Online course

Methodologies for Quantifying Renewable Energy Employment Impacts

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1 Introduction

1.1 Introduction to the Course and Learning Goals

Learning objectives: Upon completion of this course, you should be able to

- describe why employment is a key social and economic co-benefit of renewable energy
- list tools and methodologies for assessing and quantifying the employment impacts of renewable energy
- compare the advantages and disadvantages of different assessment methodologies
- identify affordable or free tools that are available for making assessments
- apply some simple assessment tools and methodologies in practice

This course will train participants in techniques to identify, quantify, and communicate the employment impacts of renewable energy. You will gain insight into methodologies, tools, background knowledge, and case studies, all of which will support you in assessing and quantifying employment impacts as co-benefits of renewable energy. Beyond the theoretical knowledge you will gain, the intention of the course is to assist you in running and conducting analyses in your own country or region, and to help you apply the tools and methodologies in practice.

In the **chapter two**, the course analyses renewable energy employment categories and explains the differences between various types of employment (i.e. direct, indirect, and induced jobs) and effects (i.e. net and gross employment effects).

In the first part of chapter three, the course provides deeper insights into three specific methodologies for quantifying the employment impacts of renewable energy; namely, employment factor analysis, gross input-output models, and full economic modelling. For each of these methodologies we will provide an overview of the general functioning, elaborate on specific calculation steps and data requirements, discuss advantages and limitations, and look into one location-specific case study. In the second part of chapter three, the course offers brief introductions to some online tools available for making assessments in practice, including the I-JEDI tool, the EIM-ES tool, and ELMA.

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Overview of course modules and topics (author's own depiction)

2 Renewable Energy Employment Categories

2.1 Types of Employment: Theory

Learning objectives: Upon completion of this page, you should be able to

- define direct, indirect, and induced employment effects
- differentiate between direct, indirect, and induced employment effects
- explain the relevance of direct, indirect, and induced effects in terms of employment impacts

In addition to the positive climate change mitigation effects of expanding renewable energy, the economic impacts of implementing renewable energy projects are of great interest to policy makers. One important indicator of positive economic effects is employment growth which is not limited to the renewable energy project itself and which therefore has an impact on the wider economy. This course takes a look at three types of employment effects [1]:

- **Direct employment effects:** primary effects that arise directly from a certain renewable energy project, e.g. new jobs created directly by a new hydropower plant
- **Indirect employment effects:** secondary effects and jobs created in related input sectors, e.g. jobs in supply sectors, such as those providing building materials for the hydropower plant
- **Induced employment effects:** economy-wide effects, or jobs created in sectors that are not directly related to renewable energies. These include jobs created through services or goods provided to people affected by direct or indirect effects, e.g. increased demand for certain services and consumer goods from people working for the newly-constructed hydropower plant leads to new jobs being created in local restaurants or shops [1, 2]

Figure 1 summarises the different kinds of employment effects detailed above. It can be seen that the employment effects of renewable energy deployment are often much more far-reaching than the immediate and direct impacts alone.

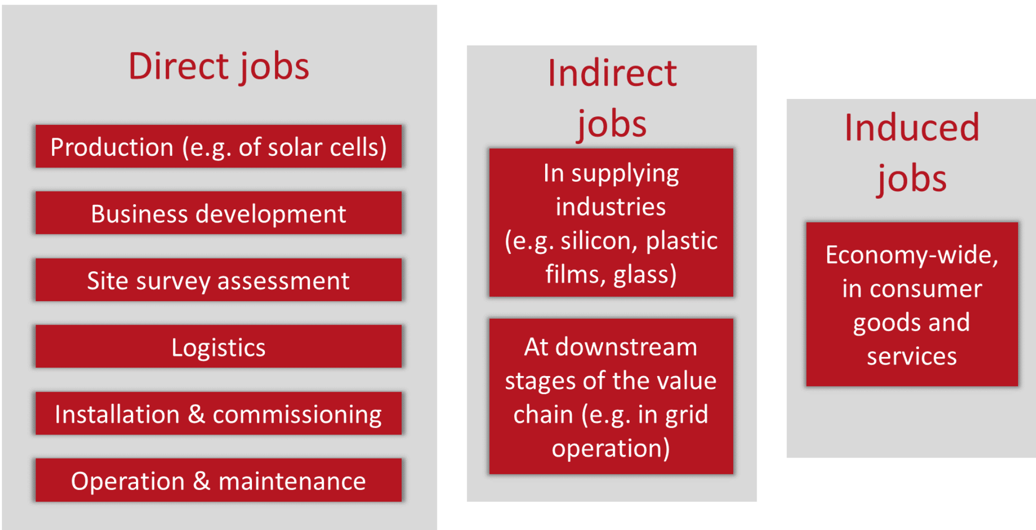


Figure 1: Creation of direct, indirect and induced jobs in the solar industry (author's own depiction)

Direct employment effects can be calculated quite easily, but there is no clear-cut computation method for indirect or induced effects; therefore, it may be more difficult to isolate such effects [3]. Also, the time period within which the effects might happen is usually not fixed. Generally, direct effects occur within a shorter time frame, while induced effects may take longer to spread throughout the economy [4].

References:

[1]: Breitschopf, B., Nathani, C., and Resch, G., 2011: Review of Approaches for Employment Impact Assessment of Renewable Energy Deployment (2011), pages 4–5, http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf

[2]: Jacob, K; Quitzow, R. and Bär, H., 2015: Green jobs: Impacts of a Green Economy on Employment, pages 42–44, https://www.researchgate.net/publication/273767132_Green_Jobs_Impacts_of_a_Green_Economy_on_Employment

[3]: Gioutsos, D. and Och, A., 2017: The Employment Effects of Renewable Energy Development Assistance, pages 2–4.

[4]: Centre for Strategy and Evaluation Services, 2006: Study on Measuring Employment Effects, page 58, https://ec.europa.eu/regional_policy/sources/docgener/evaluation/pdf/empl effect06.pdf

Further reading:

This theoretical framework by the German Federal Ministry for Economic Cooperation and Development, about how to measure the employment impacts of development cooperation, includes further information about the classification of different employment effects:

- https://energypedia.info/images/5/54/A_Systematic_Framework_for_Measuring_Employment_Impacts_of_Development_Cooperation_Interventions.pdf.

GIZ has published a guidebook for practitioners on how to conduct policy impact assessments. It includes an in-depth overview of different methods for identifying direct, indirect, and induced effects:

- GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit): *Planning Policy Impact Assessments and Choosing the Right Methods – Manual for Development Practitioners*, Bonn, 2016; available at http://www.gws-os.com/downloads/giz2016-en-Planning_Policy_Impact_Assessments.pdf

2.2 Types of Employment: Case Study

Learning objectives: Upon completion of this page, you should be able to

- recognise examples of direct, indirect, and induced effects
- identify direct, indirect, and induced effects in real case examples

The construction of a solar panel factory generates new jobs, not only at the factory itself, but in linked business areas as well – as demonstrated below. Figure 2 visualises the different impacts and the connections between them.

Direct effects: At first, jobs are created at the construction site for the factory. Following the construction phase, new manufacturing jobs will be available at the solar panel factory itself.

Indirect effects: Due to the increased production of solar panels, additional jobs are created in grid installation and operation, as well as in the silicon industry and other sectors which supply materials.

Induced effects: All workers employed in the above areas profit from a higher income, and spend their it on consumer goods and services. As a consequence, business owners supplying the workers expand their businesses, by employing more people or by opening new branches. However, if the use of solar energy rises, due to the increased availability of solar panels, this may lead to less demand for energy from conventional energy sources (e.g. fossil fuels). As a result, employees in these industries may lose their jobs, and will consequently demand less goods and services [1].

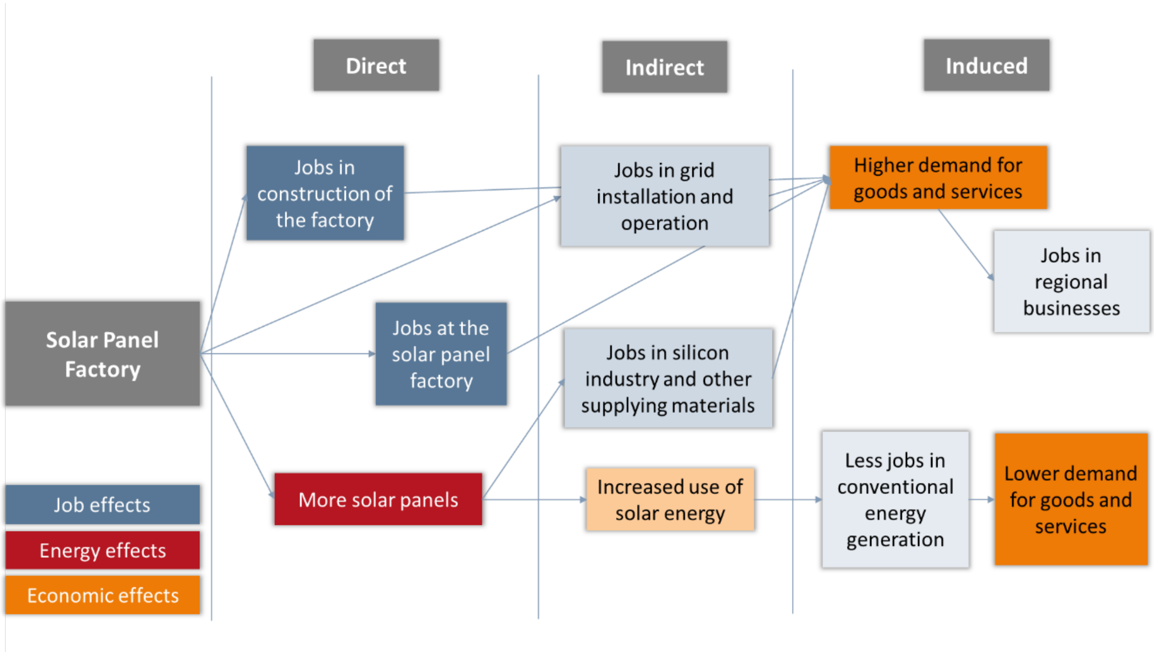


Figure 2: The direct, indirect, and induced effects of constructing a solar panel factory (author's own depiction, based on Bacon & Kojima, 2011) [1]

The boundaries between definitions of direct, indirect, and induced effects are not precisely defined. For example, if only jobs in construction of the solar panel factory are regarded as a direct effect, new jobs at the solar panel factory might be considered an indirect effect [2].

References:

[1]: Bacon, R. and Kojima, M., 2011: Issues in estimating the employment generated by energy sector activities, https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.474.4306&rep=rep1&type=pdf, 29-30

[2]: Breitschopf, B., Nathani, C., and Resch, G., 2011: Review of Approaches for Employment Impact Assessment of Renewable Energy Deployment (2011), pages 17–18, http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf

Further reading:

The latest numbers on (direct) employment generation in 2019, by country and by type of renewable energy, were published in this report by IRENA:

- https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jun/IRENA_RE_Jobs_2019-report.pdf

ILO also published a report on how jobs in the renewables sector can contribute to advancing towards a green economy. The report contains a lot of information on the expected employment numbers in different energy sectors and countries:

- https://www.ilo.org/weso-greening/documents/WESO_Greening_EN_chap2_web.pdf

2.3 Scope of Analysis (Net and Gross Employment Analysis): Theory

Learning objectives: Upon completion of this page, you should be able to

- define gross and net effects
- differentiate between gross and net effects
- explain how gross and net effects are relevant to employment impacts

There are different options and levels of complexity for calculating gross and net effects. To measure the employment impact of renewable energy deployment, a low to medium complexity approach is used. Other calculation methodologies do not include induced effects, or make distinctions between sectoral and economy-wide perspectives:

$$Gross\ effect = all\ positive\ \ effects\ (direct, indirect\ and\ induced)$$

Gross effects capture the positive impact on the economy by including only newly generated direct, indirect, or induced jobs in the renewable energy and related upstream sectors, as well as in the wider economy. However, gross effect is not a realistic measure of the employment effect on the overall economy, because it neglects any negative effects.

Therefore, we also have to calculate the net effect:

$$Net\ effect = positive - negative\ effects\ (direct, indirect\ and\ induced)$$

The net effect comprises all the positive and negative effects that arise within the renewable energy sector, and outside of it. If new wind farms are built, all newly generated jobs at the wind farms, in supplying sectors, and in related businesses represent positive effects. At the same time, a negative employment effect occurs, because jobs in the fossil fuel industry may be lost and the respective supplying sectors and related businesses experience a lower turnover, which leads to additional job losses.

In order to calculate the net employment effect of a renewable energy project, a renewable energy project scenario is compared with a business-as-usual scenario. The total of jobs lost in other sectors due to the renewable energy project is deducted from the total of jobs created by the renewable energy project [1-3]. Figure 3 summarises the differences between the gross and net effects.

	Definition	Values	Effects
Gross effects	Sum of positive effects on the overall economy	Positive	Positive: direct, indirect, and induced
Net effects	Sum of all effects on the overall economy	Positive value, if the benefits outweigh the adverse effects Negative value, if the gains are inferior to the adverse effects	Positive and negative: direct, indirect, and induced

Figure 3: Overview of gross and net effects (author's own depiction, based on Borbonus, 2017) [4]

References:

[1]: Duscha, V.; Ragwitz, M.; Breitschopf, B.; Schade, W.; Walz, R. and Pfaff, M., 2014: Employment and growth effects of sustainable energies in the European Union, pages 6–8, https://ec.europa.eu/energy/sites/ener/files/documents/EmployRES-II%20final%20report_0.pdf

[2]: Jacob, K; Quitzow, R. and Bär, H., 2015: Green jobs: Impacts of a Green Economy on Employment, page 19, https://www.researchgate.net/publication/273767132_Green_Jobs_Impacts_of_a_Green_Economy_on_Employment

[3]: Kluve, J. and Stöterau, J., (n.a.), A Systematic Framework for Measuring Aggregate Employment Impacts of Development Cooperation, page 21, https://energypedia.info/images/5/54/A_Systematic_Framework_for_Measuring_Employment_Impacts_of_Development_Cooperation_Interventions.pdf

[4]: Borbonus, S., 2017: Generating socio-economic values from renewable energies, pages 4–6, https://www.iass-potsdam.de/sites/default/files/files/iass_2017_cobenefits_assessment_methods.pdf

Further reading:

This paper conducts a meta-analysis of the empirical literature on net employment effects, including over 30 journal articles:

- https://www.sciencedirect.com/science/article/pii/S0301421519306342

Another meta-analysis of 23 impact studies can be found here:

- https://www.wifo.ac.at/bibliothek/archiv/36286/WWWforEurope_PP_12.pdf

This study reviews a large number of gross and net employment impact studies, and provides a deeper theoretical foundation for computation methods:

- http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf

2.4 Scope of Analysis (Net and Gross Employment): Case Study

Learning objectives: Upon completion of this page, you should be able to

- recognise examples of gross and net effects in real cases
- analyse simple gross / net effect calculations in real cases

In order to replace an old coal-fired power plant, a new 4 GW wind project is being implemented. Figure 4 illustrates the potential gross and net effects of the construction, in terms of job years generated. Two options (A and B) describe possible scenarios for the design of this project, each of which create different positive and negative effects.

Gross effect: Direct jobs are created in constructing the wind turbines and monitoring their functioning. Indirect and induced jobs also emerge in the steel industry, in other industries supplying material for constructing wind turbines, and in local restaurants and shops. While the positive impacts yield a positive gross effect for both options, the gross effect for Option B is higher than for Option A.

Net effect: The positive gross effect translates into a higher income for all workers benefiting from the direct and indirect jobs. The workers spend their new income on consumer goods and services, which in turn leads to increased profit and new jobs being created in the affected sectors (positive effects). However, the nearby coal power plant closes down, and its workers lose their jobs. Consequently, the unemployed workers consume less, and all the supplying sectors and businesses related to the coal power plant experience declining turnover and may have to make staff redundant (negative effects). Depending on the magnitude of the negative effects, the net impact may still remain positive (Option A) or it may become negative (Option B) [1, 2].

4 GW Wind Project (Job Years)	Option A	Option B
Positive direct effect	6,000	8,000
Positive indirect and induced effects	10,000	10,000
Gross effect	**+ 16,000**	**+18,000**
Positive effects	16,000	18,000
Negative effects	-4,000	-20,000
Net effect	**+ 12,000**	**- 2,000**

Figure 4: Project example of employment effects (author's own depiction, based on Bacon & Kojima, 2011) [1]

References:

[1]: Bacon, R. and Kojima, M., 2011: Issues in estimating the employment generated by energy sector activities, https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.474.4306&rep=rep1&type=pdf, 29-30

[2]: Duscha, V.; Ragwitz, M.; Breitschopf, B.; Schade, W.; Walz, R. and Pfaff, M., 2014: Employment and growth effects of sustainable energies in the European Union, pages 6–8, https://ec.europa.eu/energy/sites/ener/files/documents/EmployRES-II%20final%20 report_0.pdf

Further reading:

A case study about the German energy transition can be found here:

- https://wol.iza.org/uploads/articles/519/pdfs/employment-effects-of-green-energy-policies.pdf

Another case study about Australia divesting from coal is available here:

- https://www.climatecouncil.org.au/uploads/7b40d7bbefbdd94979ce4de2fad52414.pdf

The ILO and IRENA published this policy brief about progress towards SDG 7, due to interlinkages between energy and jobs:

- https://sustainabledevelopment.un.org/content/documents/17495PB13.pdf

3 Methodologies for Quantifying Employment Impacts: Overview & Employment Factor Analysis

3.1 Overview: Discussion of Data Availability and Granularity

Learning objectives: Upon completion of this page, you should be able to

- identify use cases for different assessment methodologies
- state the main data requirements for quantifying employment impacts

There are various specific methodologies for calculating the employment impacts of renewable energy. Three of the approaches to quantifying job effects are summarised below:

- **Employment Factor Analysis** is a relatively simple approach for assessing the direct job effects of different scenarios, regarding growth or changes in sectors/technologies. Information on installed capacity/electricity generation and the employment factor are the key data required for this analysis. This information is often provided in publicly available sources.
- **Gross Input-Output (I-O) Models** focus on linkages and supply chains between economic sectors. They can be used to estimate both direct and indirect economic effects. Beyond data from I-O tables (e.g. monetary data on the flow of goods and services), the calculation process requires information on newly added and total capacity, average salaries in a given sector, technology-specific employment factors, etc. I-O tables are often publicly available, but they rely on heavy data input from national statistics offices and are not always fully up to date.
- **Full Economic Modelling** methodologies, such as **Computable General Equilibrium (CGE)** models, are the most comprehensive and complex of the three approaches. CGE models enable assessments of net job effects and are able to reflect economy-wide impacts, taking into account a large range of shifting parameters in the economy. The complex calculation process requires many assumptions and inputs, such as a statistical basis (e.g. a social accounting matrix [SAM], or I-O tables), and data on exogenous elasticities and macroeconomic constraints (e.g. tax rates, inflation, etc.), which are analysed via software.

	Employment Factor Analysis	Gross I-O Models	Full Economic Modelling / CGE Model
Complexity	Low	Medium	High
Use cases	Direct (gross) employment effects	Direct and indirect gross employment effects	Net effects (direct, indirect, and induced)
Data requirements	Medium: installed capacity/electricity generation and employment factor	Medium to high: I-O tables, sector-specific salary data, technology-specific employment factor	Very high: I-O tables/SAMs, data on exogenous elasticities and macroeconomic constraints

Figure 5: Use cases for methodologies for the calculation of gross and net employment effects (author's own depiction)

3.2 Employment Factor Analysis - General Functions

Learning objectives: Upon completion of this page, you should be able to

- state the fields in which employment factor analysis is used, and the purpose of its use
- explain the basic functions of employment factor analysis

Employment factor analysis is a quick approach to estimating the creation of direct jobs. It does not consider indirect or induced effects. Two inputs are needed to calculate employment created by a renewable energy project: the employment factor, which measures the labour used to install a certain capacity (jobs/job-years per MW); and the installed capacity itself. The resulting equation is:

$$annual\ employment\ creation\ [job - years] = installed\ capacity\ [MW] * employment\ factor\ [job - years\ per\ MW]$$

Employment factors differ, depending on the work intensity and life cycle phase of a renewable energy plant (see Figure 6, below). In general, work intensity is considerably lower for operation and maintenance (O&M) than for manufacturing, construction and installation (MCI). However, O&M generates employment over the lifetime of the respective technologies, while MCI may only require several months to a few years of employment. Hence, O&M employment factors are applied to the total installed capacity, whereas MCI employment factors only refer to newly added capacities [1]. Some sources thus recommend expressing MCI and O&M employment in job-years and jobs, respectively [2].

The above equation may be used to estimate direct employment resulting from renewable energy deployment. However, different RE technologies generate different amounts of electricity. To account for changes in the energy mix, capacity should be substituted by generation (i.e. MWh per MWh, instead of MW and job-years per MW) [3].

Technology	Manufacturing (job-years/MW)	Installation (job-years/MW)	Manufacturing and Installation (job-years/MW)	Operation and Maintenance (jobs/MW)
Wind	6.6	1.5	8.1	0.2
PV	12.6	15.4	28	0.3

Figure 6: Median direct employment factors for the main phases of wind and PV deployment (author's own depiction, adapted from Van der Zwaan, Cameron & Kober, 2013) [2]

References:

[1]: Meyer, I. and Sommer, M. W., 2014: Employment effects of renewable energy supply: A meta analysis, for Europe Policy Paper No. 12, pages 13–14.

[2]: Van der Zwaan, B.; Cameron, L. and Kober, T., 2013: Potential for Renewable Energy Jobs in the Middle East, (unpublished draft).

[3]: Jacob, K; Quitzow, R. and Bär, H., 2015: Green jobs: Impacts of a Green Economy on Employment, https://www.researchgate.net/publication/273767132

[Green Jobs Impacts of a Green Economy on Employment]

Further reading:

The paper by Breitschopf, Nathani and Resch, "Review of approaches for employment impact assessment of renewable energy deployment", provides an overview of different impact assessment studies analysing employment impacts or renewable energy, and clarifies which methodological approach is best:

- http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf

The article "Renewable technologies in Karnataka, India: jobs potential and co-benefits" demonstrates how to adapt general employment factors for different energy sectors to a national context. The study also contains employment factors for the biofuel sector:

- https://doi.org/10.1080/17565529.2017.1410085

The recent instructive study, "Greening India's workforce", by NRDC and CEEW, establishes the employment factors and job impacts of solar and wind power in India:

- https://www.nrdc.org/sites/default/files/greening-india-workforce.pdf

3.3 Employment Factor Analysis: Required Data and Calculation Steps

Learning objectives: Upon completion of this page, you should be able to

- recognise what data is needed for employment factor analysis
- identify data for employment factor analysis (e.g. country-specific employment factors)
- explain the basic steps of the calculation process

Employment factor analysis relies on two main input factors: installed capacity/electricity generation and the employment factor. Installed capacity/electricity is often readily available. Employment factor data can be derived from actual data from RE facilities, the RE industry, surveys, feasibility studies, or literature [1]. However, employment factor data should be viewed with caution.

Firstly, employment is expressed in different terms, which are sometimes used interchangeably. When drawing from different sources, attention should thus be paid to different expressions, as follows:

- 'Jobs' indicate an absolute number of jobs, ignoring the actual duration
- 'Job-years' take duration into account: 1 job-year equals one job created for one year
- 'Job-year', 'person-year' and 'full-time equivalent' (FTE) job can all be used interchangeably [2]

Secondly, data may be presented as temporary versus permanent jobs, as explained above. Although employment factor analysis refers to direct employment only, indirect effects may be included in some factors, such as those across the photovoltaic (PV) supply chain. The boundaries between direct and indirect jobs vary, and must be indicated in the final calculation. Furthermore, productivity differs between economies. Lastly, dynamic effects, such as changes in labour productivity, cost decreases in technology learning rates [1]. As a result, employment found in the literature varies greatly.

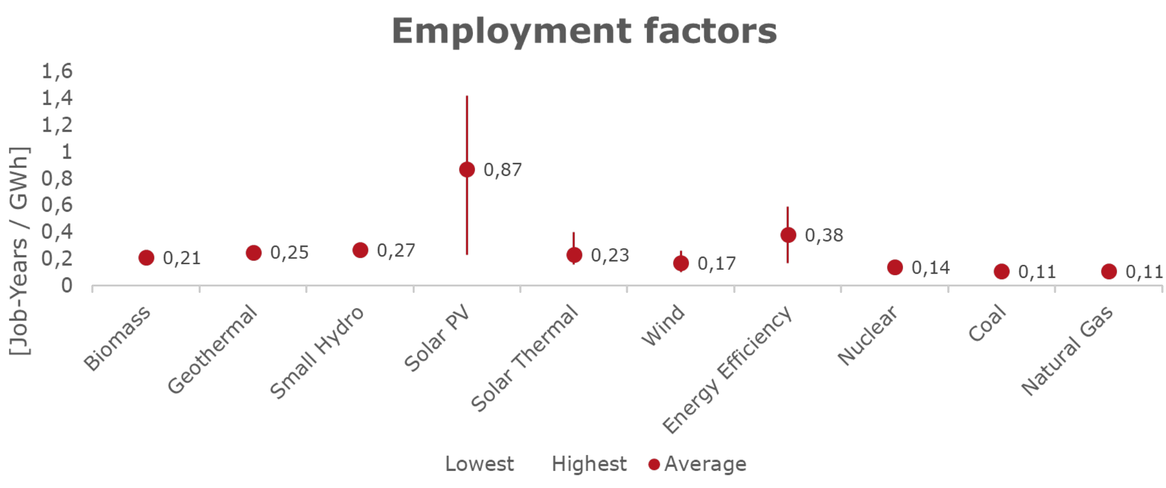


Figure 7: Direct job impacts by technology, in the USA (author's own depiction, adapted from Wei, Patadia & Kammen, 2010) [2]

Figure 7 shows the averages and ranges of *employment factors* for different technologies in the USA. A small wind farm with an annual *generation* of 60 GWh would lead to 10 job-years (60 GWh * 0.17 job-years/GWh). The same stimulus would only translate into 7 jobs in the coal industry (60 GWh * 0.11 job-years/GWh).

References:

[1]: Breitschopf, B., Nathani, C., and Resch, G., 2011: Review of Approaches for Employment Impact Assessment of Renewable Energy Deployment (2011), pages 4–5, http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf

[2]: Wei, M.; Patadia, S. and Kammen, D., 2010: Putting renewables and energy efficiency to work, How many jobs can the clean energy industry generate in the US?, Energy Policy, pages 919–931.

Further reading:

The authors Breitschopf, Nathani and Resch published a paper that provides a good overview of different methods for estimating employment. It looks at the applied methodologies in greater depth. The title of the paper is "Methodological guidelines for estimating the employment impacts of using renewable energies for electricity generation":

- https://www.researchgate.net/publication/260434928_Methodological_guidelines_for_estimating_the_employment_impacts_of_using_renewable_energies_for_electricity_generation

The report by IRENA, "The Socio-economic Benefits of Solar and Wind Energy", from 2014, discusses the domestic value creation resulting from investment in renewable energy technologies. Further, it gives an overview of the required data and calculation steps for the employment factor approach:

- https://www.irena.org/publications/2014/May/The-Socio-economic-Benefits-of-Solar-and-Wind-Energy

3.4 Employment Factor Analysis: Limitations and Advantages (Pros and Cons)

Learning objectives: Upon completion of this page, you should be able to

- recognise the benefits of employment factor analysis
- list the disadvantages of employment factor analysis

The main advantage of employment factor analysis lies in its simplicity: it is easy to carry out and interpret, enabling quick estimates and updates. The model can easily be adjusted to include different levels of productivity or technological change. Further, the model is very specific: it shows where jobs are being created, for each technology and for each life cycle phase.

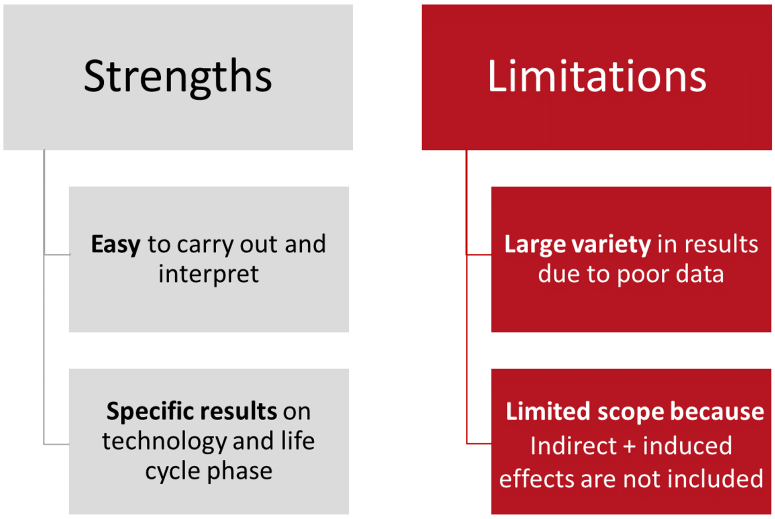


Figure 8: Strengths and limitations of the employment factor analysis (author's own depiction)

The main weakness of the model is that it produces significant variety in determined employment factors, and hence in estimated job creation. This is especially true in emerging and developing countries, which often draw on data from industrialised countries without adapting it to their local context. Technological advances and rapidly evolving labour productivity make up-to-date technology-specific and country-specific data necessary, which are hard to obtain.

Moreover, calculating the domestic share of MCI and O&M can be difficult. Official trade statistics usually record the monetary value of products, not their energy capacity (in MW). Additionally, many products are grouped with others that are not related to renewable energy: for example, when PV cells and modules are grouped with other semiconductor devices [1].

Another key weakness is that the model only covers gross (positive) effects on jobs in the renewable energy industry. It omits the indirect and induced effects on overall employment in the economy.

A summary of strengths and limitations is provided in Figure 8.

References:

[1]: Breitschopf, B., Nathani, C., and Resch, G., 2011: Review of Approaches for Employment Impact Assessment of Renewable Energy Deployment, http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf

Further reading:

The report by IRENA, "Renewable Energy and Jobs", from 2013, provides a good overview of the employment factor methodology, as well as its strengths and weaknesses:

- https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/rejobs.pdf

IRENA also provides an annual update on global renewable energy employment, by country, region and technology:

- https://www.irena.org/publications/2020/Sep/Renewable-Energy-and-Jobs-Annual-Review-2020

The report by GIZ, "Green Jobs: Impacts of a Green Economy on Employment", from 2015, showcases how the employment factor approach has been used in empirical studies, as well as the strengths and weaknesses encountered:

- https://energypedia.info/images/f/fc/Green_Jobs_-_Impacts_of_a_Green_Economy_on_Employment.pdf

3.5 Employment Factor Analysis: South Africa Case Study

Learning objectives: Upon completion of this page, you should be able to

- apply the theory of employment factor analysis to real examples
- recognise the relevance of employment factor analysis in real cases

As a result of the local content requirements for RE projects in South Africa, facilities exist across the solar PV industry value chain in South Africa [1]. For example, ARTSolar, the operator of a 100 MW solar module assembly facility in Durban, relies on the aluminium provider Hulamin in Pietermaritzburg. By 2014, more than 20,000 jobs had been created in the South African solar industry [2].

According to the Internal Resource Plan (IRP), updated in 2018, the following PV capacities are planned for South Africa [3]:

- 1,474 MW already installed in 2018
- 814 MW between 2019 and 2021 (already contracted)
- 5,670 MW to be installed between 2022 and 2030 (additional capacity)

The following employment factors are used for the calculation of job creation potential [5]:

- Manufacturing of solar modules: 16.8 job-years/MW
- Installation and construction of solar PV plants: 7 job-years/MW
- Operation and maintenance (O&M): 0.7 jobs/MW

The table shows a rough estimate of jobs resulting from existing and planned capacities, according to the IRP. Manufacturing and construction jobs are calculated by multiplying existing and newly added capacities for each stage of the IRP:

- 1,474 MW * 16.8 job-years/MW = 24,763 job-years created by 2018
- 814 MW * 16.8 job-years/MW = 13,675 job-years created between 2019 and 2021

O&M jobs, on the other hand, exist over the lifetime of a RE power plant (usually 25 years). Therefore, the resulting permanent jobs result from adding capacities:

- 1,474 MW * 0.7 jobs/MW = 1,032 jobs created by 2018
- 1,032 jobs plus 814 MW * 16.8 jobs/MW = 570 jobs amounting to 1,602 jobs created by 2021

Employment Generated by Solar PV Industry	Until 2018	2019-2021	2022-2030
Manufacturing (job-years)	24,763	13,675	95,256
Construction (job-years)	10,318	5,698	39,690
	By 2018	By 2021	By 2030
O&M (jobs)	1,032	1,602	5,571

Figure 9: Estimation of jobs created by solar PV in South Africa, if the IRP capacity goals are reached (author's own depiction, based on DoE, 2018 and Maia & Giordano, 2011) [3, 4]

References:

[1]: Ettmayr, C. and Lloyd, H., 2017: Local content requirements and the impact on the South African renewable energy sector: A survey-based analysis, South African Journal of Economic and Management Sciences, 20(1), a1538, https://doi.org/10.4102/sajems.v20i1.1538

[2]: International Renewable Energy Agency (IRENA), 2016: Renewable Energy and Jobs. Annual Review 2016, https://irena.org/publications/2016/May/Renewable-Energy-and-Jobs--Annual-Review-2016

[3]: Department of Energy, Republic of South Africa, 2018: Integrated Resource Plan 2018, http://www.energy.gov.za/IRP/irp-update-draft-report-2018.html

[4]: Maia, J. and Giordano, T., 2011: Green Jobs. An Estimate of the Direct Employment Potential of a Greening South African Economy

Further reading:

For a more detailed evaluation of the employment creation potential of different renewable energy sources in South Africa, have a look at:

- Maia, J. and Giordano, T., 2011: Green Jobs. An Estimate of the Direct Employment Potential of a Greening South African Economy.

This study assesses the impacts of a coal phase-out plan, including impacts on jobs:

- Burton, J.; Caetano, T. and McCall, B., 2018: Coal transitions in South Africa - Understanding the implications of a 2°C-compatible coal phase-out plan for South Africa, Energy Research Center, University of Cape Town, https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Rapport/20180609_ReportCoal_SouthAfrica.pdf

4 Methodologies for Quantifying Employment Impacts: Gross Input-output Models

4.1 Gross Input-output Models - General Functions

Learning objectives: Upon completion of this page, you should be able to

- describe the purpose of input-output (I-O) models
- explain the basic function of I-O models

Gross input-output (I-O) models are used to estimate the direct and indirect economic effects which result from a change in demand within a sector. The model builds on I-O tables, which visualise supply chains between economic sectors. I-O tables represent the flow of goods and services through an economy in monetary units for a given time period, usually a year [1].

The columns of an I-O table display the required inputs a sector purchases in order to produce its output (see Figure 10, below). In this way, it is possible to study the output produced by a given sector, in terms of how many inputs there are from a number of sectors. The rows of an I-O table represent where the output of a sector ends up, i.e. the number of sales to other sectors, as final domestic demand or exports.

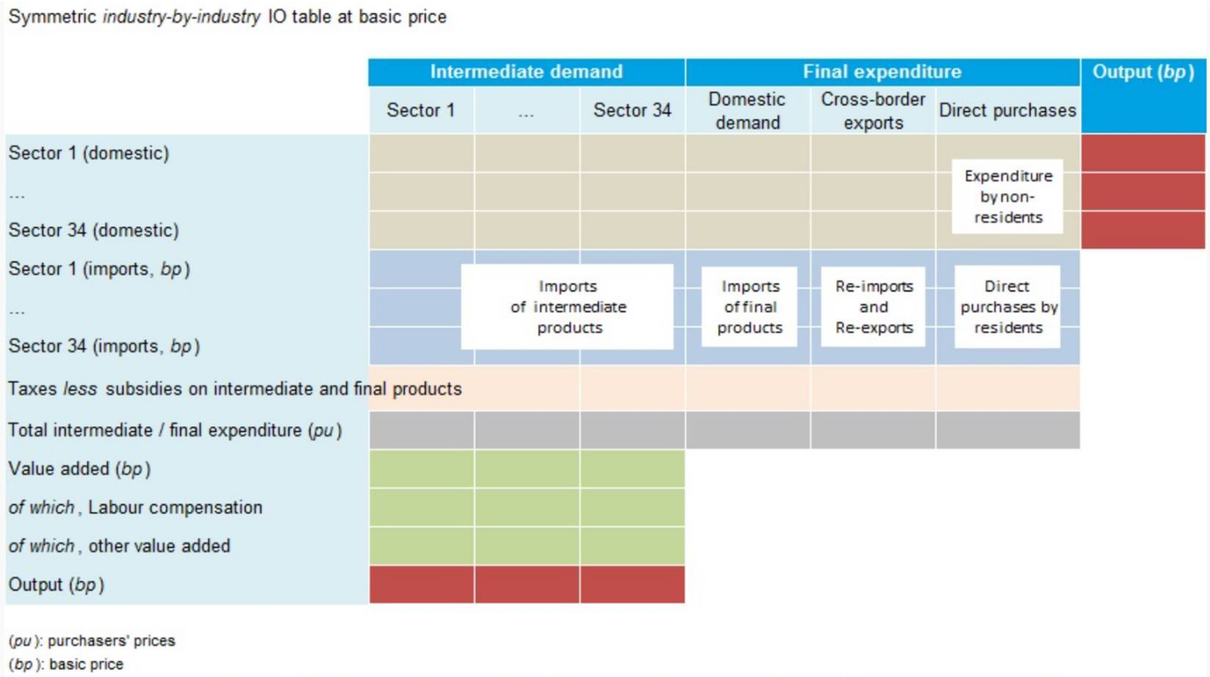


Figure 10: Example of an I-O table (OECD, 2020) [2]

Gross I-O models can be used to study employment effects resulting from a change in demand. The gross I-O model allows inputs to be disaggregated by sector and by life cycle. Employment effects can be calculated by multiplying the inputs, using a labour requirement multiplier.

The labour requirement multiplier can be determined from the I-O table, as a sector-specific employment factor. Alternatively, a technology-specific employment factor can be used. This second approach increases the accuracy of the estimate, as sectors in I-O tables are usually defined very broadly.

Indirect employment in upstream industries is determined by calculating total demand in intermediate inputs, per technology, and multiplying it with a matrix of total labour requirement multipliers.

References:

[1]: Jarvis, A.; Varma, A. and Ram, J., 2011: Assessing green jobs potential in developing countries: A practitioner's guide, International Labour Office, https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_153458.pdf
[2]: OECD, (n.a): Input-Output Tables (IOTs)), http://www.oecd.org/trade/input-outputtables.htm

Further reading:

The paper by Breitschopf, Nathani and Resch, "Review of approaches for employment impact assessment of renewable energy deployment", provides an overview of different impact assessment studies that analyse the employment impacts of renewable energy, and clarifies which methodological approach is best:

- http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf

The "Guidelines for employment impact assessment or renewable energy development" provide a comprehensive step-by-step method for assessing indirect and induced employment impacts, using I-O-tables and employment factors:

- https://ecomod.net/system/files/Paper_Ecomod_2012_Nathani.pdf

EurObserv'ER: Renewable energy employment effects – methodology report for EU-28:

- https://www.eurobserv-er.org/pdf/renewable-energy-employment-effects-methodology-report-2018/

4.2 Gross Input-output Models - Required Data and Calculation Steps

Learning objectives: Upon completion of this page, you should be able to

- identify the necessary data for I-O models
- order the basic steps of the calculation process

The gross input-output model follows five main steps [1], which are summarised in Figure 11, below.

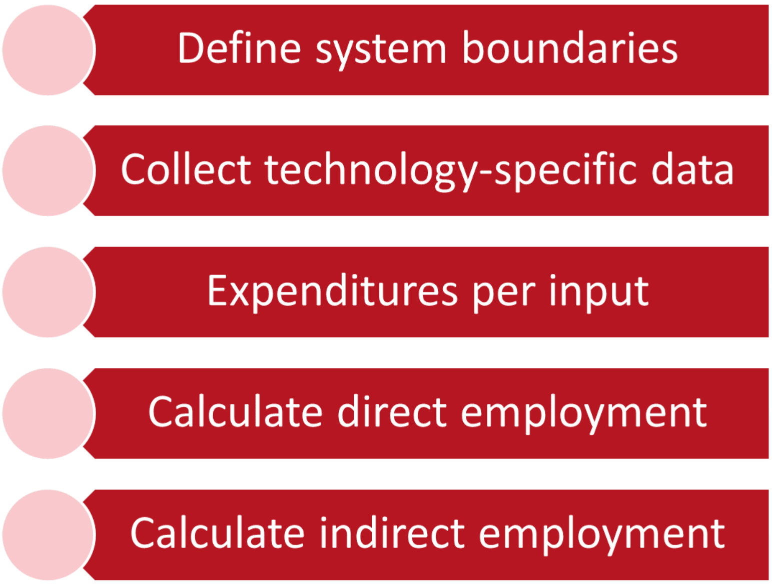


Figure 11: The main steps of an I-O model (author's own depiction, based on Breitschopf, Nathani & Resch, 2011) [1]

The first step is to determine which technologies and life cycle phases need to be analysed. Secondly, data need to be collected on newly added and total capacity, as well as cost per life cycle phase. Multiplying capacity and cost data yields total expenditure. Thirdly, expenditure is assigned to specific inputs (e.g. planning, wind turbine nacelle, turbine rotor blades, etc.) using I-O tables. Export and import shares per input are then determined and imports are subtracted, in order to obtain domestic output. These three steps yield complete I-O tables.

Fourthly, direct employment in operation and maintenance (O&M) is calculated as total O&M expenditure divided by the average wage in the sector. Direct employment in manufacturing, construction and installation (MCI) can be calculated by multiplying the output by a sector-specific direct employment factor. The employment factor can be derived from the I-O table. However, the result may be biased, as labour productivity within a sector in the I-O table might be heterogeneous. Alternatively, direct employment in MCI can be calculated by multiplying domestic output by technology-specific employment factors derived from industry surveys.

Fifthly, indirect employment is determined by calculating the total amount of intermediate inputs per RE technology and sector. Multiplying all inputs by a labour coefficient vector determines the number of indirect FTE jobs.

The necessary data includes I-O tables, the average salary per FTE job in O&M, technology-specific employment factors for MCI, and labour coefficient vectors covering all inputs. The frequency and level of detail of I-O tables varies by country, as the calculation of I-O tables requires large amounts of data and labour. Many countries' national statistics offices publish their I-O tables several years after they have been produced.

References:

[1]: Breitschopf, B., Nathani, C., and Resch, G., 2011: Review of Approaches for Employment Impact Assessment of Renewable Energy Deployment, http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf

Further reading:

I-O tables for Mexico:

- OECD.Stat, *Input Output tables,* accessible at: https://stats.oecd.org/Index.aspx?DataSetCode=IOTS.

I-O tables for Kenya:

- The Kenya Institute for Public Policy Research and Analysis, *An Input-Output Table for Kenya and its Application to Development Planning*, 2017, accessible at: https://kippra.or.ke/index.php/publications/summary/5-discussion-papers/28-an-input-output-table-for-kenya-and-its-application-to-development-planning-dp192.

I-O tables for South Africa:

- Stats SA, *Economic Analysis. Input-output tables for South Africa, 2013 and 2014*, accessible at: http://www.statssa.gov.za/publications/Report-04-04-02/Report-04-04-022014.pdf.

I-O tables for Turkey:

- Turkish Statistical Institute, *Input-Output Tables*, accessible at: http://www.turkstat.gov.tr/Start.do.
- OECD.Stat, *Input Output tables,* accessible at: https://stats.oecd.org/Index.aspx?DataSetCode=IOTS.

I-O tables of OECD members in the OECD statistics database:

- OECD.Stat, *Input Output tables,* accessible at: https://stats.oecd.org/Index.aspx?DataSetCode=IOTS.

EuroStat I-O tables for EU member states:

- Eurostat, *ESA Supply, use and Input-output tables*, 2010, accessible at: https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/data/database.

EurObserv'ER: Renewable energy employment effects – methodology report for EU-28:

- https://www.eurobserv-er.org/pdf/renewable-energy-employment-effects-methodology-report-2018/

Physical I-O tables:

- WIOD, *Environmental Accounts (for India and Turkey; including energy use, CO_2 emissions and air pollutants)*, 2013, accessible at: http://www.wiod.org/database/eas13.
- Exiobase (including raw materials and types of water uses), accessible at: https://www.exiobase.eu/index.php/about-exiobase.

4.3 Gross Input-output Models: Limitations and Advantages (Pros and Cons)

Learning objectives: Upon completion of this page, you should be able to

- recognise the benefits of I-O models
- list the disadvantages of I-O models

The main advantage of the gross I-O model is its coverage of direct and indirect effects. In addition, it allows for gross employment in the RE industry to be estimated within a comprehensive and consistent framework. The same methodological approach can also be used to calculate other economic impacts (e.g. gross value added, as a contribution to GDP). Further, the model allows technology-specific data on capacities, costs, and cost structures to be combined with economic modelling [1].

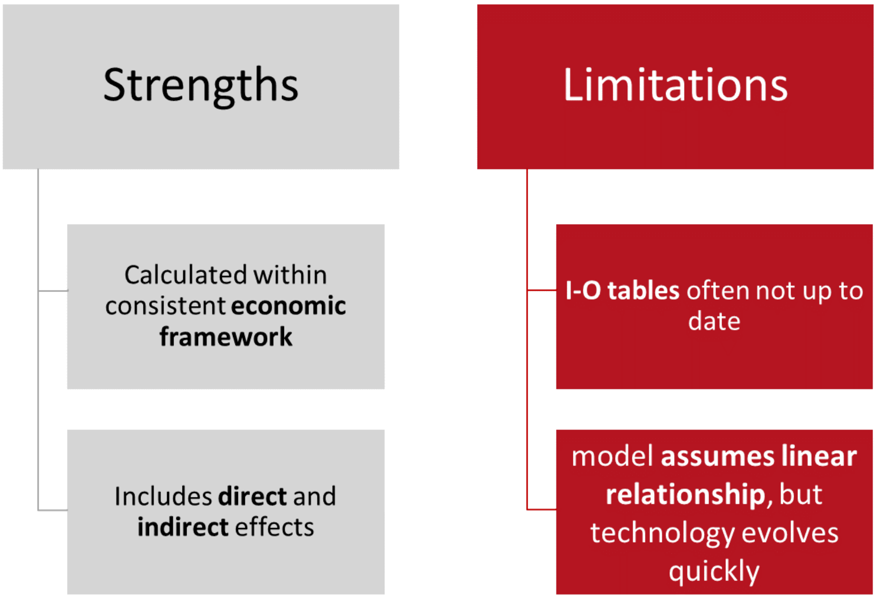


Figure 12: The strengths and limitations of I-O models (author's own depiction)

In contrast, the analysis hinges on the availability of recent I-O tables. In developing countries specifically, I-O tables are typically several years old and only partially include the informal sector [2, 3].

Another weakness is that RE technologies do not represent an individual sector in an I-O table. Instead, they are grouped under other sectors which might not always be adequate proxies for RE industry companies and their supply chains, with regard to cost structure, import relations, and employment per unit of output. This aggregation bias can be reduced by including technology-specific information in the estimation of direct employment [1].

Further, the model assumes linear input-output relationships, even though the transforming energy sector is characterised by innovation and quickly evolving labour productivity [3]. Also, the model does not take induced or net effects into account [2].

A summary of strengths and limitations is provided in Figure 12, above.

References:

[1]: Breitschopf, B., Nathani, C., and Resch, G., 2011: Review of Approaches for Employment Impact Assessment of Renewable Energy Deployment, http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf

[2]: Jacob, K; Quitzow, R. and Bär, H., 2015: Green jobs: Impacts of a Green Economy on Employment, https://www.researchgate.net/publication/273767132_Green_Jobs_Impacts_of_a_Green_Economy_on_Employment

[3]: International Renewable Energy Agency (IRENA), 2013: Renewable Energy and Jobs, https://www.irena.org/publications/2013/Dec/Renewable-Energy-and-Jobs-(2013)

Further reading:

The report by IRENA, "Renewable Energy and Jobs", from 2013, provides a good overview of the input-output model, as well as its strengths and weaknesses:

- https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/rejobs.pdf

The report by IRENA, "The Socio-economic Benefits of Solar and Wind Energy", from 2014, discusses domestic value creation resulting from investments in renewable energy technologies. Further, it compares different methodologies and provides case studies on use of the I-O model:

- https://www.irena.org/publications/2014/May/The-Socio-economic-Benefits-of-Solar-and-Wind-Energy

The report by GIZ, "Green Jobs: Impacts of a Green Economy on Employment", from 2015, showcases how the I-O model has been used in empirical studies. Further, it discusses how the I-O model can be adapted to include green economic sectors:

- https://energypedia.info/images/f/fc/Green_Jobs_-_Impacts_of_a_Green_Economy_on_Employment.pdf

4.4 Gross Input-output Models: Vietnam Case Study

Learning objectives: Upon completion of this page, you should be able to

- apply the theory of IO models to real examples
- recognise how IO models are relevant in the analysis of real cases

This case study [1] shows how I-O models are used in Vietnam, both to capture the renewable energy value chain and to calculate changes in employment and skills requirements across competing power sector planning scenarios. I-O models were used (as part of a larger approach) to derive employment factors for a number of generation technologies, and the employment replacement factor for coal, thus contributing to gross employment analyses.

Using the standard equations for I-O models (see [1], p. 10), specific factors such as equipment capital cost, wages, and share of domestic production, were adapted for Vietnam. The model then estimated the economic impacts related to the RE project lifetime. The resulting gross employment impacts - direct, indirect and induced - were calculated within each scenario, for the period 2015-2030. Four scenarios were used for the analysis, as follows:

- Base Scenario/PDP 7 (rev): represents the planned official composition of Vietnam's energy mix, as devised by the Power Development Plan VII (revised)
- DEA Stated Policies: the stated policy scenario, as developed by the Danish Energy Agency
- ADB Low-Carbon: a scenario developed by the Asian Development Bank, known as "Pathways to low-carbon development for Vietnam"
- Base & Renew: the Base & Renewable Energy scenario, as developed by GreenID

As each scenario makes different assumptions, the I-O model only treated the RE production shares and capacity additions as priorities.

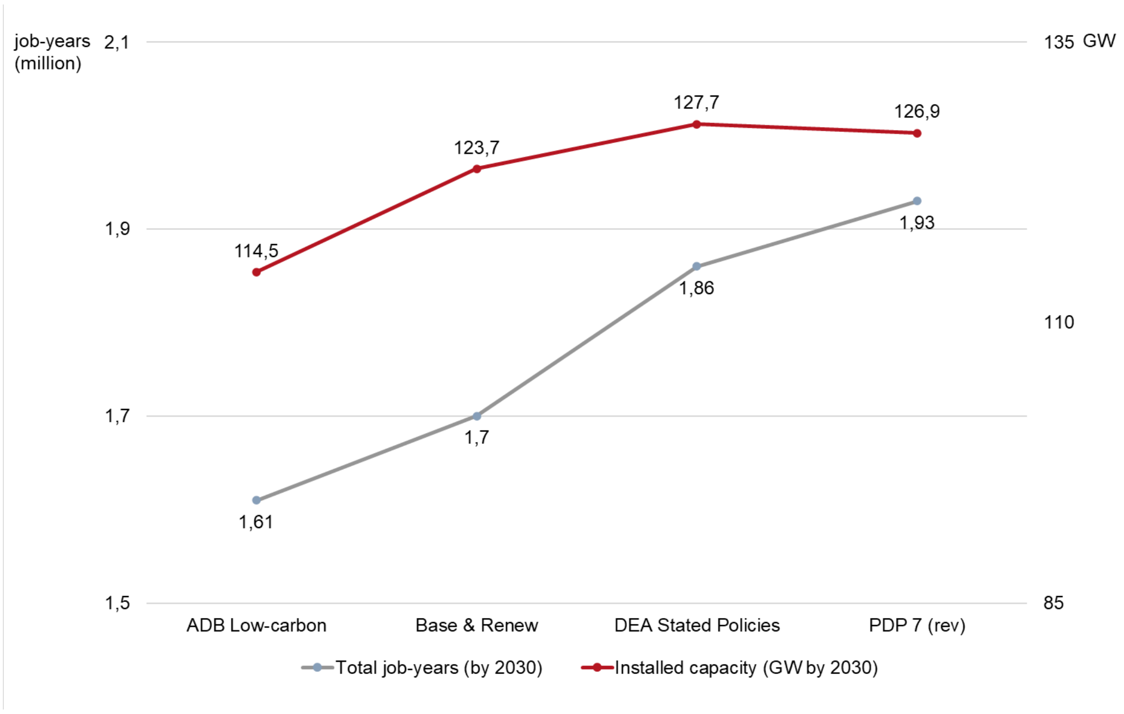


Figure 13: Employment effects between 2015 and 2030, by scenario (author's own depiction, based on Okunlola, et al. 2019, p. 13) [1]

The results are depicted in Figure 13 (above), which shows that the PDP 7 (rev) scenario would create the highest number of jobs up to 2030 (assuming 1.93 million job-years). The figure also demonstrates that generation capacity positively influences employment effects [1].

References:

[1]: Okunlola, A.; Nagel, L.; Helgenberger, S.; Thi Khanh, N.; May Dung, T. M. and Kovac, S., 2019: COBENEFITS Study - Future skills and job creation through renewable energy in Vietnam.

Further reading:

This recent paper uses an I-O modelling approach to measure RE industry gross employment in Germany:

- O'Sullivan, M. & Edler, D.: Gross Employment Effects in the Renewable Energy Industry in Germany—An Input–Output Analysis from 2000 to 2018, 2020, https://www.researchgate.net/publication/343349388_Gross_Employment_Effects_in_the_Renewable_Energy_Industry_in_Germany-An_Input-Output_Analysis_from_2000_to_2018

In this paper, I-O tables are adapted so that public and private spending in clean energy can be compared to the effects of spending on fossil fuels, with a focus on employment impacts in the short-to-medium term:

- Garrett-Peltier, H., 2017: Green versus brown: Comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model, Economic Modelling, pages 439-447.

5 Methodologies for Quantifying Employment Impacts: Full Economic Modelling

5.1 Full Economic Modelling: General Functions

Learning objectives: Upon completion of this page, you should be able to

- summarise why full economic modelling is used
- explain the basic function of full economic modelling
- cite different kinds of full economic modelling

Full economic modelling looks at economy-wide effects, and its purpose is to illustrate change processes within an economy. In the context of employment, full economic modelling aims to calculate the net employment effects of a measure or scenario [1].

There are three different types of models:

- Econometric models
- Equilibrium models (Computable General Equilibrium)
- System dynamics models

All three models build on a number of assumptions regarding impact mechanisms and interactions within an economic system. Compared to employment factor analysis and I-O models, full economic models are more complex and have greater use requirements. As a consequence, non-experts may find that the resulting data are more difficult to interpret.

This course focuses on the Computable General Equilibrium (CGE) model. CGE stands for [2]:

C	Computable	software-based simulation (for example, GEMPACK or GAMS)		
G	General	looking at the entire economy		
E	Equilibrium	under equilibrium assumptions:		
		· budget constraint:	total income =	sum of purchased commodities
		· market equilibrium:	Supply =	demand
			sum of revenues =	sum of expenditures
		· macroeconomic balance:	Savings =	investment spending

Figure 14: The main features of CGE models (author's own depiction)

The CGE model aims to illustrate economic relationships and to simulate exogenous shocks (such as policy changes) on the whole domestic economy. It considers job shifts and job increases (due to increased output, export and import, etc). However, a CGE model does not take unemployment into account, as it assumes that a flexible, market-clearing wage balances the supply and demand of labour [3].

A CGE model takes into account different economic parameters, as illustrated in Figure 15, below.

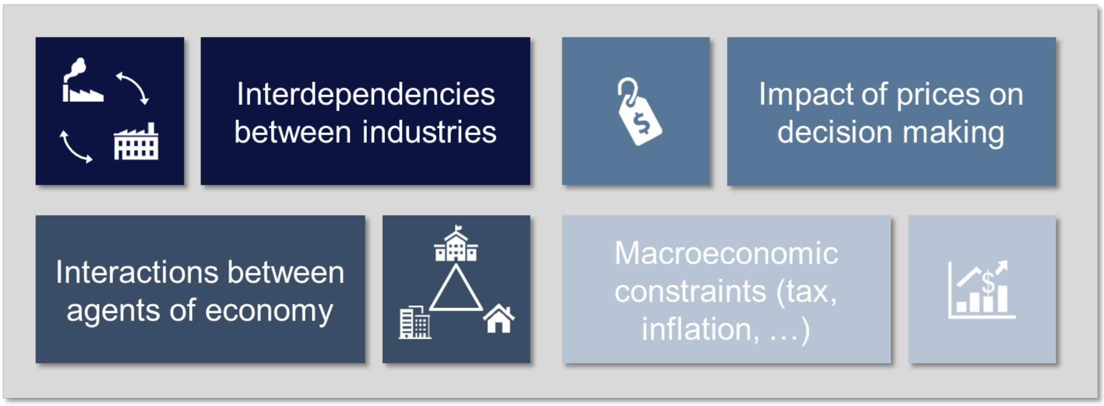


Figure 15: The economic parameters used by a CGE model (author's own depiction)

References:

[1]: Jacob, K; Quitzow, R. and Bär, H., 2015: Green jobs: Impacts of a Green Economy on Employment, https://www.researchgate.net/publication/273767132_Green_Jobs_Impacts_of_a_Green_Economy_on_Employment

[2]: Raihan, S., 2017: An Introduction to Computable General Equilibrium Modelling, https://www.unescap.org/sites/default/files/9.Intro%20to%20CGE%20Model.pdf

[3]: Boeters, S. and Savard, L., 2011: The Labour Market in CGE Models, CPB Netherlands Bureau for Economic Policy Analysis, CPB Discussion Paper 201, https://www.cpb.nl/sites/default/files/publicaties/download/discussion-paper-201-labour-market-cge-models.pdf

Further reading:

For an in-depth explanation of how CGE models work, Christoph Böhringer et al. give a detailed overview of CGE models and show in which contexts they are useful, for non-technical readers:

- Böhringer, C; Rutherford, T. F. and Wiegard, W., 2003: Computable General Equilibrium Analysis: Opening a Black Box, ZEW Discussion Paper No. 03-56 (2003), http://ftp.zew.de/pub/zew-docs/dp/dp0356.pdf

Sue Wing provides a detailed explanation of how CGE modelling works, by describing the approach for decision makers and other non-experts in this particular field:

- Wing, I. S., 2004: Computable General Equilibrium Models and Their Use in Economy-Wide Policy Analysis, http://web.mit.edu/globalchange/www/MITJPSPGC_TechNote6.pdf

For a more academic-oriented, technical overview on CGE modelling, Mary Burfisher's book is helpful in better understanding how CGE models work:

- Burfisher, M., 2012: Introduction to Computable General Equilibrium Models, Cambridge University Press.

5.2 CGE Models: Required Data and Calculation Steps

Learning objectives: Upon completion of this page, you should be able to

- identify the data required for CGE modelling
- describe the basic steps of the calculation process

The CGE analysis consists of four steps, as illustrated in Figure 16.

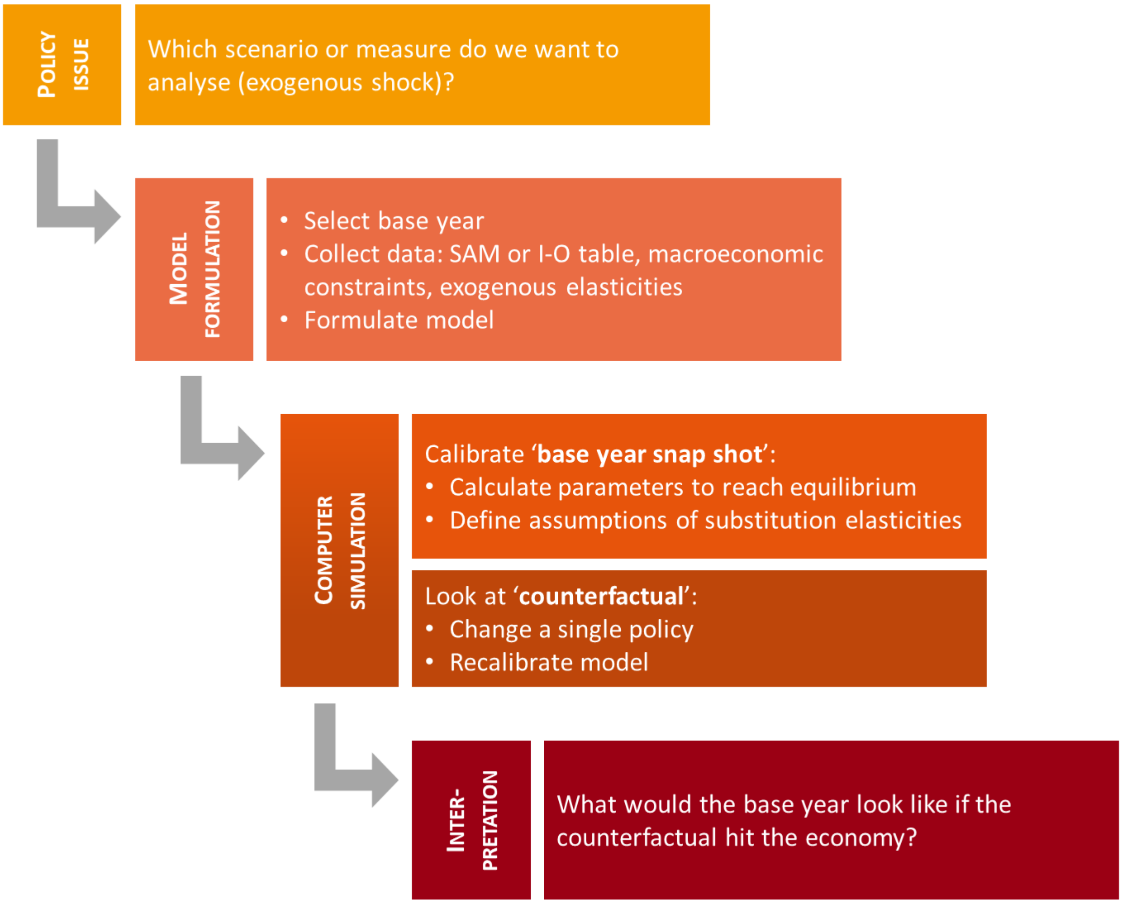


Figure 16: The steps of a CGE analysis (author's own depiction, based on Böhringer et al., 2003) [1]

Step 1: First, we need to define the scenario we want to analyse. This can be an exogenous shock (e.g. world prices, natural disasters), a structural change (e.g. productivity, resource endowment), or a policy change (e.g. an increase in installed RE capacity) [2].

Step 2: The next step is to define the base year and collect the respective data. CGE models are usually based on either a social accounting matrix (SAM) or I-O tables. Macroeconomic constraints (e.g. tax, inflation, currency exchanges, interest) and exogenous elasticities can be obtained through literature and database research.

The conceptual starting point of a CGE model is the circular flow of commodities between different agents, which is illustrated in Figure 17, in a simplified way [3]. The main interaction takes place between households, which own production factors and consume, and firms, who rent production factors and produce. Further, CGE models include interactions with the government and the rest of the world.

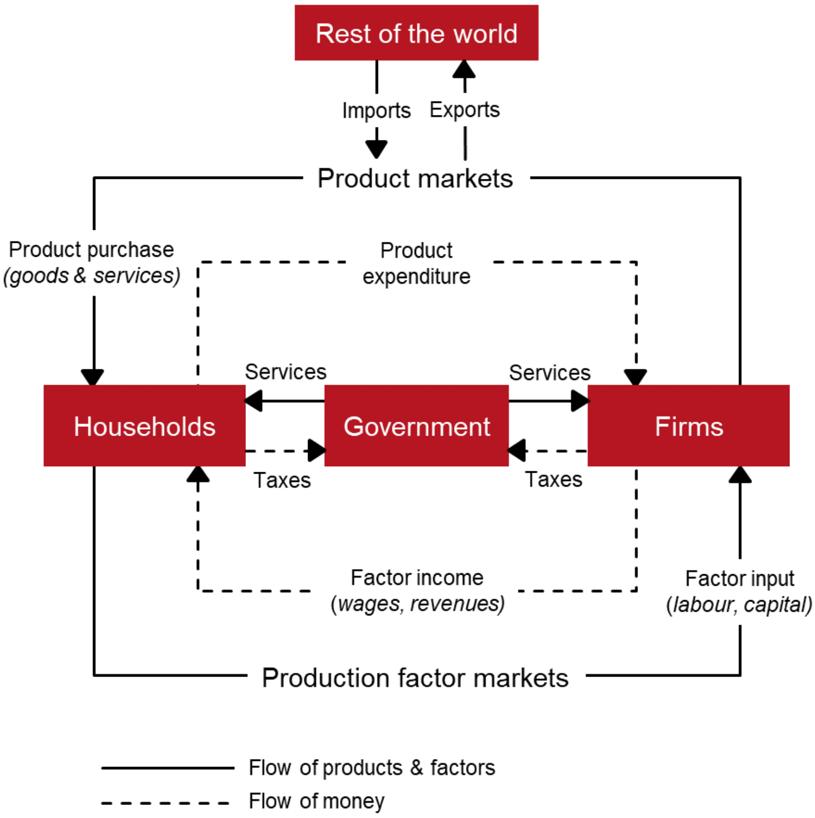


Figure 17: Simple illustration of a circular flow of commodities (author's own depiction, based on Wing, 2004) [3]

Step 3: The computer simulation consists of two sub-steps: calibration of the model (the 'base year snapshot'), and recalibration of the model by changing a single policy (the 'counterfactual').

Step 4: CGE models can analyse what the base year would look like if an exogenous shock hit the economy [2]; it is therefore *not* a forecasting method. Results can be changes in:

- commodity prices and quantities, or labour
- incomes, expenditures, and savings for agents
- macroeconomic indicators (e.g. GDP, current account balance, public deficit, investment)

References:

[1]: Böhringer, C; Rutherford, T. F. and Wiegard, W., 2003: Computable General Equilibrium Analysis: Opening a Black Box, ZEW Discussion Paper No. 03-56, http://ftp.zew.de/pub/zew-docs/dp/dp0356.pdf

[2]: Raihan, S., 2017: An Introduction to Computable General Equilibrium Modelling, https://www.unescap.org/sites/default/files/9.Intro%20to%20CGE%20Model.pdf

[3]: Wing, I. S., 2004: Computable General Equilibrium Models and Their Use in Economy-Wide Policy Analysis, http://web.mit.edu/globalchange/www/MITJPSPGC_TechNote6.pdf

Further reading:

Lofgren et al. give an overview of the Software GAMS, which is open source and can be used for CGE modelling:

- Lofgren, H. et al., 2012: A Standard Computable General Equilibrium (CGE) Model in GAMS, http://www.un.org/en/development/desa/policy/mdg_workshops/training_material/lofgren_lee_and_robinson_2002.pdf.

The Partnership for Economic Policy (PEP) offers extensive training in CGE modelling. The following video provides a general introduction to the main features of a CGE model:

- PEP, 2018: Introduction to Training on Computable General Equilibrium Modelling, https://www.youtube.com/watch?v=xuUDwTOgEx0.

5.3 CGE Models: Limitations and Advantages (Pros and Cons)

Learning objectives: Upon completion of this page, you should be able to

- summarise the benefits of CGE models
- state the disadvantages of CGE models

The main advantage of the CGE model lies in its analysis of economy-wide net effects. It identifies resource reallocations: *What industries expand? What industries contract? What happens to employment in the different sectors?* It also takes into account dynamic and macroeconomic effects (such as substitution elasticities), which are dependent on either prices or limited capacities. Thanks to their internal consistency, and by always keeping the economic system in general equilibrium, CGE models enable comparative analysis of different policy scenarios [1]. As CGE models are based on clear theoretical foundations, any missing data can be replaced by assumptions. Another advantage of CGE models is that they account for direct, indirect, and induced effects, which means they can also capture co-benefits along the value chain, such as the emissions produced by a specific sector.

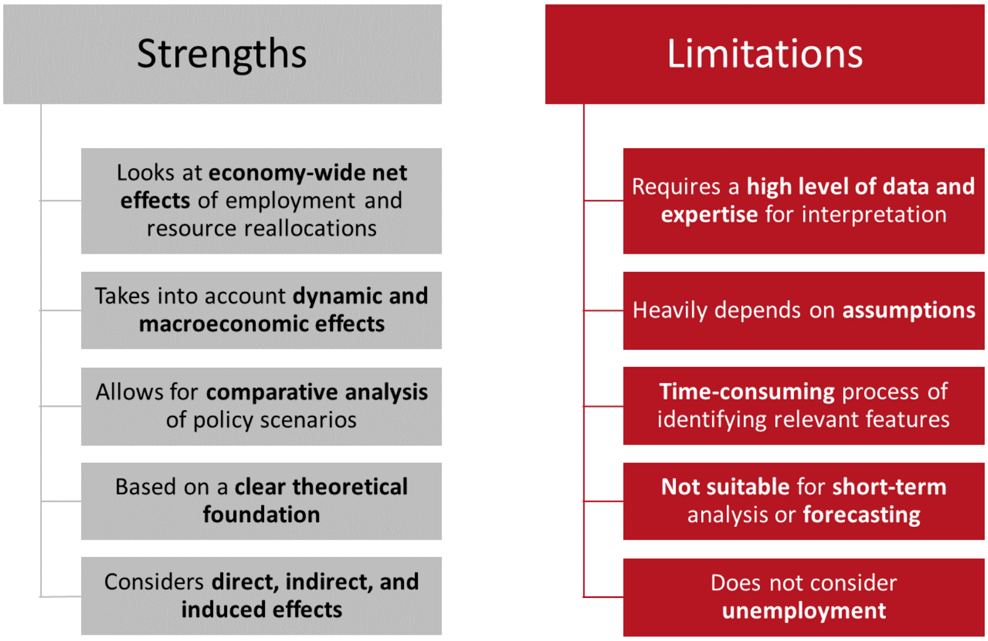


Figure 18: The strengths and limitations of CGE models (author's own depiction)

One of the main challenges with CGE models is the requirement for a high level of scientific knowledge. The models are difficult for non-experts to understand. In addition, CGE models require massive input data (SAM/I-O table) [2]. Since missing data can be replaced by assumptions, external consistency (or, conformity with the 'real world') can be disputed [1]. Unearthing the features that drive the results can be a time-consuming activity. Therefore, CGE models are generally not considered suitable for short-term analyses, and forecasting is not possible [1]. Another critique is that CGE models assume the clearance of markets with inelastic labour supply and free labour mobility across sectors. In this way, they fail to take into account frictional, structural, or cyclical unemployment [3, 4].

A summary of strengths and limitations is provided in Figure 18.

References:

[1]: Rennings, K., 2013: Modelling. Economic modelling. LIAISE Toolbox.
[2]: Jacob, K; Quitzow, R. and Bär, H., 2015: Green jobs: Impacts of a Green Economy on Employment, https://www.researchgate.net/publication/273767132_Green_Jobs_Impacts_of_a_Green_Economy_on_Employment
[3]: Wing, I. S., 2004: Computable General Equilibrium Models and Their Use in Economy-Wide Policy Analysis, http://web.mit.edu/globalchange/www/MITJPSPGC_TechNote6.pdf
[4]: Hafstead, M. A. C.; Williams III, R. C. and Chen, Y., 2018: Environmental policy, full-employment models, and employment: a critical analysis, NBER Working Paper No. 24505, https://www.nber.org/papers/w24505.pdf

Further reading:

Hafstead et al. analyse the challenges and advantages of full-employment CGE models in detail:

- Hafstead, M. A. C.; Williams III, R. C. and Chen, Y., 2018: Environmental policy, full-employment models, and employment: a critical analysis, NBER Working Paper No. 24505, https://www.nber.org/papers/w24505.pdf

Iqbal and Siddiqui critically analyse the different outcomes of a policy, depending on the CGE model set-up, with two real case examples:

- Iqbal, Z. and Siddiqui, R., 2001: Critical Review of Literature on Computable General Equilibrium Models, MIMAP Technical Paper Series No. 9, https://www.researchgate.net/publication/238778373_Critical_Review_of_Literature_on_Computable_General_Equilibrium_Models.

5.4 Full Economic Modelling: COBENEFITS Case Study in South Africa

Learning objectives: Upon completion of this page, you should be able to

- apply the theory of different kinds of full economic modelling to real examples
- recognise the how different kinds of full economic modelling are relevant to the analysis of real examples

The COBENEFITS South Africa case study [1] used full economic modelling to analyse the gross and net employment impacts of transition from coal to RE energy, via four different scenarios:

1. IRP16 (baseline): Integrated Resource Plan 2016
2. IRP18: increased RE share in energy mix
3. CSIR_LC: least-cost alternative to IRP16
4. DEA_RD: rapid GHG emissions reduction, with high RE increase

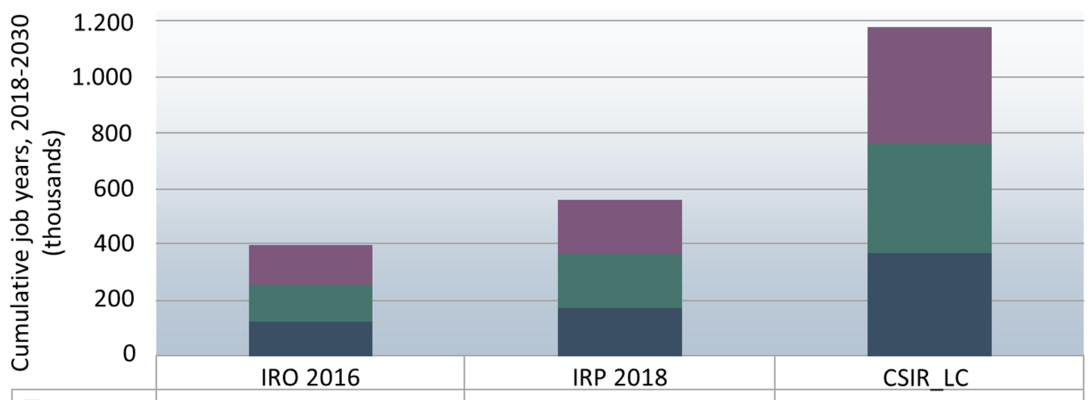
Quantitative assessment of employment impacts was carried out via different models:

- I-JEDI model, to estimate gross employment impacts using an I-O model
- SATIMGE model, to estimate net employment effects. It links two models:
  - SATIM: the bottom-up engineering model for South Africa's energy system

- e-SAGE: the top-down CGE economy-wide model

Sources of data included: Statistics South Africa (StatsSA), South Africa’s 2012 energy balance, Integrated Resource Plan 2016, and employment factors by Pauw (2007) [2].

The gross employment effects are separated into direct, indirect, and induced effects. Compared to the baseline scenario 1, the number of gross job-years increases by 42 % (during construction) in scenario 2. In scenario 3, the numbers triple (see Figure 19, below).



	IRO 2016	IRP 2018	CSIR_LC
Induced	139763	198194	413100
Indirect	133778	188273	393586
Direct	126030	178918	371909

Figure 19: Cumulative job years created by wind and solar PV during the construction phase, between 2018 and 2030 (Okunlola et al., 2019, p. 16) [1]

The net employment effects are reported by sector. A distinction between direct, indirect, and induced impacts is not possible, because these appear across sectors. In scenario 2, net employment decreases in the medium term (by 2030), whereas it increases significantly in the long term (by 2050) (see Figure 20, below). This makes the importance of looking at net effects evident; whereas gross effects show a considerable increase of job-years in 2030, net effects indicate a negative effect in 2030.

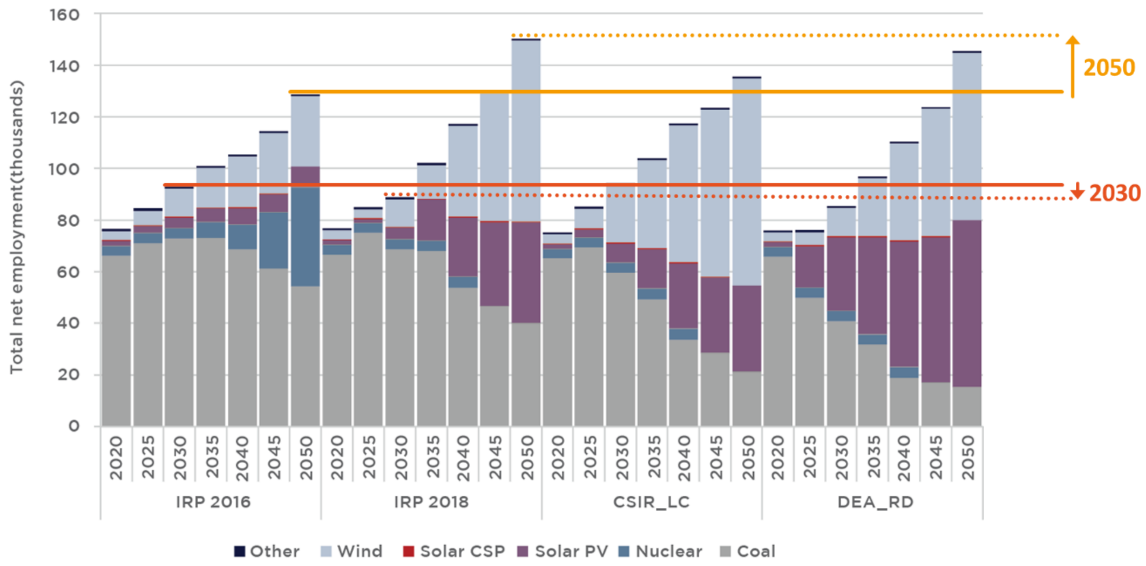


Figure 20: Evolution of net employment in the power sector between 2018 and 2050, by technology (author's own depiction, adapted from Okunlola et al., 2019, p.18) [1]

References:

[1]: Okunlola, A.; Jacobs, D; Ntuli, N.; Fourie, R.; Borbonus, S.; Nagel, L and Helgenberger, S., 2019: Future skills and job creation through renewable energy in South Africa – Assessing the co-benefits of decarbonising the power sector, IASS Potsdam, CSIR and IET, https://www.cobenefits.info/resources/cobenefits-south-africa-jobs-skills/

[2]: Pauw, K., 2007: Economy-wide modeling: an input into the long term mitigation scenarios process. LTMS Input Report 4, Energy Research Centre, https://open.uct.ac.za/bitstream/handle/11427/16745/Pauw_Economy_wide_Modeling_An_2007.pdf?sequence=1&isAllowed=y

6 Methodologies for Quantifying Employment Impacts: Overview of Open-access Online Tools

6.1 Overview of Open-access Online Tools: The I-JEDI tool

Learning objectives: Upon completion of this page, you should be able to

- identify use cases for the I-JEDI online tool
- list the potential advantages and limitations of the I-JEDI online tool

The International Jobs and Economic Development Impact (I-JEDI) model is a freely available economic model that estimates gross economic impacts from the construction and operation of RE (wind, solar PV, biomass, and geothermal) power plants. The model yields results on employment, earnings, gross domestic product (GDP), and gross output impacts, for a specific country or region. By quantifying impacts and benefits, the model thus helps governments to make objective decisions regarding different project options. There are two versions of the I-JEDI tool: an Excel-based tool, and a web-based version.

I-JEDI uses an I-O model, which calculates the effects of a certain RE project on the whole economy. In order to run the model, construction and operation & maintenance (O&M) costs must be entered, as well as the percentage of domestic expenses. As of 2020, the Excel-based and web-based model comprise data from South Africa, Colombia, Mexico, the Philippines, and Zambia. Calculations for these countries can be run instantly. In the Excel-based version, data can be changed and customised regions can be added.

If one of the pre-set countries is selected, project size and dollar year must be inserted in the input sheets for the respective technology, to adjust for inflation. Construction costs can also be adjusted - i.e. one-off and O&M costs as annual costs, as well as domestic expenditure (e.g. if 50% of PV modules were sourced domestically). Accordingly, I-JEDI calculates two sets of results in three categories (direct, indirect, and induced impacts) for: the number of jobs, earnings from all jobs calculated, economic output, and gross domestic product (GDP, value added).

The limitations of the tool include: obtaining gross results only; linear impact calculations, which produce the same results for ten 8 MW plants as for one 80 MW plant; and disregard of any price, policy or technology changes.

Figure 21 shows the economic and job impacts for a 100 MW solar PV power plant in Mexico.

Impact Totals				
Construction Phase (Single-Year Equivalent)				
	Jobs	Earnings	Output	GDP (Value Added)
Direct	5,938	USD 22,247,693	USD 120,030,086	USD 61,392,175
Indirect	2,103	USD 10,426,637	USD 78,457,097	USD 45,116,824
Induced	4,181	USD 12,267,629	USD 100,086,460	USD 35,924,301
Total	12,222	USD 44,941,960	USD 298,573,644	USD 142,433,301
Operations and Maintenance Phase (Annual, Ongoing)				
	Jobs	Earnings	Output	GDP
Direct	54.9	USD 165,104	USD 746,395	USD 375,394
Indirect	15.3	USD 69,568	USD 482,351	USD 285,654
Induced	30.0	USD 88,108	USD 718,837	USD 258,014
Total	100.2	USD 322,781	USD 1,947,583	USD 919,062

Figure 21: Economic and job impacts, in USD, for a 100 MW Solar-PV power plant in Mexico, 2015 (author's own calculation, using the I-JEDI Excel version)

References:

[1]: Keyser, D.; Flores-Espino, F.; Uriarte, C. and Cox, S., 2016: User Guide for the International Jobs and Economic Development Impacts Model.

[2]: NREL, 2020: I-JEDI Video Tutorial, https://www.i-jedi.org/resources_training.html

Further reading:

The following study explains in detail how I-JEDI can help specify economic impacts from a wind power plant in Box Elder County, Utah, USA:

- Parker, J.; Hartman, C.L. and Stafford, E.R., 2013: An Analysis of state-level economic impacts form the development of wind power plants in Box Elder County, https://digitalcommons.usu.edu/manage_facpub/187/.

The COBENEFITS Study in South Africa used the I-JEDI model as part of its quantitative analysis for gross employment impacts:

- Okunlola, A.; Jacobs, D; Ntuli, N.; Fourie, R.; Borbonus, S.; Nagel, L and Helgenberger, S., 2019: Future skills and job creation through renewable energy in South Africa – Assessing the co-benefits of decarbonising the power sector, IASS Potsdam, CSIR and IET, https://www.cobenefits.info/resources/cobenefits-south-africa-jobs-skills/

6.2 Overview of Open-access Online Tools: The EIM-ES Tool

Learning objectives: Upon completion of this page, you should be able to

- employ the EIM-ES online tool
- state the potential advantages and limitations of the EIM-ES online tool

The Economic Impact Model for Electricity Supply (EIM-ES) is a freely available Excel-based tool, which measures domestic employment impacts for different technologies in the electricity sector. It also calculates other economic indicators, such as investment requirements, value added, and trade.

Up to 35 different technologies, and up to ten different scenarios, can be run simultaneously. The tool thus aids policy decision-making and planning, in terms of comparing different development pathways for electricity supply and their impact on a particular economy. Scenarios must be developed, e.g. through stakeholder processes.

Using I-O tables, the tool estimates direct, indirect and induced employment, based on investment across different sectors and salaries. Other input data comprise new capacity, generation, domestic share, future pathways for electricity supply, technology development, and fuel price development. Default data for the baseline scenario are currently available for Argentina and South Africa, with other countries currently under development.

Direct employment is calculated over time (by technology and sector), and it can be compared per MW, GWh and USD invested for each scenario. In addition, economic indicators, i.e. indirect and induced employment impacts, investment, value added, and direct domestic investment, can be compared across the scenarios.

In order to run the tool successfully, a minimum of intermediate Excel expertise is required. Cost estimates are linearly scaled, which neglects economies of scale, and I-O tables are often either not up to date or not available for all countries. Though learning curves and fuel price development can be adapted over time, they remain uncertain, which impairs the accuracy of scenario results.

Figure 22 shows the EIM-ES job estimates for South Africa, in four different scenarios.

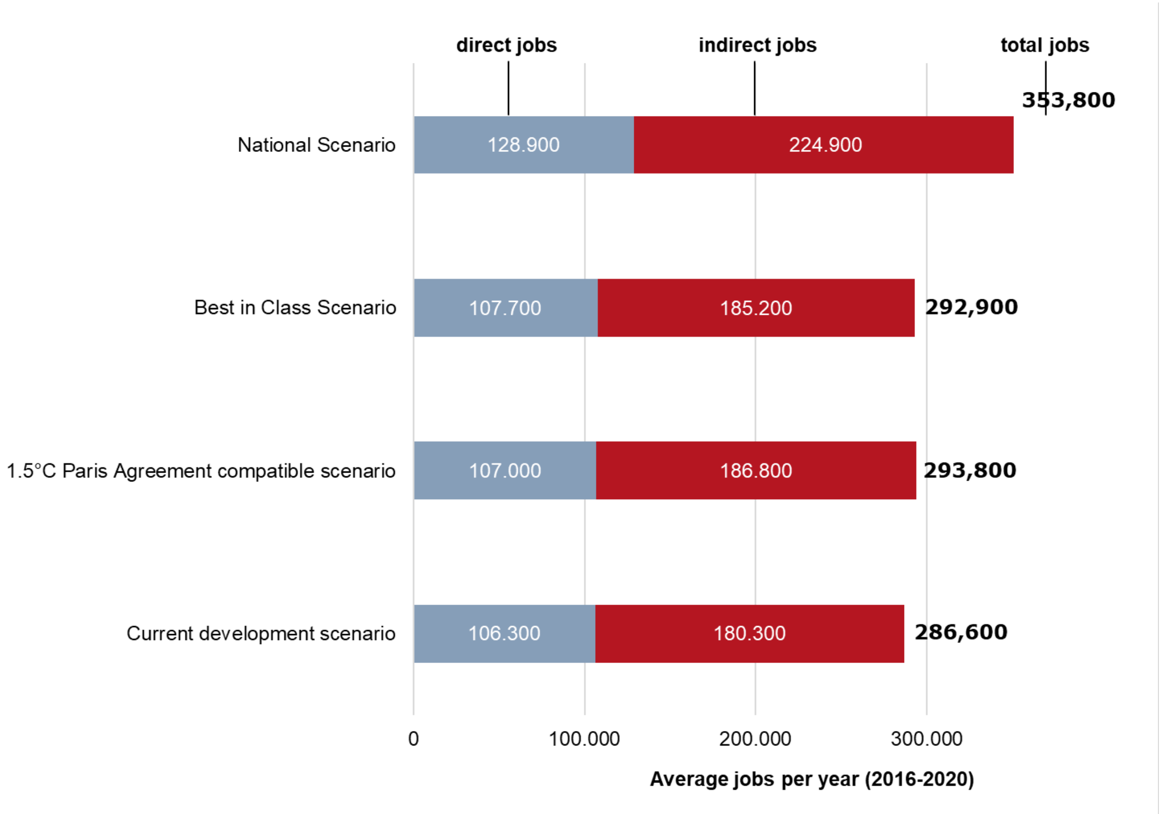


Figure 22: EIM-ES job estimates for South Africa, in different scenarios (New Climate Institute, Ecofys and Climate Analytic, 2018) [3]

References:

[1]: Fearnehough, H., 2019: Economic Impact Model for Electricity Supply EIM-ES – Userguide, https://newclimate.org/2018/11/30/eim-es-economic-impact-model-for-electricity-supply/.

[2]: Fearnehough, H., 2019: Economic Impact Model for Electricity Supply EIM-ES – Overview, https://newclimate.org/2018/11/30/eim-es-economic-impact-model-for-electricity-supply/.

[3]: New Climate Institute; Ecofys and Climate Analytics, 2018: Scaling up climate action – South Africa, https://climateactiontracker.org/publications/scalingupsouthafrica/.

Further reading:

In addition to South Africa, the EIM-ES model was applied in Argentina:

- New Climate Institute & Climate Analytics, 2019: Scaling up climate action – Argentina, https://climateactiontracker.org/publications/scaling-up-argentina/.

The methodology note on the EIM-ES tool comprises a comprehensive overview of the model, plus its input data, results, and limitations:

- Fearnehough, H., *Economic Impact Model for Electricity Supply – Methodology note*, https://newclimate.org/2018/11/30/eim-es-economic-impact-model-for-electricity-supply/.

6.3 Overview of Open-access Online Tools: ELMA

Learning objectives: Upon completion of this page, you should be able to

- illustrate a use case for the ELMA online tool
- summarise the potential advantages and limitations of the ELMA online tool

Employment and Labour Market Analysis (ELMA) is a tool developed by GIZ, which provides a comprehensive analysis of the labour market, the employment situation, and its underlying causes within a specific country. Its multi-dimensional and extensive approach aims to derive recommendations and thus promote increased employment. ELMA focuses on whole economies, and takes a medium-term (2-6 years) to long-term perspective (up to 10 years). Therefore, it is useful to a number of different stakeholders, including policy decision makers, sector experts, and the project managers of international partnerships. ELMA requires extensive training and resources, but the results are highly differentiated and produced in a collaborative way between stakeholders.

ELMA focuses on three dimensions of the labour market: labour supply, labour demand, and their interdependencies. The dimensions are examined via a five-stage approach, which answers the following key questions:

A. What is the basic national potential for employment?
B. What prevents firms from demanding more labour?
C. What prevents the labour force from offering (in sufficient quantities) the necessary skills?
D. How do labour market institutions, regulations, and policies impact the matching process?
E. What are the main challenges to employment creation?
F. What might be the consequences of national reform efforts and national development cooperation programmes which support employment promotion?

In general, ELMA follows a qualitative approach, but it should be based on the quantitative analysis of past and future trends, using studies, reports and research papers. Figure 23 shows a sample process for implementing ELMA. Given its complexity, GIZ should be contacted for support if the use of ELMA is being considered.

Organising **in-country meetings with main stakeholders** (e.g. representatives from partner institutions as well as implementing agencies including development cooperation programme managers) **to agree on the objective, scope, and mode of implementation of ELMA** (including assessing time and resource requirements and financing issues)

↓

Establishing a core analytical team, preferably including national researchers and/or experts with high-level knowledge of the country's context, steering committee, and principles for coordination and communication

↓

Conducting ELMA based on a combination **of desk study and field interviews**

↓

Involve all stakeholders in a conference/workshop to validate the results

↓

Organise follow-up, by initiating further research/discussions on: adopting the recommendations; using the ELMA insights to facilitate the design of employment and labour market policies by partner institutions; guiding the support of implementing agencies and development cooperation project planning, etc.

Figure 23: Recommended process for implementing ELMA (GIZ, 2014) [1]

References:

[1]: GIZ, 2014: Guidelines for an Employment and Labour Market Analysis (ELMA)

[2]: Meyer, K., 2015: Employment and Labour Market Analysis (ELMA), SE4Jobs Training Workshop, Cairo

Further reading:

The User Guidelines provide step-by-step instructions for conducting an ELMA:

- *Guidelines for an Employment and Labour Market Analysis (ELMA)* (2014), accessible at: https://www.academia.edu/6830811/Guidelines_for_an_Employment_and_Labour_Market_Analysis_ELMA_

These studies document ELMA conducted in the Lebanon and Ethiopia in detail:

- Knobloch C.; Kirschner, Th. and Osman, Z., 2019: Employment and Labour Market Analysis Lebanon, https://data2.unhcr.org/en/documents/details/43215.
- GIZ, 2019: Employment and Labour Market Analysis (ELMA) in Ethiopia, http://moshe.gov.et/files/1585239428568.pdf.

7 Summary

The course has demonstrated the significance of employment impacts as a co-benefit of renewable energy, and introduced methodologies for calculating such impacts. An overview of different renewable energy employment categories in the first part of the course has shown the importance of being precise and distinguishing between analytical levels when calculating employment impacts. Direct, indirect, and induced employment effects account for job gains or losses arising directly from a renewable energy activity, indirectly in related input sectors, or as induced jobs in sectors not directly related to renewable energies. It has also been demonstrated that it is important to differentiate between gross effects (all positive effects) and net effects (deducting all negative effects from gross effects).

An overview of various approaches to quantifying employment impacts has exemplified use cases for different methodologies that assess the employment effects of renewable energy, specifically (see Figure 24, below). It can be seen that employment factor analysis is a simple approach, which allows us to estimate the creation of direct jobs as gross employment effects. Gross input-output (IO) models can be used to understand the links between economic sectors and to estimate the direct and indirect economic effects resulting from changes in demand. Lastly, the course illustrated how comprehensive (and far more complex) full economic modelling methodologies, such as the Computable General Equilibrium (CGE) model, can be useful for conducting net effect analyses of an economy as a whole.

Employment	Direct Effects	Indirect Effects	Induced Effects
Gross effects	Employment factor analysis Gross IO Models	Gross IO Models	
Net effects	Full Economic Modelling / CGE Model	Full Economic Modelling / CGE Model	Full Economic Modelling / CGE Model

Figure 24: Use cases for methodologies to calculate gross and net employment effects (author's own depiction, based on Meyer & Sommer, 2014) [1]

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