleum refineries requires a large amount of project and location-specific data. These data include feedstock types, process unit capacities, detailed project capital costs, labor rates, state specific input-output multipliers and personal expenditure patterns, and price deflators, among others. Project-specific differences, such as refinery complexity and type and number of process units installed, storage capacity, distillation capacities (or crude oil charge rate as represented in the model), and availability of equipment and specialized labor can significantly impact costs. As a result, it is not possible to identify a "one-price fits all situations" solution. The limited availability of detailed project cost data makes efforts to analyze the economic impacts even more difficult. This lack of data is due to the fact that no new refineries (grassroot) have been built in the United States since the 1970s and developers consider a project's financial data proprietary due to competitive forces in the marketplace. Due to the complex nature of developing cost estimates for petroleum refineries, and the relative lack of detailed cost data publicly available, the default costs were derived from a variety of industry data and cost estimating sources (see Resources in the Appendix).

Building upon the plant construction and O&M statistics and costs derived from the sources noted, the model provides default values for all inputs necessary to perform an analysis. Project costs and estimation formulas from these resources were compared between sources where appropriate and updated using the Nelson-Farrar inflation indexes[10] to form the baseline for the cost analysis.

The project-specific data include a bill of goods (detailed costs associated with actual construction of the facility, roads, storage tanks, etc., as well as costs for equipment and other services required), annual O&M costs, the portion of expenditures spent locally, financing terms, and tax rates, among others. More specifically, the model incorporates the following project inputs:

1. Location factor
2. Crude oil charge rate (or feed capacity of the crude – atmospheric – distillation units)
3. Process unit costs
4. Utility system costs
5. Security and environmental installation costs
6. Storage and dispatch costs
7. Infrastructure costs
8. Labor costs
9. Other costs
10. Annual O&M costs (variable costs such as chemicals and catalysts, utilities; fixed costs such as labor, maintenance, and some materials and services)

[10] Oil & Gas Journal 2013.

11. Feedstock costs
12. Local shares.

The JEDI Petroleum Refinery Model contains several parameters related to the size, location and finished products that affect overall project costs and the resulting economic impacts. Crude oil charge rate and complexity are two important parameters that directly affect the type of process units, storage requirements, process and system capital costs, and labor force required to build and operate a refinery.

6.1 Location Adjustment Factor

A location adjustment factor, specific to the state where the refinery is built, is applied to all construction expenditures to account for cost differences due to variations in climate (and its effect on design requirements and construction conditions), building regulations, and availability of construction labor, among other factors.[11] Both the simple and advanced model options incorporate a default location adjustment factor in the analysis; however, if the user has more localized or current information, the value can be altered.

6.2 Crude Oil Charge Rate

Crude oil charge rate refers to the input or feed capacity of the crude (atmospheric) distillation units at the refinery. The charge rate varies by refinery design configuration and strategic decisions related to projected demand and economics. Refinery capacities in the United States currently range from less than 2,000 barrels per calendar day to 600,000 barrels per calendar day. Thus, there is no standard or typical capacity for a refinery. Both the simple and advanced model options require the user to input the crude oil charge rate. In addition to determining the overall refinery costs, the charge rate is used to determine projected storage/tankage capacity. (See Storage and Dispatch in this section.)

6.3 Process Unit Costs

Process unit costs are based on the crude oil charge rate (capacity), the complexity of the refinery and the location. Complexity refers to the ability to convert heavy products, such as crude oils, into lighter products such as motor gasoline, diesel, and kerosene, among others. The types of process units included in the analysis are determined by the user choosing the level of refinery complexity. The JEDI model provides three complexity options: simple, complex and very complex.

- Simple refers to a refinery with atmospheric distillation units, catalytic reforming units and middle distillate hydrodesulfurisation units with limited conversion capacity to upgrade heavy oil fractions to lighter, higher value products.
- Complex refers to a refinery with the units noted above as well as conversion units, such as fluid catalytic crackers, hydrocrackers or visbreakers, and greater integration to produce more high value products.
- Very complex refers to a refinery with the units noted above as well as deep conversion process units to convert residues to high value products.

[11] U.S. Army Corps of Engineers 2012.

Once the complexity is determined, and thus an estimated list of the refining processes, the cost for each of the process units is derived from the refinery capacity (in 1,000 barrels per stream day) and process unit cost (*pc*) functions. These process unit cost functions include a base cost parameter (*a*) for each type of process unit and a capacity scaling parameter (*b*) for each type of process unit.[12] The cost for each type of process unit is calculated as: $pc = a * capacity^b$.

Users may override the process unit costs (default values) in the advanced model option and input their own unit costs.

6.4 Utility System Costs

Utility system costs (*uc*) include steam and electricity production systems, steam and utility distribution systems, production and distribution systems for other utilities, and cooling water systems. Each of the utility system costs are calculated as a function of the total process unit costs (*pc*) and the average percentage of process unit cost (*ppc*) for each of the utility costs, which are then adjusted using a capacity/complexity adjustment (*c/c*). Offsites[13] (*o*) percent of total major facilities is in included in the calculation for distribution system and other costs.

The steam and electricity production system costs and cooling water system costs are calculated as $uc = ppc*pc*c/c$.

The steam and utilities distribution systems and production and distribution systems for other utilities system costs are calculated as: $uc = ppc*pc*c/c*o$.

The average offsite percent of total major facilities costs is used as the basis for determining capacity-related cost variations: < 30,000 BPSD = 50 percent; 30,000-100,000 = 30 percent, >100,000 = 20 percent.[14]

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

6.5 Security and Environmental Installation Costs

Security and Environmental Installation costs (*sec*) include firefighting and flare and effluent treatment systems. Each of the system costs are calculated as a function of the total process unit costs (*pc*) and the average percentage of process units costs (*ppc*), adjusted for capacity/complexity (*c/c*) and offsites percent of total major facilities (*o*).

The security and environmental installation costs are calculated as: $sec = ppc*pc*c/c*o$.

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

[12] Kaiser et al. 2007, p. 92.

[13] Offsites refer to those systems and facilities not included in the major facilities. Offsites include: steam and utilities distribution, production and distribution of other utilities, security and environmental installations, storage and dispatch, and infrastructure. Major facilities include all process units, steam and electricity production systems, and cooling water systems.

[14] Favennec 2001, p. 148.

6.6 Storage and Dispatch Costs

Storage and dispatch costs (*sdc*) include tanks, piping, transfer pumps and tank loading facilities. To derive the storage and dispatch costs, the required storage capacity (barrels) is determined and then multiplied by an average cost per barrel of storage.

The total amount of storage capacity is a function of the crude capacity (barrels per calendar day), the number of days of crude storage (*cs*) required, and the number of days of finished product storage (*fps*) required. The total of the two is the total storage capacity required. The default number of days of storage in the model is set to 12 days for crude and 25 days for finished product.

The crude storage capacity (number of barrels) is calculated as: *sdc = capacity*cs storage days*.

The finished product storage capacity (number of barrels) is calculated as: *sdc = capacity*fp storage* days.

The model's default cost per barrel of storage is $105 (2007$). The value is based on an average storage and dispatch cost percentage of total cost for a typical plant and assuming 50 barrels of storage per barrel per day processed.[15] This value is consistent with storage costs which can vary widely from $50 per barrel of storage to over $130.[16]

The storage and dispatch costs are calculated as $105 multiplied by the total barrels of storage.

Users may override the default number of storage days in the simple or advance model option and the storage and dispatch system cost defaults in the advanced model option and input their own storage days and system costs.

6.7 Infrastructure Costs

Infrastructure costs (*ic*) include site preparation, roads, general infrastructure, and buildings. Each of the infrastructure costs is calculated as a function of the total process unit costs (*pc*) and the average percentage of process units costs (*ppc*) for each of the infrastructure costs and offsites percent of total major facilities (*o*).

The infrastructure costs are cal culated as *ic = ppc*pc*o.*

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

6.8 Labor Costs

Labor costs (*lc*) include the labor portion of all the expenditure categories (e.g., process units, utilities, storage, etc.) for both skilled and common labor and associated employer costs (social security, workers compensation, benefits, etc.). Labor costs are calculated as a function of the total process unit costs (*pc*) and the average labor percentage of process units costs (*lppc*).[17]

The labor costs are calculated as: *lc = lppc*pc.*

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[15] Favennec 2001. page 148; Gary et al. 2007. page 356.
[16] Gary et al. 2007. page 355.
[17] Page 1984. page 635.

Wage rates for all labor during construction are contained in the ProjectData worksheet in the model under Payroll Parameters. Data sources include: the Bureau of Labor Statistics[18] and inflation adjusted estimates of industry data contained in the cost estimating source documents (see Resources in the Appendix).

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

6.9 Other Costs

Other costs (oc) include engineering and design services, construction services and project general management. Other costs are calculated as a function of all costs (*ac)* and the average percentage of all costs (*pac*) for each of the individual costs.[19]

The other costs are calculated as $oc = pac*ac$.

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

6.10 Annual Operating and Maintenance Costs

Once a petroleum refinery is operational, there are variable, fixed and feedstock costs each year. Variable costs include chemicals, catalysts and utilities, but exclude feedstock costs, which are accounted for separately.

Variable costs (*vc*) are a function of the plant capacity and the average costs (a*vc*) per barrel capacity for each variable cost.[20]

The variable costs are calculated as: $vc = capacity*avc$.

Fixed costs include labor, maintenance and other costs (overhead). Labor cost includes salaries and employer costs for all plant staff employed on-site to operate and maintain a facility. Typical staff includes: plant managers,[21] engineers, technicians, site operators, lab personnel and clerical staff. Maintenance cost includes materials only; maintenance labor is accounted for under labor costs. Other costs include insurance, taxes, debt payments, miscellaneous supplies[22] and other operating costs (e.g., administration, quality control, procurement, IT, community relations and contribution to main office costs, among others).

Fixed costs (*fc*), not including other costs, are a function of the plant capacity and the average costs (*afc*) per barrel capacity for each fixed cost.[23]

The fixed costs are calculated as: $fc = capacity*afc$.

[18] BLS 2012; BLS 2011.
[19] Page 1984, p. 566.
[20] Favennec 2001, p. 154.
[21] Plant management typically includes one refinery manager, one operations manager and one maintenance manager.
[22] Miscellaneous supplies includes chemical for corrosion control, drinking water, office supplies, etc.
[23] Gary et al. 2007, p. 384.

O&M job estimates shown in the results summary of the JEDI model are annual FTE jobs for the operating life of the refinery. It is recognized that a plant may use part-time employees and that the optimal staff size will vary by location and plant configuration.

Other costs (*oc*), within fixed costs, are a function of the total plant investment (*I*), which includes all construction costs, and the average percentage of plant investment (*ppI*) for each of the other costs.[24]

The other costs are calculated as: $oc = I*ppI$.

Wage rates for all labor during annual operating and maintenance are contained in the ProjectData worksheet in the model under Payroll Parameters. Data sources include: the Bureau of Labor Statistics[25], and inflation adjusted estimates of industry data contained in the cost estimating source documents (see Resources in the Appendix).

Users may override any of the O&M cost defaults in the advanced model option and input their own O&M costs.

6.11 Feedstock Costs

Feedstock costs (*fdc*) are for crude oil. Feedstock costs are a function of the crude capacity, on-stream time (*st*), and the purchase price per barrel (*$/bbl*) of crude oil. The default on-stream time is set to 93 percent (i.e., 93% of the fuel capacity).

The feedstock costs are calculated as $fdc = capacity*365*st*\$/bbl$.

Users may override the feedstock cost defaults (either the purchase price per barrel in the Project Description data or the actual total feedstock cost – both on the Project Data page) in the advanced model option and input their own O&M costs.

6.12 Local Share

A local share percentage is assigned to fields 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 prep during the plant construction phase will likely be sourced locally and 100 percent of the cost associated with purchasing the materials and services is assigned to the local economy by JEDI. Conversely, an engineering firm familiar with pipeline techniques is a specialized profession and may not be available in the chosen area.

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 refinery operations, such as Texas or California, offer many of the services, equipment, and materials required in a refinery project. If one of these states is chosen as the project location, then a higher

24 Gary et al. 2007. page 384.
25 BLS 2012; BLS 2011.

local impact will be realized compared to a project located in a state without an established refinery industry.[26]

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.

[26] Default local shares values were derived by the author in December 2012 based on a review of states with existing refineries and associated industry equipment and service providers.

Appendix

Resources

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