EC-LEDS
ENHANCING CAPACITY FOR LOW EMISSION DEVELOPMENT STRATEGIES

USER GUIDE FOR THE INTERNATIONAL JOBS AND ECONOMIC DEVELOPMENT IMPACTS MODEL

September 2016

David Keyser, Francisco Flores-Espino, Caroline Uriarte, and Sadie Cox

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ABBREVIATIONS

EC-LEDS	Enhancing Capacity for Low Emission Development Strategies: U.S. government effort that assists partner countries in developing and implementing LEDS
GDP	gross domestic product
I-JEDI	International Jobs and Economic Development Impact: a model developed by NREL with support from USAID that is intended to provide countries outside of the United States a tool to estimate gross economic impacts that could be supported by the construction and operation of renewable energy facilities
I-O	input-output: model depicting country-specific relationships within industries and sectors, with the aim of demonstrating how inputs to one industrial sector may affect outputs in another industrial sector
NAMA	Nationally Appropriate Mitigation Action
NREL	National Renewable Energy Laboratory
OECD	Organisation for Economic Cooperation and Development
STAN	STructural ANalysis: an OECD database for industrial analysis that can be used to analyze industrial performance at a detailed level of activity across countries
USAID	United States Agency for International Development

Introduction

The International Jobs and Economic Development Impacts (I-JEDI) model is a freely available economic model that estimates gross[1] economic impacts from wind, solar, bipower, and geothermal energy projects for several different countries. Building on the original JEDI model,[2] which was developed for the United States, I-JEDI was developed under the USAID Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) program to support countries in assessing economic impacts of LEDS actions in the energy sector.

I-JEDI estimates economic impacts by characterizing the construction and operation of energy projects in terms of expenditures and the portion of these expenditures made within the country of analysis. These data are then used in a country-specific input-output (I-O) model to estimate employment, earnings, gross domestic product (GDP), and gross output impacts. Total economic impacts are presented as well as impacts by industry.

This user guide presents general information about how to use I-JEDI and interpret results as well as detailed information about methodology and model limitations. Any questions that are not addressed in this guide should be sent to jedisupport@nrel.gov.

The JEDI model has been used by academic institutions, consultancies, and governments to assess economic impacts of low-emission development projects in the energy sector. I-JEDI's interface has been designed to allow users of different expertise levels to work with the model seamlessly. Users with more experience and sophisticated knowledge will be able to tailor their analyses more finely, but even first-time users will be able to obtain and interpret results in short time.

JEDI History and Validity

The JEDI suite of models was first developed in 2004 in collaboration between the National Renewable Energy Laboratory (NREL) and MRG & Associates[3] to address a gap in publicly available economic impact models. Most models allow only estimates of economic impacts of a general set of industries, such as those classified by the North American Industry Classification System codes or International Standard Industrial Classification codes.[4] These codes do not include renewable energy technologies.

I-O modeling typically requires estimates of project expenditures and the geographical area where these expenditures are made. To make JEDI approachable by a wide audience, default costs and percentages of goods and services sourced from the country of analysis are included. These defaults come from a variety of sources such as

[1] The difference between gross and net economic impacts is explained in the Limitations and Interpreting Results section of this user guide.
[2] For more information about the JEDI models in general, visit www.nrel.gov/analysis/jedi/.
[3] MRG & Associates can be contacted at mrgassociates@earthlink.net.
[4] Information about North American Industry Classification System codes can be found at www.census.gov/eos/www/naics/ and information about International Standard Industrial Classification codes can be found at unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27.

energy periodicals, journal articles, industry experts, and engineering cost models. Model users can use these defaults or modify expenditures if they have information about a specific project.

JEDI models have been used in many high-profile studies such as the U.S. Department of Energy (DOE) Wind Vision study (DOE 2015) and the DOE Hydropower Vision study (DOE 2016) as well as in peer-reviewed journal articles such as Barbose et al. (2016) and Wiser et al. (2016). JEDI has also been used in numerous other studies by academic institutions, consultancies, and governments.

JEDI results in the United States have been vetted, and they typically conform to employment figures reported in press releases by developers and operators, and impact estimates are similar to those found by other researchers (Billman and Keyser 2013).

Previous versions of JEDI have included only state and national data for the United States. Model users can include their own economic multipliers, but extensive data and knowledge about I-O models would be needed to use the model outside of the United States, especially in developing economies.

Pilot Study: Zambia

As one element of collaboration between the Government of Zambia and USAID under the EC-LEDS program, the first iteration of the I-JEDI model was developed for Zambia using I-O data from the International Food Policy Research Institute and the Central Statistical Office of Zambia.[5] This first-iteration model did not contain default costs or local content figures, and for this reason, was not as approachable as the U.S. JEDI models. Under this effort, I-JEDI was used to inform development impact assessment of National Appropriate Mitigation Actions (NAMAs) in Zambia.

Updates

EC-LEDS has continued to support development of the I-JEDI model for use in other countries. The 2016 version of I-JEDI, which was funded by USAID, improves model usability by including default cost and local content figures and expanding the number of countries included using I-O data from the Organisation for Economic Cooperation and Development (OECD) and country-specific statistical agencies. The 2016 version of the model also provides a method for using the model for countries that are not included if I-O data are available (see the Entering Custom Regions section below). Countries included in the 2016 version of I-JEDI include Colombia, Mexico, Philippines, South Africa, and Zambia.

To get more information on I-JEDI in the context of EC-LEDS and to access an online I-JEDI tutorial, visit https://www.ec-leds.org/tools-page/development-impact-assessment-tools.

[5] More about these institutions can be found online at www.ifpri.org and www.zamstats.gov.zm.

Using I-JEDI

The interface of the I-JEDI model includes worksheets for each technology (solar, wind, biopower, and geothermal) as well as a "General Impacts Estimate" tab that is not technology-specific (Figure 1). These tabs are used to characterize projects and view results.

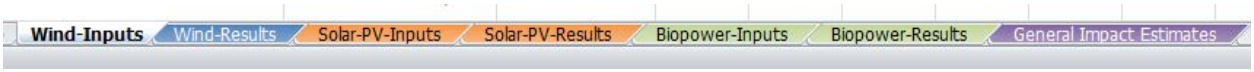

Figure 1. I-JEDI Worksheets

Each energy technology uses two worksheets: an input worksheet and a results worksheet. Project inputs worksheets are used to develop project characteristics while the results sheet shows gross economic impacts of the project in question.

Figure 2 shows an example of an inputs worksheet, in this case for biopower. Values within the boxes with black borders can be edited; other figures in the worksheet are locked to clarify what data are used by the model.[6] Anything entered outside the boxes is not connected to the I-O model and is therefore not included in the impact estimates.

The model pre-populates the values within the black-bordered boxes with default data (see the Default Data section below). The user can alter these values to reflect different conditions. To repopulate each spreadsheet with default data, use the "Insert [Technology] Defaults (Macros Must be Enabled)" button.

I-JEDI - Biopower	Project Inputs		Click for Help	
Project Description				
Country	Mexico			
Project Size (MW)		500		
Plant Capacity Factor		80%	*(used to calculate fuel use and utility O&M impacts)*	
Plant Heat Rate (Btu/kWh)		14,000	*(used to calculate fuel use)*	
Boiler Type	Stoker boiler		*<- Select from List*	
Dollar Year		2014		
Insert Biopower Defaults (Macros Must be Enabled)				
Biopower Facility Construction				
Equipment	Cost		**% Manufactured in Mexico**	
Feedstock handling equipment	$	221,281,472	15%	
Turbines, boilers, and air quality control equipment	$	663,844,417	15%	
Other equipment	$	-	0%	
Equipment Subtotal	**$**	**885,125,889**		
General Construction	Cost		**% Residing in or Purchased in Mexico**	
Construction Labor	$	221,281,472	100%	
General Construction Subtotal	**$**	**221,281,472**		
Contractors and Balance of Plant			**% Purchased in Mexico**	
Balance of Plant	$	189,669,833	20%	
Professional Services (legal, engineering, development, etc.)	$	284,504,750	90%	
Contractors and Balance of Plant Subtotal	**$**	**474,174,583**		

Figure 2. Example of an I-JEDI Project Inputs Worksheet

[6] An unlocked version can be obtained by e-mailing jedisupport@nrel.gov.

For each project, the user must select a country of analysis and dollar-year.[7] Dollar-years beyond what are available at the time of the model publication assume 2% annual inflation. The latest year of data can be found in the "Default Data" worksheet. Estimated data are highlighted in blue and actual data are highlighted in brown. Countries other than Colombia, Mexico, South Africa, the Philippines, and Zambia can be used by entering direct and total requirements and data in the "CustomRegion" worksheet. This is further explained in the "Entering Custom Regions" (below).

I-JEDI calculates only the economic impacts that occur within the country being analyzed. Therefore, the percentages of goods, workers, and services manufactured, residing, and purchased domestically (see Column C of the Project Inputs tabs) affect the calculation of total economic impacts.

The results worksheet displays basic information about a project and the calculated economic impacts for it. Figure 3 shows total estimates for a 500-megawatt (MW) biopower project. In addition to total estimates, estimates by industry are also shown. All estimates are linear and proportional. In other words, the results per MW would be the same as long as the costs per MW and local content numbers were the same. The "Limitations and Interpretation of Results" section (below) contains an explanation of these impacts.

I-JEDI - Biopower

Estimated Gross Economic Impacts

Mexico

Click fof help

Return to inputs

Nameplate Capacity (MW)	500			
Annual Generation (MWh)	3,506,400			
Boiler Type	Stoker boiler			
Fuel	Forest Residues			
Dollar Year	2014			
Impact Totals				
Construction Phase (Single Year Equivalent)		($ 2014 US)		
	Jobs	Earnings	Output	GDP (Value Added)
Direct	18,740	$ 75,899,339	$ 614,846,376	$ 155,094,659
Indirect	10,848	$ 59,884,287	$ 421,885,927	$ 198,833,228
Induced	13,693	$ 57,836,941	$ 859,841,478	$ 213,906,899
Total	43,281	$ 193,620,567	$ 1,896,573,782	$ 567,834,787
Operations and Maintenance Phase (Annual, Ongc		($ 2014 US)		
	Jobs	Earnings	Output	GDP
Direct	10	$ 131,548	$ 1,090,150	$ 367,755
Indirect	24	$ 162,077	$ 1,254,142	$ 707,101
Induced	30	$ 125,186	$ 1,861,097	$ 462,994
Total	64	$ 418,811	$ 4,205,389	$ 1,537,851

Figure 3. Example of I-JEDI Results

[7] Inflation changes the value of money. Setting a dollar-year specifies the dollar value used as a baseline.

The “General Impact Estimates” worksheet differs from the technology-specific worksheets (Wind, Solar, Geothermal, Biopower). It does not contain line items for expenditures such as wind turbines or photovoltaic panels. Rather, it contains a set of industries that are included in the selected country’s I-O table. This allows model users to estimate impacts for technologies that are not included in I-JEDI or estimate negative project impacts. In this case, expenditures in the “General Impact Estimates” worksheet need to be tied to specific industries. Purchases from a mining company, for example, would be entered as payments to the “Mining and quarrying” industry. Only payments within the country of analysis should be entered.

Entering Custom Regions

Countries or regions that are not included in the default set of I-JEDI countries can be used for analysis. The three “CustomRegion” worksheets in the I-JEDI model contain different options for aggregation schemes.[8] CustomRegion1 and CustomRegion2 use the same aggregation scheme as the OECD STructural ANalysis (STAN) database, and CustomRegion3 uses the scheme used by the International Food Policy Research Institute. Although NREL made a significant effort to make the design of the I-JEDI interface as user friendly as possible, it is recommended that model users entering custom region data have a general knowledge of social accounting matrices and I-O tables formatting and function.

Four sets of information need to be entered in these regions: a direct requirements table (including value added and labor payments as a percentage of output), average earnings per worker by industry, and two total requirements tables. The Type 1 total requirements table, which is used to calculate indirect impacts, should not include workers or households. The Type 2 Total Requirements table, which is used to calculate induced impacts, should include workers and households. An explanation of this terminology and instructions for calculating direct and total requirements are in the appendix.

Custom region worksheets are structured exactly the same as the included country worksheets (e.g., “Colombia-IO-Data”). These country worksheets can be used as a template or guide for CustomRegion Worksheets 1 and 2.

[8] Aggregation schemes refer to the way data are ordered (or structured) in each table. The International Food Policy Research Institute and OECD use different schemes to order their data.

Methodology

I-O Methodology

I-O models are based on social accounting matrices that contain sales and purchases made by sectors of the economy such as industries, households, investors, governments, and the rest of the world (via imports and exports). Each sector contains a "basket of goods" that includes either expenditures or inputs for production. For example, manufacturers of generators may purchase copper wire from the copper wire manufacturing sector. The wire is an input purchased by the generator manufacturer as well as an output produced by the copper wire manufacturer.[9]

This comprehensive representation of inputs and outputs allows modelers to study complex interactions between industries and to estimate a comprehensive set of results that could arise as a result of a modeled expenditure.

The appendix contains additional information about I-O methodology, including the linear algebra used to estimate results.

Default Data

Default data included in I-JEDI allow for analysis of projects without detailed knowledge of either project costs or where components or other inputs are purchased. These are general estimates that do not account for factors that could influence project impacts such as economies of scale, developer preferences, or country-specific factors such as roads or other infrastructure that may need to be built to access site locations or connect generation facilities with the grid. As mentioned above, model users can modify default data when they have better or more current data.

Default data in the I-JEDI model come from several sources, including energy organizations, research institutions, and consultants (see References and Bibliography). Default data reflects the costs of larger-scale systems, rather than distributed generation. Over the life of the I-JEDI model, these sources are likely to be updated. Data reported in this user guide are what is included in the 2016 release of I-JEDI.

I-O tables for Colombia, Mexico, South Africa, and the Philippines come from the OECD (STAN) databases (OECD 2015). The I-JEDI model uses the 2015 data release. I-O data for Zambia comes from the International Food Policy Research Institute (Chikuba et al. 2013). These tables do not report average earnings per job by industry, which are required to calculate employment.

When earnings and employment are collected separately from social accounting data, estimates may require generalization to conform to the social accounting data. For example, if a country reports only earnings and employment for the manufacturing industry while the social accounting data contain 16 different manufacturing industries, earnings would have to be generalized and all of these sectors would have the same

[9] The appendix of this user guide contains detailed information about I-O models, including an expanded set of terminology, definitions, and algebra.

average earnings and employment. If a manufacturing worker earned $20,000 annually, $20,000 in computer and electronics manufacturing would support one job, as would $20,000 in textile manufacturing. This is simply a limit caused by a lack of available data. As data become available these parameters will be updated and improved.[10]

Data sources for cost estimates are included in the "Default-Data" worksheet of I-JEDI. These may change over time and sources will be updated in the model; the most current sources should come from the model itself rather than this user guide.

Default construction and installation costs were derived from a blend of sources including Bloomberg New Energy Finance, the International Renewable Energy Agency, and the International Energy Agency. In all cases, proprietary data were used in conjunction with other estimates and extrapolations in a way that would not allow third parties to reverse-engineer such data. The default data are not proprietary in any way and can be altered by model users with different information.

For wind and solar default values, NREL used the most up-to-date data available. In some cases, installation cost data were not available. Most commonly, this was because there were not a sufficient number of installations in certain countries to adequately inform cost data. For example, solar photovoltaics (PV) development in Colombia is still in its initial stages. In such cases, NREL used data from countries with similar resources, renewable energy goals, and long-term renewable energy deployment estimates, and adjusted these as necessary.

Installation costs of biomass projects have not changed as rapidly as wind and solar. For this reason, NREL used cost data from 2012 and 2010 (see Bibliography). The biomass cost data used in I-JEDI reflect the changes in biomass price due to the particular characteristics of the countries in the model such as prevailing prices.

Geothermal drilling estimates were obtained from Kipsang (2015). There is limited information about drilling costs in different countries, although information about costs of oil and gas exploration is available (Kristopher 2016). While the costs of the two activities do not always compare well (Augustine et al. 2006), they do share many similarities such as rig availability, which can affect project feasibility and cost. Drilling costs were adjusted based on these differences, which are between 77 and 98 percent of costs in the United States. Other costs such as the costs of globally sourced equipment were estimated using calculations from the JEDI Geothermal Model (Johnson et al. 2012) and, when possible, using country-specific inputs such as labor costs.

Model users are also encouraged to enter their own cost and domestic content data when such information is available, as default estimates are generalized. These defaults are also linear, so the same cost per megawatt would be applied to small and large projects alike.[10]

[10] This applies to the 2016 release of the model.

Limitations and Interpretation of Results

Definitions of Impact Metrics

I-JEDI reports results similarly to most I-O analyses, using direct, indirect, and induced impacts. Impacts cover both construction and operation of projects.

Project expenditures themselves are known as the *direct impact*. Spinoff economic activity among industries that could occur as a result of these expenditures is the *indirect impact*. In the example of the generator manufacturer that purchases copper wire, the direct effect would be the purchase of a generator and the indirect effect would be the purchase of copper wire by the generator manufacturer. Indirect effects could include business-to-business services, natural resources, and any other activity that is supported by industry expenditures. Other indirect economic impacts from the example above include purchasing a coil-winding machine and hiring a consultant to diagnose faulty generators. The *induced impact* is activity that could occur from household expenditures made by worker earnings that are supported by direct and indirect impacts. For example, if workers from the generator manufacturer and the wire manufacturer go to a restaurant, their payments to the restaurant would be the induced impact.

Figure 4 depicts an example of these types of impacts, including what is referred to as the “ripple effect” because indirect and induced impacts are supported by direct impacts.

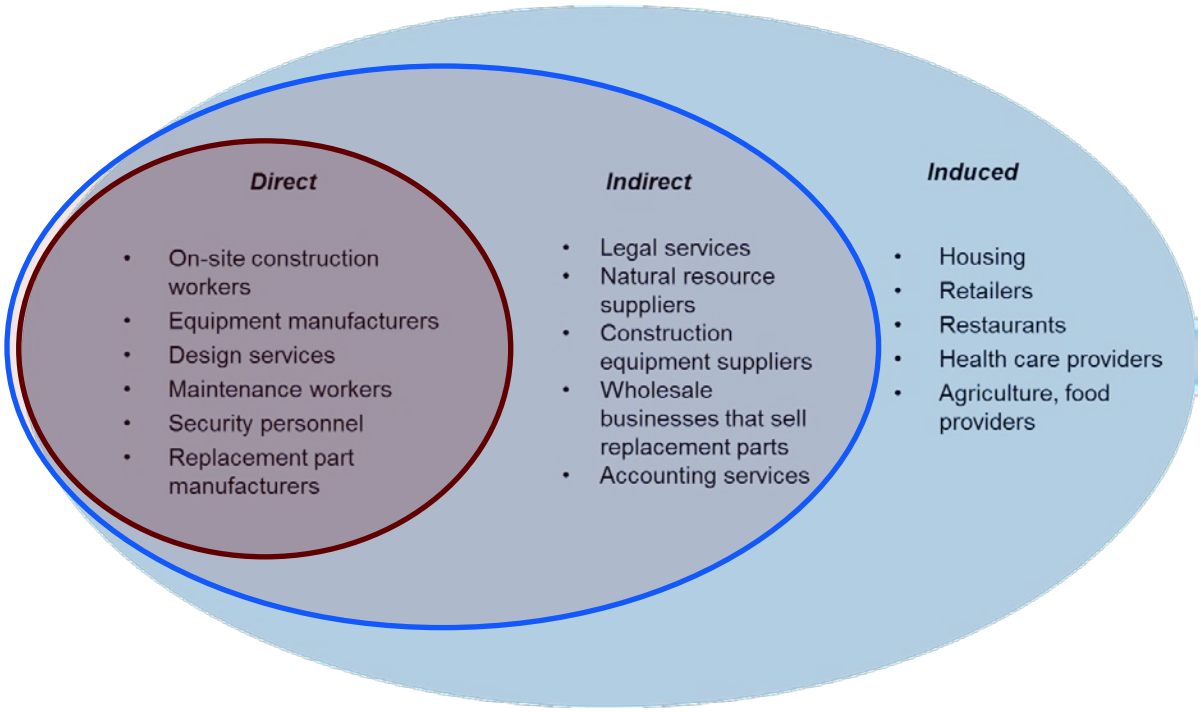

Figure 4. Types of Impacts in I-JEDI: The “Ripple Effect”

In I-JEDI, the direct impact is the set of expenditures to construct or operate an energy facility. For example, a solar photovoltaic project could include payments to the installer, cost for mounting hardware purchased locally, and engineering costs. Indirect impacts might include things such as accounting services, utilities, and raw materials. Induced impacts are supported by the direct and indirect workers.

I-JEDI also reports jobs, earnings, GDP, and gross output. *Jobs* reflect a given level of employment for average earnings reported by each country. For example, if a country reported average annual earnings of $10,000 per job in the agricultural industry, earnings of $20,000 would support two jobs. *Earnings* are all compensation for work, including benefits. *GDP*, also called *value added*, is the value of an industry's production to the country of analysis. It consists of labor payments, property-type income (including profits), and taxes. *Gross output* is a measure of overall economic activity. It consists of value added as well as all transactions between industries for inputs.

Results

I-JEDI estimates only the economic impacts of an activity within the country of analysis. Domestic content percentages (set in Column C of each "Inputs" worksheet) limit the direct effects to expenses made within the country (e.g., domestic services and equipment purchased domestically). Additionally, the I-O data account for imported inputs or household expenditures on imported products when calculating indirect and induced impacts.

Domestic content percentages only apply to direct effects. If a generator is purchased from a local manufacturer that imports its copper wire, the domestic content of the generator purchase should be entered as "100%." The I-O model would factor in the copper wire imports.

Construction impacts differ from operation and maintenance impacts in time scale. Construction impacts are made only once, and results are for the equivalent of one year. For example, if I-JEDI reports that a project supports 500 jobs during construction but construction actually takes two years, this represents an average of 250 jobs annually during the two-year construction period. Operations and maintenance expenditures are made annually, so operations and maintenance impacts are considered to continue for the life of the project. For example, if a wind plant with a 25-year life span supports 100 jobs, this represents an annual average of 100 jobs for 25 years.

Limitations

As with any economic model, I-JEDI has limitations, and results should be interpreted in the context of these constraints.

I-JEDI results are gross, not net. Impact estimates for each technology do not factor in far-reaching effects such as displaced economic activity or alternative uses for project funds. For example, if a wind plant replaces a coal plant, the closure of the coal plant would not be included in estimated results.

Because I-JEDI results are linear and proportional, the estimated economic impacts of ten 1-MW plants would be the same as those of one 10-MW plant.

With solar PV, defaults do not distinguish between residential rooftop, commercial rooftop, or utility-scale solar PV. Because these defaults are averages, defaults reflect what is primarily installed in the country of analysis. If there is primarily utility-scale PV with few rooftop installations in the country, default costs reflect utility-scale PV.

I-JEDI also does not estimate impacts from changes in prices, utility rates, taxes, or wages. If utility rates increase to fund a project, for example, the model does not estimate impacts of these changes. If taxes were used for a project, rather than some other use, the model would not estimate the impact of that alternative use of taxes.

I-JEDI does not estimate constraints in resources, which can also be associated with price increases. The model assumes that all inputs, including necessary labor and investment, are available and at the same cost regardless of the quantity needed.

Many factors could drive project costs higher or lower than default data in I-JEDI. For example, constructing roads to transport wind turbines increases costs but is not included in the default data. Project costs can also vary with developer preferences and practices, such as whether manufactured components are purchased locally or imported. Model users are encouraged to enter their own data or verify that default data are accurate— to the extent possible—for the project or set of projects being modeled.[11]

The I-O tables are also a limiting factor, as they represent an estimate of the structure of an economy in a given year and are subject to change. Technology, relative price changes, and several other factors drive these changes. For example, a price of one input may drive a company to substitute a different input or change the location from which they purchase the input. This represents a limitation because data are often lagged for some time. The 2016 version of I-JEDI uses OECD data released in 2015, although the 2015 release contains tables for 2011. I-JEDI lists the year of I-O data in the I-O data worksheets for each country.

I-O tables are generated using officially reported statistical data. These data do not include economic activity that is not tracked, such as black market or informal transactions. For this reason, these are not included in impact results.

[11] Feedback on default data is encouraged. Please send this to jedisupport@nrel.gov.

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Appendix: I-O Terminology and Algebra

An I-O model can be represented using linear algebra, although it is useful to present definitions of the data.

A **social accounting matrix** (SAM) is a table showing the transactions and transfers among all the different industries and institutions within the economy in a specific geographic area.

Gross output is a measure of total economic activity. It includes payments that industries and businesses make to one another for inputs used in production. Such inputs could include raw materials, services, or anything a business purchases to produce its products or services. Gross output also includes value added.

Value added, also known as **gross domestic product or GDP**, is the value of an industry's production to the country of analysis. It consists of labor payments, property-type income (including profits), and taxes on production.

Intermediate inputs are payments that business or industries make to one another in order to operate.

Direct requirements are the proportion of intermediate inputs used in production. Indirect impacts include only payments between industries while induced impacts include labor payments and household expenditures.

Final demand is demand for a good or service that is not an input to something else. For example, food purchased by households for personal consumption is part of final demand. Copper wire purchased by a generator manufacturer that is used in the motor is an input and not part of final demand.

Total requirements are what are multiplied by final demand to estimate gross output. A Type 1 total requirements matrix only includes industries while a Type 2 total requirements table includes labor payments and household expenditures.

In the algebra below, *x* represents an n·1 vector of gross output and $\hat{x}$ is an n·n matrix of zeroes with *x* on the diagonal. *Z* is an n·n matrix of intermediate inputs, *F* is an n·1 vector of final demand, and *A* is the n·n direct requirements matrix. *I* is an n·n identity matrix.

Direct requirements can be estimated using:

$$A = Z(\hat{x})^{-1}$$

Output is defined as intermediate inputs (Ax) and final demand (F):

$$x = Ax + F$$

This can be rearranged:

$$x = (I-A)^{-1}F$$

The total requirements matrix is then $(I-A)^{-1}$.

All estimates are linear and proportional. Value added, earnings, and jobs, are then simply proportional to output (*x*).