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

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The following corrections were made to this report:

Section 7 Validation of JEDI Results pages 24 and 25.

Page 24 - Table 3, Row 3, Column 4: The number "12" has been changed to "10".
Source reference has been changed to "U.S. DOE Loan Programs Office 2012" and the
footnote has been changed as well. Similar reference on page 25 has been changed also.

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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 used to estimate the local economic impacts of constructing and operating power generation projects. JEDI models cover a range of conventional and renewable energy technologies, including geothermal. The *JEDI Model Geothermal User Reference Guide* provides basic instructions on model operation and add-in features, discusses how to interpret results, and explains the model's underlying methodology as well as the parameters and references used to develop JEDI's cost data.

Based on project-specific inputs from the user, the model estimates job creation, earning, and output (total economic activity) for a given power generation project. This includes the direct, indirect, and induced economic impacts to the local economy associated with the construction and operation phases. The model estimates project costs and direct economic impacts for both hydrothermal and Enhanced Geothermal Systems (EGS) power generation projects based on exploration and drilling activities, power plant construction, and ongoing operations. Project cost and job data used in the model were gathered from existing geothermal projects, a literature review, conversations with industry professionals, and existing models such as the Geothermal Electricity Technology Evaluation Model (GETEM). Local direct and indirect economic impacts were estimated using economic multipliers derived from Impact Analysis for Planning (IMPLAN) software. By determining the regional economic impacts and job creation for a proposed power facility, the geothermal JEDI model can be used to answer questions about the value geothermal power may bring to the local community.

List of Acronyms and Abbreviations

AFE	Authorization for Expenditure
BE	Brine Effectiveness
BLS	Bureau of Labor Statistics
CERA	Cambridge Energy Research Associates
CREST	Cost of Renewable Spreadsheet Tool
DOE	U.S. Department of Energy
EGS	Enhanced Geothermal Systems
FTE	full-time equivalent
GEA	Geothermal Energy Association
GETEM	Geothermal Electricity Technology Evaluation Model
H_2S	hydrogen sulfide
IMPLAN	Impact Analysis for Planning
JEDI	Jobs and Economic Development Impact Model
kg/s	kilograms per second
kW_e	kilowatt
MIT	Massachusetts Institute of Technology
MW_e	megawatt
NCG	non-condensable gas
NREL	National Renewable Energy Laboratory
PPI	Producer Price Index
SAM	System Adviser Model
w-h/lb	watt-hours per pound

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1 Introduction

The geothermal Jobs and Economic Development Impact (JEDI) model is designed to demonstrate the economic impacts associated with developing and operating geothermal power plants in the United States. The model's primary purpose is providing geothermal developers, renewable energy advocates, government officials, decision makers, and other probable users with a tool that identifies the potential local economic impacts, including job creation potential, associated with constructing and operating geothermal power systems. The model may be used for analyzing conventional hydrothermal and Enhanced Geothermal Systems (EGS) using either a binary or single-flash power generation facility to produce electricity. The economic impacts are categorized into direct, indirect, and induced effects on site labor and professional services impacts, local revenues and equipment, and supply chain impacts and induced impacts.

NREL placed strong emphasis on designing the model in a user-friendly format that can be easily modified to match different levels of project-specific information and user skill. The tool can be used by inexperienced spreadsheet users as well as those accustomed to conducting sophisticated economic impact analysis.

This document describes general use of the model, how to interpret results, and technical assumptions and cost models used within the model. In general, the model relies on historical cost data to develop default values. When historical cost data were not available, engineering cost models were used to develop a set of reference cost data. While the data incorporates significant uncertainties—in part due to the many variables associated with developing geothermal resources—JEDI was developed with the most detailed, current, and accurate information available. For questions regarding the JEDI models or model updates, please refer to the *Jobs and Economic Development (JEDI) Models* page at http://www.nrel.gov/analysis/jedi/.

2 Model Overview

The JEDI model can analyze a hydrothermal or EGS project utilizing either a single-flash or binary power plant. Given basic information about a geothermal project (minimally, the state in which it is to be located, the year of construction, and the size of the system), users can estimate project capital and operating expenditures as well as the number of jobs, income (wages and salary), and economic activity that a state will accrue from the project. To evaluate these impacts, input-output analysis, also commonly referred to as multiplier analysis, is used.[1]

Input-output models were originally developed to trace supply linkages in the economy. For example, they show how purchases of geothermal plant equipment not only benefit equipment manufacturers but also the metal industries and other businesses supplying inputs to those manufacturers. The benefits generated by expenditures for geothermal systems 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 different levels 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 geothermal project, JEDI examines three types of impacts for each expenditure. Often these effects are referred to as direct, indirect, and induced effects. To provide results that are more intuitive, these impacts are labeled in the geothermal JEDI model as follows:

- **Project development and on-site labor impacts:** The on-site or immediate effects created by an expenditure. In constructing a geothermal power plant, it denotes the on-site jobs of the contractors and crews hired to construct the plant.

- **Turbine and supply chain impacts:** The increase in economic activity that occurs when contractors, vendors, or manufacturers receive payment for goods or services and are able to pay others who support their businesses. For example, this impact includes the banker who finances the contractor who pays the drilling 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 geothermal plant equipment. For example, this may include geothermal steam turbines, drill pipe, drill bits, condensers, heat exchangers, etc. that are used in the construction of the plant.

- **Induced impacts:** The effects driven by reinvestment and spending of earnings by direct and indirect beneficiaries. Induced impacts include business at local restaurants, hotels, and retail establishments, but they can also extend to include child care providers, service providers, and any other entities affected by increased economic activity and spending occurring at the first two tiers.

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[1] By default, JEDI provides state-level analysis. However, the model includes a "User Add-in Location" feature which allows users to customize the model to fit smaller or larger regions. To learn more, refer to Section 5 – User Add-in Location.

The sum of direct, indirect, and induced impacts yields the total economic effect from an expenditure. To accomplish this analysis at the state level, JEDI uses state-specific multipliers and personal expenditure patterns. These state multipliers for employment, wage, and salary income and output (economic activity), and personal expenditure patterns were derived from state data.[2]

To accommodate the variability in user skill level and availability of project information, JEDI employs default values representative of a "typical" geothermal project. These values can be changed by the user. The default values represent a reasonable expenditure pattern for constructing and operating geothermal projects in the United States. Resource characteristics, project size, location, financing arrangements, and numerous site-specific factors influence actual construction and operating costs. Similarly, several factors affect the costs and the economic impacts that the state or region accrues. JEDI can provide more localized analysis when the user has and can incorporate project-specific data.

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[2] IMPLAN is a social accounting and impact analysis tool. Minnesota IMPLAN Group (MIG, Inc). www.IMPLAN.com. Accessed January 2011. The initial version of the JEDI geothermal model contains multipliers and personal expenditure patterns for 2010, the most current year available at the time the model was released for public use. IMPLAN Professional model Version 3.0 2008.

3   Using JEDI

The JEDI model is designed to accommodate all users; it requires minimal experience with spreadsheets and no background in economic modeling. The model includes instructions for entering data and informative comments explaining the type of data required in specific cells. To view comments, point the cursor to the triangle located in the corner of the cell.

Please note: The model formulas and default data are protected, and user-modified data is 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 close the model and reopen it to start over with the default values.

3.1   Getting Started
The geothermal JEDI model is an Excel based model. To begin using it, open the geothermal JEDI Excel file. The JEDI model opens to the "Start" tab, which briefly explains the model's purpose and outlines the steps to completing an economic impact analysis.

To learn more about the model version and history, click on the "About" tab.

To begin a JEDI analysis, either click on the "Start Economic Impact Analysis" button or go to the "Project Data" tab.

3.2   Model Input
JEDI offers two modeling options to accommodate users with a wide range of knowledge about geothermal projects.

3.2.1   Simple Input Option
Those users with little or no experience with geothermal power plants or economic impact analysis may prefer JEDI's simple input option. The simple option requires minimal inputs such as year constructed the planned location (state), nominal size of the power plant, and type of plant technology. Users may enter additional information about the project, such as details about the geothermal resource's temperature, the depth of the wells to be drilled, and the expected well flow rate. Because these details have a significant impact on the costs of developing and operating a geothermal power plant, the user is encouraged to enter as much detail as possible about the project. The simple model uses a set of cost curves[3] that estimates drilling costs based on depth; it does not allow user changes to the cost data.

3.2.2   Advanced Input Option
Users with more experience and knowledge of geothermal projects and for those who can provide specific project details may prefer JEDI's advanced input option. The primary differences between the simple model and advanced model options are how the model estimates

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[3] GETEM (2009). Geothermal Electricity Technology Evaluation Model (GETEM), Department of Energy - Energy Efficiency and Renewable Energy. http://www1.eere.energy.gov/geothermal/geothermal_tools.html.

drilling costs (for both exploration and production drilling) and the user's ability to view and edit detailed model input data. The advanced model lets users tailor drilling costs according to the time required for drilling (based on the drilling rate and well depth) and customizable daily rates. Users can also combine cost expenditures for exploration and production wells. The advanced option also allows the user to override default inputs for all other phases of the geothermal project development. The advanced option default costs were derived from industry production wells and authorizations for expenditures (AFE) supplied to NREL by geothermal contractors.

Model updates are incorporated in the analysis instantaneously as the user enters or changes data. A project summary is shown on the right hand side of the "Project Data" tab and can be used to review the project details. Once project descriptive data input is complete, the user can go to "Summary Results" to view the results of the analysis by clicking on "Go To Summary Results." JEDI economic impact and job creation values are estimates for constructing and operating a hypothetical power facility; 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. For a hard copy, 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. Alternately, users can export the data and results to a separate Excel file by clicking the "Export" button. 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 "block" and "copy" any desired cells to another spreadsheet or document.

3.4   Accessing and Viewing Model Work Areas

Several of the intermediate work areas have been hidden from view. These areas include: default data, calculations, deflators, household expenditures, multipliers and numerous geothermal-specific 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.*

4 Interpreting JEDI Results

Regardless of the amount of project-specific data entered, JEDI provides sufficient information to help users better understand the magnitude of the economic impacts associated with the system 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. It 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 lease payments, if applicable.

4.1 Economic Impacts and Job Creation

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

For example, users interested in understanding the job creation and economic impacts from installing a 30 MW_e net electricity output hydrothermal binary plant in Colorado built in the year 2010 can easily generate an estimate by using the JEDI model. Figure 1 shows a job and economic impact summary for a 30 MW_e hydrothermal binary facility (simple model option) constructed in 2010 with a resource at a depth of 2,000 m (depth of wells drilled), resource temperature of 200°C, and well flow rates of 70 kg/s. By inputting a few items and accepting the rest of the model defaults, a user obtains the summary results. The project data summary and local economic impacts summary results from the model run are also shown. The results from this model run show that 432 full-time equivalent (FTE)[4] jobs are supported, generating over $26 million in earnings and over $61 million in total economic activity during project development and construction. These include a total of 223 FTE jobs[5] from project development (201 construction and 21 construction services), 128 from the turbine and supply chain, and 81 from induced impacts. Once the project is producing power, the user finds that 14 full-time operations and maintenance jobs are created and sustained for the life of the facility, with another 10 supporting jobs through supply chain and induced impacts, for a total of 24 full-time jobs associated with O&M operations.

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[4] Job calculations are based on a full time equivalent (FTE) basis for a year. One FTE job = 2080 hours worked in a year.
[5] Due to the allowance of partial FTE's and independent rounding, total jobs reported may not equal the sum of FTE's listed in subsets of the summary table.

Geothermal Plant - Project Data Summary (based on Simple analysis)

Project Location	COLORADO		
Year of Construction	2010	Installed Project Cost ($/kW)	$3,565
Construction Period (months)	21	Annual O&M Cost ($/kW)	$149
Nominal Plant Size (MW net output)	30.0	Money Value (Dollar Year)	2010
Nameplate Capacity (MW)	35.9	Installed Project Cost	$106,947,804
Technology	Hydrothermal	Local Spending	$35,367,261
Plant type	Binary	Total Annual Operational Expenses	$40,905,247
Resource Temperature (degrees Celsius)	200	Direct Operating and Maintenance Costs	$4,461,474
Resource Depth (Meters)	2000	Local Spending	$1,876,282
Number of Exploration Wells	2	Other Annual Costs	$36,443,773
Number of Production Wells	6	Local Spending	$0
Number of Injection Wells	3	Debt and Equity Payments	$0
Production Well Flow Rate (kg/s)	70	Property Taxes	$0
Well Flow (lb/hr)	555,564	Land Lease	$0
Total Flow (lb/hr)	3,442,290		

Local Economic Impacts - Summary Results

	Jobs (FTE)	Earnings (Millions of 2010)	Output (Millions of 2010)
During construction period			
Project Development and Onsite Labor Impacts	223	$12.42	$18.63
Construction Labor	201	$10.56	
Construction Related Services	21	$1.86	
Turbine and Supply Chain Impacts	128	$9.52	$31.05
Induced Impacts	81	$4.18	$11.76
Total Impacts	**432**	**$26.12**	**$61.44**
During operating years (annual)			
Onsite Labor Impacts	14	$1.88	$1.88
Local Revenue and Supply Chain Impacts	5	$0.28	$2.67
Induced Impacts	5	$0.23	$0.68
Total Impacts	**24**	**$2.39**	**$5.22**

Notes: Earnings and Output values are millions of dollars in year 2010 dollars. Construction and operating jobs are full-time equivalent (FTE) for a period of one year (1 FTE = 2,080 hours). Plant workers includes operators, field technicians, administration and management. Economic impacts "During operating years" represent impacts that occur from plant and wellfield 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. Results are based on user defined Simple analysis.

Figure 1. Project data summary and local economic impacts summary results[6] from geothermal JEDI run for a hydrothermal project

4.2 Comparing Results among JEDI Models

Capacity factor and energy generation should be considered when comparing the economic development benefits from different power generation technologies. When comparing results from JEDI models for different power technologies (i.e. solar, wind, fossil), it is best to compare between facilities with equivalent energy generation rather than comparing facilities with a similar nameplate capacity. That is, it is preferable to compare jobs per kilowatt-hours per year, not jobs per kilowatts installed.

4.3 Caveats

1. The intent of the geothermal impact model is to construct a reasonable profile of expenditures (i.e., geothermal exploration, drilling, power plant construction and operating costs) and demonstrate the magnitude of the economic impacts that will likely result, assuming a project occurs during the stated period of analysis. Given the unique

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

nature of geothermal resources and the changing nature of the industry, including expected changes as EGS technologies mature, 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.

2. JEDI is considered a static model. As such, it relies on inter-industry relationships and personal consumption patterns existing in the particular year the multipliers were derived. 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. In addition, the model does not automatically account for industry productivity improvements that may occur over time; nor does it account for changes that may occur in the construction or O&M processes (e.g., production recipe for labor, materials, and service cost ratios) for new power plants.

3. JEDI was not designed to provide cash flow projections or for use as a cash flow analysis tool. NREL has detailed financing models and tools that address cash flows in detail.[7]

4. The analysis assumes the output from the geothermal system and the specific terms of a power purchase agreement generate sufficient revenues to accommodate the equity and debt repayment and annual operating expenditures. To the extent 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.

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

5 User Add-in Location Feature

The initial design of the JEDI 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 impractical.

To accommodate users who desire this higher level of analysis, a User Add-in Location feature is provided in the model. This feature allows users with the capability to derive the necessary data to complete analysis for a specific region of interest (other than the state level) 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, entered in decimal format, for each industry, totaling 100% combined) for the 14 aggregated industries. 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 IMPLAN Version 3 software or the most current available, create a new model with the desired region (one county, group of counties, or group of states).
3. Construct the model.

4. Aggregate the model. This step requires creation of 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.

5. Reconstruct the model.

6. Export household local commodity demand (personal consumption expenditures) and multipliers for employment, employee compensation, and output to spreadsheet files.

7. Format data contained in each of these files to input (i.e., cut and paste) into 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 is entered into the JEDI model, the user need only identify the location of the geothermal system (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 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 multiplier and consumer expenditure data from another input-output modeling tool.

2. Purchase the necessary data (aggregated multiplier and consumer commodity demand— see description above) from someone skilled in input-output modeling.

3. Purchase the necessary data (aggregated multiplier and consumer commodity demand— see description above) from Minnesota IMPLAN Group, Inc. (IMPLAN).

4. Purchase the necessary data (aggregated multiplier and consumer commodity demand— see description above) from MRG & Associates, the model developer.

6   Data Sources and Cost Categories

Analyzing the economic impacts of constructing and operating geothermal plants requires a large amount of project and location specific data. These include project capital costs, labor rates, state specific input-output multipliers and personal expenditure patterns, and price deflators. Many developers consider this type of information proprietary due to competitive forces in the marketplace. Similarly, project specific differences, such as resource temperature, geology, or average production well flow rates significantly impact costs. As a result, it is not possible to identify a "one price fits all" solution. Nevertheless, the model provides default values for each of the inputs noted above and all those necessary for the analysis. Project costs such as drilling expenses, plant construction, and O&M costs were derived from a variety of sources including: GETEM –Version 2009-A15[8]; System Advisor Model (SAM) – Version 2010.11.9[9]; *The Future of Geothermal Energy* 2006 Massachusetts Institute of Technology (MIT) study[10]; AFEs; communication with geothermal industry professionals; renewable and fossil fuel energy studies; and project-related case studies. These sources helped to establish a baseline for cost analysis.

The project specific data includes a bill of goods (which contains detailed costs associated with actual construction of the facility, roads, etc., as well as costs for equipment and other services and fees required), annual operating and maintenance costs and data on the portion of expenditures spent locally, financing terms, and tax rates, among others. More specifically, the model requires the following project inputs:

1. Exploration costs

2. Drilling costs

3. Stimulation costs (if EGS is chosen)

4. Plant Construction costs (materials and labor)

5. Equipment costs (turbines, generators, surface piping, condensers, etc.)

6. Other costs (engineering, insurance, etc.)

7. Annual operating and maintenance costs (personnel, materials and services)

8. Other parameters (financial – debt and equity, taxes and land lease).

6.1   Exploration Costs

Exploration costs in JEDI include permitting, pre-drilling exploration costs, and exploration drilling costs. Costs for permitting and pre-drilling exploration activities are based on the default values for exploration activities listed in GETEM and on input wages[11] for individual occupations. Exploration drilling costs for the simple input option are based on a user-input well

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[8] The current version of GETEM may be downloaded at:
http://www1.eere.energy.gov/geothermal/geothermal_tools.html.
[9] The System Advisor Model (SAM) can be downloaded at: https://www.nrel.gov/analysis/sam/.
[10] Tester, J.W., et al. (2006). The Future of Geothermal Energy. INL/EXT-06-11746. Work performed by MIT. Cambridge, MA: http://www1.eere.energy.gov/geothermal/future_geothermal.html.
[11] Wage rate data and sources are listed in the "Job Rates and Wages" worksheet of the geothermal JEDI model.

cost multiplier applied to individual well costs, described in the next section. The advanced model option allows the user to add greater detail for well cost estimates, but requires in-depth user knowledge. See the next section on individual well costs for more information.

6.2 Drilling and Wells
6.2.1 Individual Well Costs
Well costs for the simple input JEDI model are based on drilling cost curves used in GETEM. Three drilling cost curve options are allowed by the model: low, medium, or high. The three exponential cost curves are expressed using the following equations:

- Low Cost (thousands of 2004 $) = $580 * e^{(0.0001188 * \text{Depth in feet})}$

- Medium Cost (thousands of 2004 $) = $580 * e^{(0.000149 * \text{Depth in feet})}$

- High Cost (thousands of 2004 $) = $580 * e^{(0.000189 * \text{Depth in feet})}$.

Recent industry well cost data matches best with the medium cost curve, which is the default setting. Under the simple input option, users can change to the low or high cost curve if they choose. The simple input uses the same drilling cost curves for exploration, production, and injection wells when calculating project costs. Exploration well costs are determined based on the user-input exploration well cost multiplier. Similar to GETEM, JEDI adjusts drilling costs from 2004 US$ to the user-defined project year using the Bureau of Labor Statistics Oil and Gas Well Drilling Cost Index.[12]

Users may override the default drilling cost curves by using the advanced model option to add greater detail for well cost estimations. As previously noted, the advanced model requires in-depth user knowledge of drilling costs. For example, drilling progress is an input field that allows the user to choose from easy, medium, or hard drilling rates. This reflects the variable rate of penetration that drillers encounter for different rock types, geology, and structure. The advanced model user is also able to input wages for geologists, drilling engineers, drilling fluid servicemen, directional engineers, etc.[11] Other cost input options include site maintenance, outside services, administration, fuel, and drilling tools, among others.

6.2.2 Total Number of Wells and Total Well Cost
The total number of wells is found by summing the number of exploration wells, production wells, and injection wells:

- Exploration Wells: The user enters the number of exploration wells for both simple and advanced input options.

- Production Wells: The number of production wells is determined using three[13] user supplied inputs—nominal plant size, input temperature, and flow rate per well. The input temperature is used to determine the BE (brine effectiveness - parasitic losses, see Section 6.4.1). Power sales per production well is then derived from the flow per well and

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[12] BLS (2010). Oil and Gas Drilling Cost Index, Bureau of Labor Statistics.
[13] If the user chooses "Input Value" for Plant Size Scalar, then four user supplied inputs are used in determining the number of production wells.

multiplied by the effective BE value. Finally, the total number of production wells required is calculated by dividing the nominal plant size by the power sales per well.

- Injection Wells: The number of injection wells equals the number of production wells divided by the user input option for production-to-injection ratio for both simple and advanced input options.

Once the cost per well and total number of wells is known for the project, a total project well cost is calculated simply by taking the cost per well multiplied by the total number of wells needed for the project.[14]

6.2.3 Drilling Material Costs

Cement and casing costs are designated as material costs in the JEDI model (default values are in 2010 dollars). Other material costs associated with drilling the wells make up a very small portion of the well costs relative to casing and cement, and were not included. Material costs vary as a function of depth. With increasing depth, a larger portion of the total well costs are spent on material costs following an exponential curve. According to the MIT report, material costs vary from approximately 27% to 36% of total well cost, based on depth.[15]

The simple model option calculates drilling material costs as a percentage of the total well cost, ranging from 29% to 32%, depending on the cost curve chosen by the user. However, the advanced model option calculates drilling material costs as a function of depth. The relationship was determined based on detailed well data obtained for a recently drilled production well and from the AFE data in the 2006 MIT report. Costs were normalized to 2010 dollars.

Drilling material costs are calculated as a function of depth (D, in meters), using the following cost curve equation:

Drilling Material Costs $= 0.0000000144*D^4 - 0.000149*D^3 + 0.636*D^2 - 406*D$

Users may override the material cost default in the advanced model option and input their own material costs.

6.3 EGS Stimulation Costs and Reservoir Creation

The primary difference between hydrothermal and EGS projects is that EGS requires the reservoir to be stimulated to create or enhance the geothermal reservoir. When EGS is chosen as the project technology, JEDI calculates the costs and economic impacts associated with reservoir stimulation activities. EGS reservoir stimulation is an emerging technology. As a result, stimulation methods are still being researched and developed, and detailed data on the activities and costs associated with stimulation are limited.

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[14] For the JEDI analysis, makeup wells that may be required as a result of reservoir decline are not considered.
[15] Tester, J.W., et al. (2006). *The Future of Geothermal Energy*. INL/EXT-06-11746. Work performed by MIT. Cambridge, MA: http://www1.eere.energy.gov/geothermal/future_geothermal.html.

For the JEDI model, three scenarios consisting of stimulations occurring over different lengths of time were developed.[16] The user can select one of three EGS well stimulation cost choices available in a drop-down menu ($400k, $700k, or $1M per well). The three choices represent different rates of reservoir stimulation. A $400k stimulation will be completed in approximately 1-3 days; a $700K stimulation will be completed in 16-18 days; and a $1M stimulation will take approximately 30 days. Both fixed and variable costs are used when determining the total stimulation cost. Table 1 shows sample cost schedules for 3-day and 30-day stimulations. Mobilization/demobilization is the major share of the fixed cost in either stimulation. Rig rate daily cost is the largest component in variable costs. Currently, a standard drill rig is used in an EGS well stimulation and acts as a pump rig for the water used during stimulation.

Table 1. EGS Well Stimulation Costs for 3-day (left) and 30-day (right) EGS Stimulation Scenarios in JEDI

3 Day Stimulation		30 Day Stimulation	
Associated Variable Costs:		Associated Variable Costs:	
Reservoir Engineer (per day)	1600	Reservoir Engineer (per day)	1600
Geologist	-	Geologist	-
Geophysicist (day)	700	Geophysicist (day)	700
Drill Rig (EGS)	15000	Drill Rig (EGS)	15000
Additional Crew	-	Additional Crew	-
Fuel	2000	Fuel	2000
Daily Total	19300	Daily Total	19300
Total Variable Cost	57,900.00	Total Variable Cost	579,000.00
Associated Fixed Costs:		Associated Fixed Costs:	
Injection Testing	25,000	Injection Testing	25,000
Mobilization/Demobilization	250,000	Mobilization/Demobilization	250,000
Water ($1.38/Kgallons)	27,600	Water ($1.38/Kgallons)	27,600
Downhole Logging	30,000	Downhole Logging	30,000
Total Fixed Cost	332,600	Total Fixed Cost	332,600
SubTotal	390,500.00	SubTotal	911,600.00
Contingency (5%)	19,525.00	Contingency (5%)	45,580.00
Total Cost per well	410,025.00	Total Cost per well	957,180.00

JEDI assumes that both the production and injection wells require stimulation. Using the advanced input option, the user can override any of the component costs associated with the well stimulations shown in Table 1.

6.4 Power Plant

The geothermal JEDI model contains sensitive parameters related to power plant performance that affect overall project economics. Plant thermal efficiency (also referred to as brine effectiveness in GETEM) and gross power output are two important parameters that directly affect the plant size, capital cost, and labor force required. Input resource temperature directly influences the thermal efficiency which is used in determining the geothermal fluid flow rates required for a given nominal plant size. Economies of scale are exhibited with increasing plant

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[16] The stimulation scenarios, activities, and market rates for the associated services were developed through conversation with Rob Stacy at Geothermex, Inc., a reservoir engineer knowledgeable on EGS stimulation research and component costs (Personal Communication with Chris Johnson, April 20, 2011).

size and reduced costs on a $/kW installed basis. Both flash and binary plant types exhibit decreasing average plant costs with increasing power capacity.

6.4.1 Thermal Efficiency
Thermal efficiency values are referred to in GETEM as brine effectiveness values, measured in watt-hours per pound (w-h/lb). Brine effectiveness (BE) values used in JEDI are identical to the correlations given in GETEM documentation[17] and typically increase with temperature. For the JEDI model, binary plant BE values are not designed to be used with temperatures below 140°C and above 268°C. Above this temperature, the model deteriorates and diminishing BE values are observed. Below this range, the model may output negative project costs. Single-flash BE correlations were used for steam plants. Resource temperatures below 180°C are not recommended for flash plant analysis.

6.4.2 Power Plant Size
The JEDI model needs the user to enter the nominal (net) power plant size. It then calculates the gross or nameplate power plant size based on plant parasitic losses. Parasitic losses in the geothermal system include power requirements for injection and production well pumps, condenser system power use, binary fluid pump requirements, etc., and account for the difference between nominal and gross power. In JEDI, parasitic losses and the ensuing gross power plant size is described by the plant size scalar. For both the simple and advanced input options, JEDI allows use of the model-derived plant size scalar or a custom input. Calculation of the model-derived plant size scalar is described below.

Gross power is a function of nominal plant size, resource temperature, flow rate, resource depth, and the thermal efficiency of the geothermal brine.[18] Gross power for both binary and flash plants are determined by polynomial curve-fitting using data tables built from GETEM and System Adviser Model (SAM) output values.[19] With the JEDI model, "the derivation of the performance and cost correlations for the flash plant required that the plant parasitic loads be characterized, allowing a gross plant output to be determined. Although the different plant parasitic loads are calculated, the final performance and cost projected by GETEM for the plant are in terms of the net plant power definition given".[20]

For a single-flash plant, three separate data tables were built from GETEM model runs to determine how SAM correlations of gross and nominal power output vary as a function of temperature, flow rate, and depth. First, temperature was incremented in SAM from 180° to 350°C for a nominal plant size of 50 MW$_e$ at a reference depth of 2,000 meters and reference flow rate of 60 kilograms/second (kg/s) per well. Gross power was recorded and a polynomial

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[17] GETEM Technical Appendix III can be accessed at:
http://www1.eere.energy.gov/geothermal/pdfs/getem_vol_iii_technical_appendixes.pdf
The correlations used for brine effectiveness are also given in the "Brine Effectiveness" worksheet in the geothermal JEDI model.

[18] A 95% plant utilization rate was assumed for thermal efficiency analysis.

[19] For the purposes of the JEDI model, gross plant size is used in determining O&M costs. Plant costs are determined from cost curves derived from nominal plant size.

[20] DOE (2005). Geothermal Electricity Technology Evaluation Model (GETEM) Washington, D.C. Volume III - Detailed Technical Appendices.

curve fit to the values based on the gross power as a percentage of nominal. A similar table was built when flow rate was varied from 20 to 130 kg/s at 200°C and 2,000 meter (m) depth. Finally, depth was incremented from 1,500 m to 10,000 m at 200°C and 60 kg/s. This process allowed for flow rate and depth corrections to be applied to a curve derived from temperature correction factors, where flow rate and depth were determined to be necessary components of gross power determination to allow for a broader range of resource configurations. For example, at 270°C, a single-flash facility will require a gross capacity 19.5% above the nominal output to account for parasitic losses. Thus, for a 50 MW_e nominal power output facility, a nameplate capacity of approximately 59.75 MW_e would be installed.

Table 2 shows the parasitic losses used by JEDI for a flash plant at the reference conditions over the range of valid model temperatures. JEDI uses this percentage as the plant size scalar to determine the gross or nameplate capacity. The following polynomial curve fit describes the curves for parasitic losses for the flash plant:

$Parasitic\ Losses\ (\%\ of\ gross\ plant\ output) = 1.9093E\text{-}09*T(°C)^4 - 2.2261E\text{-}06*T(°C)^3 + 9.7847E\text{-}04*T(°C)^2 - 1.9192E\text{-}01*T(°C) + 1.4353E\text{+}01$

Figure 2. Flash plant pump work (parasitic losses) as a percentage with varying temperatures (2,000m at 60 kg/s)

JEDI adjusts for parasitic losses for plants operating at conditions other than the reference conditions by applying correction factors to the parasitic losses for geothermal fluid flow rate and reservoir depth. The following polynomial curves describe the correction factors.

Flow rate:
$Y_1 = 1.5191E\text{-}04*Flow\ Rate\ (kg/s)^2 + 2.9170E\text{-}03*Flow\ Rate\ (kg/s) + 2.7812E\text{-}01$

Depth:
$Y_2 = -1.0843E\text{-}04*Depth(m) + 1.2169E\text{+}00$

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Gross power for binary plants was determined using a similar method, with a temperature range of 130° to 270°C.

Figure 3 shows the parasitic losses used by JEDI for a binary plant at the reference conditions over the range of valid model temperatures. The following polynomial curve fit describes the curves for parasitic losses for the flash plant:

Parasitic Losses (% of gross plant output) = 1.2575E-08*T(°C)⁴ - 1.0923E-05*T(°C)³ + 3.5388E-03*T(°C)² - 5.0752E-01*T(°C) + 2.7383E+01
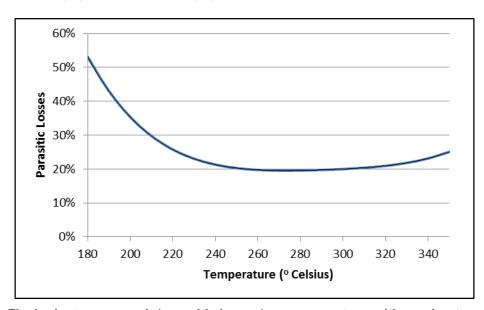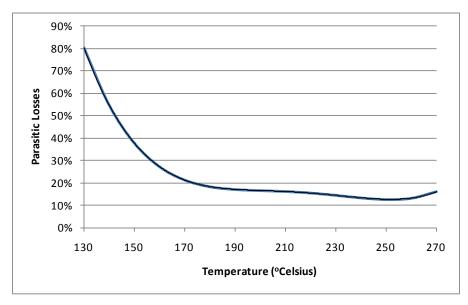

Figure 3. Binary plant pump work (parasitic losses) as a percentage with varying temperature (2000m at 60 kg/s)

JEDI adjusts for parasitic losses for plants operating at conditions other than the reference conditions by applying correction factors to the parasitic losses for geothermal fluid flow rate and reservoir depth. The following polynomial curves describe the correction factors.

Flow rate:
$Y_1 = 10.0179*Flow\ Rate\ (kg/s) - 0.0745$

Depth:
$Y_2 = -1.0843E-04*Depth(m) + 1.2169E+00$

Example Calculation: A 50MW binary plant has a flow rate of 70 kg/s at 3,000 m at 200°C. First, the resource temperature is used in the model to determine the initial parasitic loss. At 200°C, this is 16.7%. This percentage is multiplied by the flow correction to give a 19.7% parasitic loss. Finally, the depth correction is applied to the flow-corrected percentage, giving the final parasitic loss of 19.8%.

6.4.3 Power Plant Costs
Power plant cost correlations in JEDI were based on information and data tables obtained from the GETEM model and technical appendices. GETEM considers many user-inputted variables in

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determining geothermal power plant costs, resulting in a lengthy and complex set of calculations. To the end of maintaining the usability and simplicity of the JEDI model, cost correlations were developed considering only the two factors that were found to have the biggest impact on cost: resource temperature and plant size. The general methodology used for the cost correlations is as follows:

1. Determine plant cost for a reference plant for the user-defined resource temperature.

2. Adjust plant cost based on user-defined plant size relative to reference plant size.

3. Adjust plant cost for year of construction.

Separate cost correlations were developed for binary and flash plant types as described below. The same plant cost curves were used for both hydrothermal and EGS projects.

6.4.3.1 Flash Plant

Flash plant cost correlations were developed based on polynomial curves fit to flash plant costs from a data table populated with GETEM output data. Flash plant costs were determined for 5, 25, 50, 75, and 100 MW_e-flash facilities with temperatures ranging from 180° to 350°C. Best-fit polynomial curves of costs as a function of temperature were developed for each plant size to capture the relationship in decreasing costs ($/kW basis) with increasing resource temperatures. Figure 4 shows cost curves output from GETEM for temperatures varying from 180° to 350°C for plant facilities ranging in plant size from 5MW to 100MW.[21]
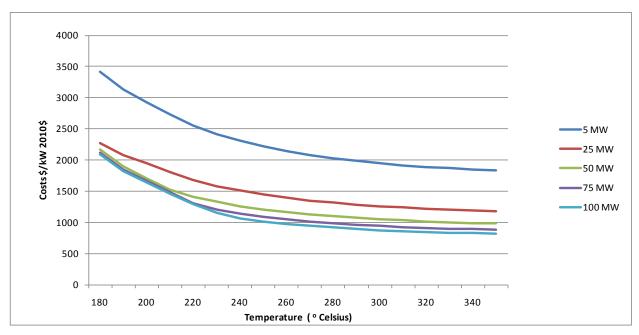
Figure 4. Flash plant cost curves from GETEM output data used to develop cost correlations

The cost correlation for the flash plant closest in size to the user-input plant size is chosen by the JEDI model and used to calculate the plant cost as a function of temperature. Next, this cost is adjusted based on user-defined plant size relative to reference plant size using the temperature

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[21] Costs were adjusted from 2008 to 2010 dollars using the CERA plant cost index, described later in the section.

cost correlation. Plant costs as a function of size were compiled in 5 MW$_e$ increments from 5 MW$_e$ to 100 MW$_e$ assuming a resource temperature of 200°C. The resulting cost curves for both flash and binary power plants are shown in Figure 5. Based on the cost curve, the following plant size correction factor for flash plants was developed:

Flash plant size correction factor = 0.9944 * (User Defined Plant Size/Reference Plant Size)$^{-0.26}$)

Using the temperature correlation and plant size correction factor, JEDI would estimate flash plant costs that deviated at most 4% from GETEM estimates.
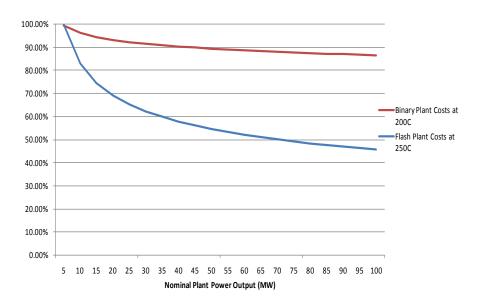
Figure 5. Flash and binary plant economy of scale discount curves

6.4.3.2 Binary Plant

Binary plant costs for a given resource temperature are initially determined for a 50MW$_e$ facility using the cost correlation defined in GETEM documentation, shown in Figure 6. Plant costs are then adjusted to the user-defined plant size using a plant size correction factor, similar to the method for flash plants described above (see Figure 5). Based on this method, the following plant size correction factor for binary plants was developed:

Binary plant size correction factor = 0.9936 * (User Defined Plant Size/50 MW$_e$)$^{-0.46}$)

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The cost correlation used in GETEM is based upon a curve fit of these costs for the NGGPP 50 MW plant with the adjusted current costs. This cost correlation used has the following form:

For $T \leq 190°C$
$$Cost = K_0 + K_1 * T + K_2 * T^2 + K_3 * T^3, \text{ where}$$
    Cost is 50 MW plant cost in \$/kW
    T is fluid temperature, °C
    $K_0 = 21520.78$
    $K_1 = -331.34$
    $K_2 = 1.854876$
    $K_3 = -0.003491132$

For $T > 190°C$
$$Cost = Cost@190°C - 3.08*(T - 190)$$
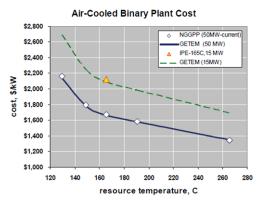
Figure 6. Binary plant cost correlations for a 50 MW$_e$ plant

Source: GETEM Technical Appendix III

6.4.3.3 Plant Cost Index

Both flash and binary plant costs are adjusted to plant construction year using the Cambridge Energy Research Associates (CERA) Power Capital Costs Index (PCCI), which tracks and forecasts the costs associated with the construction of a portfolio of 30 different power generation plants in North America.[22] The PCCI tracks the costs of building coal, gas, wind, and nuclear power plants, indexed to year 2000. For the JEDI model, it was assumed that the PCCI index also applied to geothermal power plants.
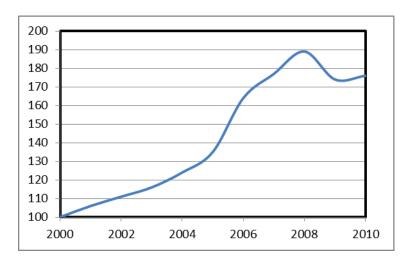
Figure 7. Power plant cost index

Data Source: CERA 2010

6.4.4 Plant Equipment and Labor Costs

Plant equipment costs are used in the JEDI model to determine supply chain economic impacts. Plant equipment is a significant capital expenditure in the overall project construction and it is essential to have good estimates for equipment costs. Both binary and flash plant equipment

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[22] CERA (2010). IHS CERA Power Capital Costs Index (PCCI) Cambridge, MA, Cambridge Energy Research Associates.

costs were determined using output from GETEM. Binary equipment costs are shown on GETEM worksheet Table 4d and are broken down by plant component: turbine-generator, geothermal fluid heat exchanger, air cooled condenser, and well field pumps. Worksheet 5d in GETEM shows the flash plant equipment costs broken down by: turbine-generator, flash vessels, cooling tower, condenser, well field pumps, non-condensable gas (NCG) removal system, and hydrogen sulfide (H_2S) removal system. For flash plants, the equipment cost percentages were derived by averaging five plant configurations of varying temperatures (200^oC, 225^oC, 250^oC, 275^oC, 300^oC). The fixed parameters were: nominal plant size (50MW$_e$), depth (2,000 m), and flow rate (70 kg/s).[23] The figures below show the average taken of these plant configurations showing equipment cost as a percentage of total plant equipment. Only 1-4% cost deviations from GETEM were observed in the plant configurations tested. Binary plant equipment costs had more variance than flash plants due to variations in temperature significantly affecting the air-cooled condenser costs. The equipment cost percentages were obtained by taking the average of six plant configurations of varying temperatures (150^oC, 200^oC, 250^oC) and nominal plant size (10, 50 MW$_e$). The fixed parameters were depth (2,000 m) and flow rate (60 kg/s). Table 2 shows the average cost of equipment for flash and binary power plants used by the JEDI model based on these assumptions. In the advanced model, the user can override the equipment cost calculations.

Table 2. Binary and Flash Plant Equipment as Percentages of Total Equipment Cost Used in JEDI

Binary Plant		Flash Plant	
Equipment	% of total plant equipment cost used for JEDI model	Equipment	% of total plant equipment cost used for JEDI model
Geothermal Fluid Heat Exchanger	7.67%	Turbine Generator	68.74%
Air Cooled Condenser	37.8%	Flash Vessels	2.38%
Well Fluid Pumps	3.73%	Cooling Tower	10.21%
Turbine Generator	50.8%	Condenser	12.02%
		Well Field Pumps	5.29%
		NCG Removal System	0.35%
		H_2S Removal System	1.01%

For the simple input option, plant labor costs are based on a percentage of the total plant capital costs and broken out by occupation.[24] These default values can be overridden using the advanced input option.

6.5 Operations and Maintenance

Once a geothermal power facility is operational, a number of personnel are required to operate and maintain the facility. Plant managers, engineers, technicians, and site operators are typically employed on-site. A typical O&M team covers three distinct areas of the power plant operation: the power generating unit, the steam or brine gathering system, and the subsurface geothermal

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[23] It was observed that depth and flow rate have little impact on equipment cost variance.

[24] Wage rate data and sources are listed in the "Job Rates and Wages" worksheet of the geothermal JEDI model.

reservoir.[25] The turbine or power generating unit requires regular inspections and maintenance to ward off corrosion and ensure turbine performance. The steam gathering system must be carefully monitored for corrosion, scaling, leaks, and worn parts that need replacement. The geothermal reservoir also must be maintained, which may require re-drilling of a makeup production and/or injection wells. As noted previously, re-drilling of makeup wells is not included in the JEDI analysis.

O&M jobs are determined using data tables outlined in GETEM. O&M job estimates shown in the results summary of JEDI are annual FTE jobs staffed for the lifetime of the power facility. The staffing requirements in the table below include a direct labor rate multiplier of 2.5. The multiplier accounts for employer payroll costs and other related costs. It is recognized that a plant may use part-time employees and that the optimal staff size will vary by location and plant configuration. Figure 8 shows O&M FTE values used in JEDI for flash plants, while Figure 9 shows the equations used to calculate O&M FTE values for binary plants. O&M FTE calculations are identical for hydrothermal and EGS projects.

Job Type	<5MW	<10MW	<20MW	<30MW	<40MW	>40MW
Operations	0.23	1	1	1.5	1.5	2
Maintenance	0.125	0.5	0.9	1.3	1.3	1.5
Office	0.2	0.33	0.67	1	1	1

Figure 8. Flash plant O&M jobs – number of FTE jobs per year per category

Source: GETEM Table 5.b

Operators $= 0.25 * Plant\ Capacity^{.525}$

Maintenance mechanic $= 0.25 * Plant\ Capacity^{.525}$

Electrician $= 0.25 * Plant\ Capacity^{.525}$

General maintenance labor $= 0.25 * Plant\ Capacity^{.525}$

Facility manager/plant engineer $= 0.075 * Plant\ Capacity^{.65}$

Operations manager $= 0.075 * Plant\ Capacity^{.65}$

Clerical $= 0.075 * Plant\ Capacity^{.65}$

Figure 9. Binary plant O&M jobs – number of FTE jobs per year per category

Source: GETEM Table 4.b

6.6   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, cement which is used in the drilling and plant construction phase will likely be sourced locally and 100% of the cost associated with purchasing the material is assigned to the local economy by JEDI. Conversely, an exploration geologist familiar with geothermal exploration techniques is a specialized profession, and may not be available in the chosen area.

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[25] GEA (2009). GEA Issue Brief: Geothermal Energy and Jobs. Washington, D.C.

JEDI assumes that activities that do not require specialized skills, such as construction and general labor, are assumed to be 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 either oil and gas[26] or geothermal operations, such as California and Nevada[27], offer many of the services, equipment, and materials required in a geothermal project. If one of these states is chosen as the project location, then a higher local impact will be realized compared to a project located in a state without an established geothermal industry where the majority of these services, equipment and materials are not available in-state and must be sourced from other states. A list of eligible states offering the various geothermal services was compiled from industry research and personal communication with industry professionals.

Turbine generators were not assigned any local share for US geothermal power plants. Flash geothermal turbines are generally manufactured in Japan. Toshiba, Mitsubishi, and Fuji are the top three manufacturers. Ormat leads the binary geothermal turbine market and accounts for over 90% of binary market share. Ormat turbines are manufactured in Israel.[28]

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[26] Many of the same technologies used in a geothermal project are similar to those used in oil and gas. For example, drill rigs used in oil and gas drilling may also be used for drilling a geothermal field.

[27] A list of eligible states offering the various geothermal services was compiled from industry research and personal communication with industry professionals. The list of states and the local share percentages that accrue from them can be found in the "Local Share" worksheet in JEDI.

[28] Taylor, M. (2010). "The Global Geothermal Turbine Market: the Accidental Leaders." Bloomberg New Energy Finance, Geothermal-Turbine Market Share-Research Note.

7 Validation of JEDI Results

JEDI model results[29] were compared against job creation statistics reported for two binary hydrothermal projects that were part of the Department of Energy (DOE) Section 1705 Loan Guarantee Program. Table 3 shows the FTE O&M jobs (permanent) and FTE construction jobs that were reported as supported through these two projects.[30]

Table 3. Job Impacts for Geothermal Projects Funded by Section 1705 Loan Guarantee Program

Project	Developer	State	Jobs Supported	
			Permanent	Construction
Blue Mountain	Nevada Geothermal	Nevada	14	200
Neal Hot Springs	U.S. Geothermal	Oregon	10	150

Source: U.S. DOE Loan Programs Office 2012

Nevada Geothermal's Blue Mountain-Faulkner 1 plant was brought online in 2009. Plant information was input into JEDI and used to create the results summary. Resource information was gathered from Nevada Geothermal's website, press releases, and online media library and entered into JEDI as shown in Figure 9. Figure 10 shows the summary results from JEDI. It estimates that 225 FTE construction jobs and 17 O&M jobs will result directly from the 49.5MW capacity plant (39.5 MW net). These estimates are close to the figures reported by the DOE Loan Programs Office of 200 FTE construction and 14 permanent O&M jobs for this facility. Additionally, JEDI estimates the indirect and induced job and economic impacts from the facility. As a consequence of the activities and jobs directly supported by the project, JEDI estimates that an additional 454 FTE positions during project construction and 11 permanent jobs can be attributed to the Blue Mountain geothermal project.

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[29] Due to continuous updates to the JEDI model, it may not be possible to exactly reproduce the results of these model runs.

[30] U.S. Department of Energy Loan Programs Office. (2012). https://lpo.energy.gov/ Accessed Dec. 10, 2012.

Project Descriptive Data

Geothermal Input Sheet

Select Model Analysis Type (Simple or Advanced)	Simple	
User Input:		
Project Location	NEVADA	
Year of Construction	2010	
Construction Period (months)	21	
Nominal Plant Size (MW net output)	39.5	
Technology: (Hydrothermal or EGS)	Hydrothermal	
Plant Type (Flash or Binary)	Binary	
Resource Temperature (select Celsius or Farenheit)	374	Farenheit
Resource Depth (select meters or feet)	2500	Feet
Plant Size Scalar	25.25%	
Ratio of Production to Injection Wells	1.5	
Number of Exploration Wells	2	
Exploration Well Cost Multiplier	0.5	
Production Well Flow Rate (kg/s)	110	
Drilling Cost Curve (Simple Model - Select Low, Medium,	Medium	
Contingency (percent of all costs)	5.0%	
Plant O&M Equipment Cost (percent of Plant cost)	2.0%	
Money Value (Dollar Year)	2010	

Figure 10. JEDI input for Blue Mountain 39.5 MW resource and plant configuration

Local Economic Impacts - Summary Results

	Jobs (FTE)	Earnings (Millions of $2010)	Output (Millions of $2010)
During construction period			
Project Development and Onsite Labor Impacts	225	$11.50	$17.25
Construction Labor	204	$9.66	
Construction Related Services	21	$1.83	
Turbine and Supply Chain Impacts	283	$17.52	$65.98
Induced Impacts	171	$6.86	$21.06
Total Impacts	**679**	**$35.87**	**$104.28**
During operating years (annual)			
Onsite Labor Impacts	17	$2.24	$2.24
Local Revenue and Supply Chain Impacts	5	$0.23	$2.95
Induced Impacts	6	$0.27	$0.83
Total Impacts	**28**	**$2.73**	**$6.02**

Figure 11. Job estimation and economic impact output for 39.5 MW binary plant

The U.S. geothermal facility at Neal Hot Springs in Oregon was also modeled in JEDI.
Management expects that 4-5 production wells will be needed to meet output expectations, while
an injection strategy is still being formulated. JEDI input is shown in Figure 12, and the
summary results are shown in Figure 13. JEDI estimates 146 FTE construction and 12 O&M
jobs result directly from the 23 MW net output facility, while the DOE Loan Programs Office
reported 150 FTE construction and 10 O&M jobs for this facility. JEDI estimates an additional
128 FTE positions during construction and 9 additional permanent positions during plant
operation can be attributed to the plant from indirect and induced impacts. The indirect and

construction are not as great for the Neal Hot Springs project in Oregon as they are for the Blue Mountain project in Nevada. This is because Nevada has an established geothermal industry, and is assumed to have a large local share in JEDI, while Oregon is assumed to have little existing geothermal industry so that more specialized activities are assumed to be non-locally sourced and the project has fewer indirect and induced local impacts.

Project Descriptive Data		
Geothermal Input Sheet		
Select Model Analysis Type (Simple or Advanced)	Simple	
User Input:		
Project Location	OREGON	
Year of Construction	2010	
Construction Period (months)	18	
Nominal Plant Size (MW net output)	23	
Technology: (Hydrothermal or EGS)	Hydrothermal	
Plant Type (Flash or Binary)	Binary	
Resource Temperature (select Celsius or Farenheit)	286	Farenheit
Resource Depth (select meters or feet)	2895	Feet
Plant Size Scalar	13.00%	
Ratio of Production to Injection Wells	2	
Number of Exploration Wells	2	
Exploration Well Cost Multiplier	0.5	
Production Well Flow Rate (kg/s)	130	
Drilling Cost Curve (Simple Model - Select Low, Medium, or High)	Medium	
Contingency (percent of all costs)	5.0%	
Plant O&M Equipment Cost (percent of Plant cost)	2.0%	
Money Value (Dollar Year)	2010	

Figure 12. JEDI input for Neal Hot Springs 23 MW resource and plant configuration

Local Economic Impacts - Summary Results	Jobs (FTE)	Earnings (Millions of $2010)	Output (Millions of $2010)
During construction period			
Project Development and Onsite Labor Impacts	146	$5.27	$7.90
Construction Labor	144	$5.10	
Construction Related Services	2	$0.17	
Turbine and Supply Chain Impacts	72	$3.88	$13.88
Induced Impacts	55	$2.26	$6.65
Total Impacts	**274**	**$11.42**	**$28.43**
During operating years (annual)			
Onsite Labor Impacts	12	$1.57	$1.57
Local Revenue and Supply Chain Impacts	4	$0.19	$2.14
Induced Impacts	6	$0.25	$0.72
Total Impacts	**21**	**$2.01**	**$4.43**

Figure 13. Job estimation and economic impact output for 23 MW binary plant