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Methodological guidelines for estimating the employment impacts of using renewable energies for electricity generation

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About IEA-RETD

The International Energy Agency's Implementing Agreement on Renewable Energy Technology Deployment (IEA-RETD) is one of the key outcomes of the International Conference for Renewable Energies in Germany in June 2004. The member countries of the RETD want to encourage the international deployment of renewable energy sources through improved policies. While the other IEA's implementing agreements on renewable energy focus on specific technologies, the IEA-RETD intends to complement these by taking a technology cross-cutting and policy-focused approach.

About the consortium

The **Fraunhofer Institute for Systems and Innovation Research (ISI)** in Karlsruhe, Germany, is part of the Fraunhofer Society for Applied Research in Germany, a non-profit corporation, which promotes applied research and assures the link between fundamental and industrial research. The Fraunhofer ISI, the Project leader, complements the scientific and technological spectrum of the Fraunhofer Institutes through interdisciplinary research on the interdependence between technology, economy and society. The main fields of research of its Competence Center Energy Technology and Energy Policy are energy efficiency, renewable energy sources, energy economics analyses and energy and climate policy.

Rütter + Partner is a private and independent research and consulting firm based in Rüschlikon, Switzerland. Its activities are focused on socio-economic research and consulting for government agencies, private enterprises and public institutions.

The **Energy Economics Group (EEG)** is part of the Institute of Power Systems and Energy Economics at Vienna University of Technology, Austria. EEG has managed and carried out many international as well as national research projects funded by the European Commission, national governments, public and private clients in several fields of research, especially focusing on renewable and new energy systems.

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Abbreviations

AGC: additional generation cost (direct, indirect)

BS: biomass supply

CE: conventional energy (based on nuclear and fossil energy sources)

CET: conventional energy technology

CT: conventional energy generating technology

EF: employment factor

FIT: feed-in tariffs

FLH: full-load hour

FTE: full-time equivalent

GWh: giga-watt-hour

IO: input output

IOT: input-output table

kWh: kilo-watt-hour

MCI: manufacturing, construction, installation

MO: merit order

MWh: mega watt hour

MWp: mega watt peak

O&M: operation and maintenance

R&D: research and development

RE: renewable energy

RET: renewable energy technology

TGC: tradable green certificate

WPP: wind power plant

#: number

1 Introduction and objectives of the guidelines

Promoting the use of renewable energy (RE) is universally recognised as an important part of energy policy. The impact of increased renewable energy technology (RET) deployment on employment is a central issue of public interest that has been analysed in a large number of studies. These studies are conducted using a large variety of methodological approaches to answer inconsistent and inhomogeneous questions which makes it difficult to discuss and compare the results.[1] Given this situation, the **IEA-RETD has commissioned a project to develop methodological guidelines for assessing the employment impacts of using RE, focusing on electricity generation from renewable energy sources.**

In the first phase of the project the existing impact assessment studies were studied (Breitschopf et al. 2011) and the results reported at http://iea-retd.org/archives/ongoing/employ. Since the impact assessment studies address different questions, it was concluded that the guidelines should distinguish between two principal types of employment assessment studies: “gross” (sectoral jobs) and “net” (economy wide) employment impact studies. For each type of study, two methodological approaches are proposed: employment factor and gross input-output approach for gross employment impacts; net input-output approach and full economic model for net employment impacts.

The purpose of these guidelines is to present a framework for assessing the employment impacts of RET deployment in a structured and coherent way to design, implement and evaluate various (energy) policies. The guidelines, presented in this report, aim at **two target groups**, decision makers and analysts assessing employment effects (see Figure 1-1). The objectives of the guidelines are:

a) to help policy makers understand which type of employment they are looking at (Chapter 2) and advise them in choosing the most appropriate methodological approach, given their interest (research question) as well as budget and data restrictions (Chapter 3).

b) to help analysts understand the crucial aspects or economic mechanisms of the approaches in order to answer the respective policy question (Chapter 2) and provide them with step-by-step guidance to calculate employment impacts (Chapter 4 and 5).

The structure of the guidelines is as follows: Chapters 2 and 3 are written specially for policy-makers. The chapters provide insights into the type of policy questions which can be addressed (Chapter 2), and guide the policy makers in choosing a suitable approach to calculate the employment impacts, depending on the specific policy questions which need to be answered and the available budget (Chapter 3).

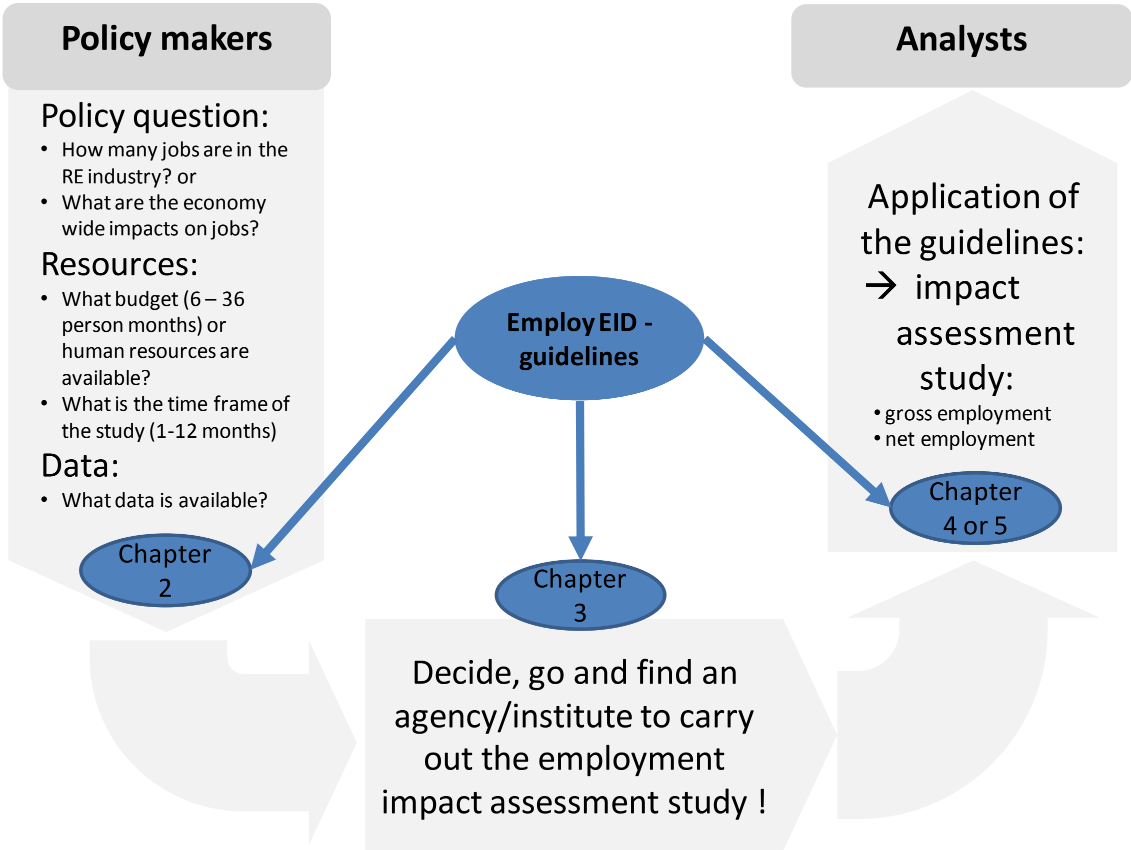
1 For example: Lehr et al. 2011, Haas et al. 2006, Wei et al. 2010, Rutovitz 2009, etc. see References.

Next, the step-by-step guidelines are presented for the gross (Chapter 4) and net (Chapter 5) employment assessment approaches. This part is written for the agencies or institutes assigned to calculate the employment impacts.

Background information and definitions of the terms used are given in Annex 1.

The guidelines for the gross impact studies have been tested by the research team for the RETD member countries and Tunisia. Annex 2 gives an overview of the testing phase of the guidelines. This Annex serves as a practical example of the guidelines for gross impacts outlined in Chapter 4, and can be used by agencies or institutes.

Figure 1-1: Using the guidelines?



2 What are the guidelines about? Summary for policy makers

2.1 Impacts of RET deployment – overview for readers in a hurry

What is the impact of RET deployment on employment? – A crucial question for policy makers when deciding on RET deployment targets and promotion policies. The following Table 2-1 provides an overview of the two main groups of assessment studies.

Table 2-1: Overview: the two main types of impact assessment studies

1. What is the **relevance** of the **RE industry** (and its upstream industries) measured in sectoral employment? → This type of assessment is called a **gross employment impact study** and provides figures about **jobs** in all RE-related industries. This is a partial impact analysis – restricted to the RE industry (and its upstream industries). To answer questions about the impacts on employment in the **RE industry** (gross employment), only the (positive) effects of RET deployment in the RE industry are considered. Two methodological approaches are recommended: • The **Employment Factor** approach (EF): This approach quantifies the number of jobs in the RE industry that are **directly** involved in manufacturing, construction and installation (MCI) of RE technologies or RE-related services. • The **gross Input-Output** model (gross IO): This approach allows the number of jobs in the RE industry AND its upstream industries that are **directly and indirectly** involved in MCI of RE technologies, RE-related services or materials, etc., to be assessed.
2. What is the **impact on economy-wide** employment (in all economic sectors)? → This type of assessment is called a **net employment impact study** and provides figures about **changes in employment** throughout the entire economy, i.e. in all industries and service sectors. To answer questions about the impacts on **economy-wide employment** (net employment), **positive** and **negative, direct, indirect and induced effects** of RET deployment on employment are considered. These include impulses from (avoided) investments, from (avoided) operation and maintenance and other RE-related activities along the value added chain (R&D for RE, manufacturing, etc.) and also allows for changes in electricity prices and income. Two approaches are recommended:[2] • The **net Input-Output** model: This is a static model in which industries' interactions are based on fixed coefficients. It is primarily used for assessing employment changes in the present or for very simple assessments of future impacts. • The **full economic model**: This is a dynamic model with several feedback loops and multipliers. It is complex and knowledge-intensive but very comprehensive, handling all the positive and negative potential effects of RET deployment. It is mainly used for the assessment of future employment impacts.

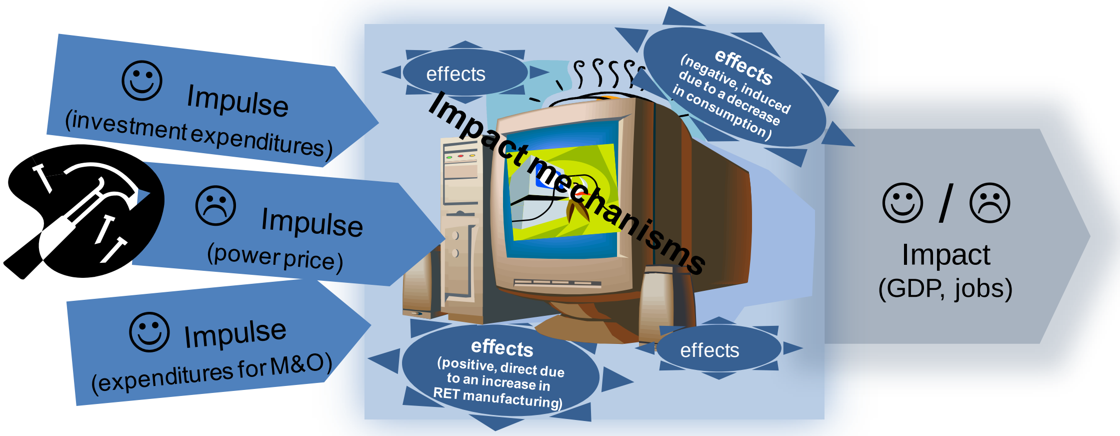
2 See Review of impact assessment approaches in Breitschopf et al. 2011.

2.2 More details - questions addressed by impact assessment studies, included effects and approaches

2.2.1 From economic activities to employment impacts

To assess impacts on employment, the economic impulses that trigger the impacts must be identified. Therefore, the life cycle e.g. of a wind power plant is subdivided into different life cycle phases. The life cycle phases can be interpreted as economic activities that provide impulses in form of expenditures that trigger diverse economic effects. Further impulses like changes in power prices could be induced by policies. The relationship between impulses, effects and impacts is depicted in Figure 2-1 in a simplified way.

Figure 2-1: Relationship between impulses, effects and impact mechanisms and impact on employment (simplified)



Impulses (e.g. expenditures for operation and maintenance, manufacturing and construction of RET) are regarded as exogenously determined parameters that spark an economic mechanism that leads to several effects. Effects (e.g. a direct positive effect could be an increase in manufacturing RE; a negative induced effect could be a decrease in consumption of goods) refer to how impulses affect the economy – positively, negatively, directly, indirectly or induced. They add up to economic impacts, which are the final results or outcomes (endogenous variable) measured here as the number of jobs or changes in employment. The most important impulses are:

- the impulses from investment and operation expenditures in RE use, fuel supply and exports of RE equipment, including impacts in upstream industries (positive direct and indirect effects),
- the impulse from displaced investment and operating expenditures in non-RE use and exports, including impacts in upstream industries (negative direct and indirect effects),

- the impulse from household income[3] due to employment changes in the RE and/or conventional energy (CE) industry (induced effect of type 1), and
- the impulse due to changes in energy prices[4] affecting consumption expenditures in households and cost structures in industries (induced effect of type 2).

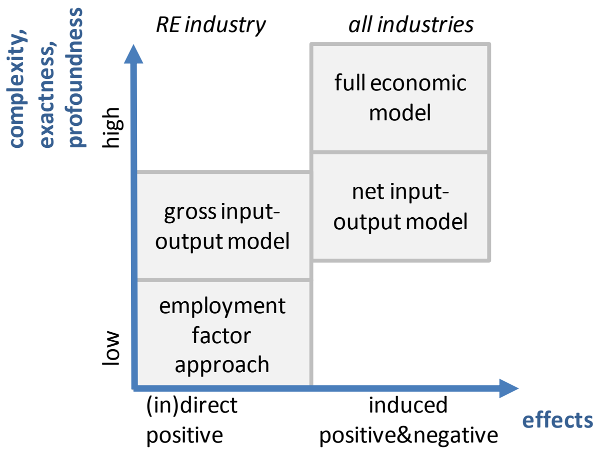
2.2.2 Questions addressed by impact assessment studies

This section introduces two principal types of impact assessment studies addressing two different questions. The two types of study may seem to be complementary regarding the specific contribution to employment in the national economic system, but they are not: A gross employment study assesses the number of jobs in the RE industry (or rather the relevance of the industry), whereas a net employment impact assessment analyses employment changes in the entire economy (economy-wide) due to RET deployment. The principal policy questions that can be answered by the respective impact study are:

1. **What is the impact of RET deployment on jobs in the RE industry – impact on gross employment or sectoral (RE industry) employment?** Positive directs and indirect effects are considered.
2. **What is the impact of RET deployment on economy-wide jobs – impact on net employment?** Positive, negative, in/direct and induced effects are included in this analysis.

A total of four methodological approaches, two for each of the two types of questions are proposed in these guidelines: the gross approach for RE industry employment, the net approach for economy-wide employment impacts. The approaches do not necessarily have a common conceptual framework like mathematical models or scenarios. The key features (axes) of the approaches are illustrated in Figure 2-2.

Figure 2-2: Overview of the proposed approaches



3 Measured at constant prices.

4 Measured at constant prices.

2.2.3 Characteristics of gross (sectoral) employment approaches

Gross employment approaches or gross impact assessment studies assess employment in industries that are related to the use of RE. Direct employment in the RE industry as well as indirect employment in upstream industries is considered. The relevance (with respect to employment) of the **RE industry (and its upstream industry) within the economy** of a country is highlighted. It can also be applied as a tool for a structural analysis of the RE industry e.g. highlighting the importance of the different technologies (solar, wind, etc.), or the relevance of domestic RE use versus exports as drivers of the RE industry's level of employment. This approach allows specific strengths and weaknesses of the RE industry to be assessed and suitable policy support options to be suggested. Apart from the current RET deployment status, the development of the RE industry as a consequence of continued and increased RET deployment can be monitored or forecast with the help of scenarios. Chapter 4 describes in detail how to calculate present impacts.

Sectoral jobs in the RE industry or gross employment can be calculated using one of the following two approaches (see Table 2-2):

- **Employment Factor (EF) approach**: Methodologically, this is the simplest approach. It combines data on installed capacities and power generation for each RE technology with employment factors that reflect only **direct employment** in the RE industry. Indirect employment in upstream industries is generally not included in this approach. The employment factor approach requires the following data:

  - physical data on installed capacities and electricity output by RE technology, and
  - employment factors relating the number of jobs to the physical data (e.g. labour input per installed capacities or generation).

  Physical capacity and output data are usually available, so the accuracy of the results depends on the accuracy of the employment factors used. If reliable data on employment factors are not available, resource requirements (e.g. interviews, statistical data) to derive these employment factors can be large. Furthermore, taking exports into consideration requires additional information. This approach is not suitable for calculating indirect impacts (i.e. jobs in upstream industries) but it could provide detailed information on the type of jobs (e.g. in PV manufacturing, PV service sector, etc.).

- **Gross Input-Output (IO) model**: This approach combines data on expenditures for domestic RE use and RE-related exports with input-output modelling to calculate the **direct employment** effects in the RE industry **and indirect employment** effects in the respective upstream industries. This approach relies on the input-output table of a country that captures the economic interdependencies between industries. IO modelling know-how is required for this approach.
  Gross input-output modelling combines techno-economic data with input-output modelling. Knowledge of input-output modelling is a prerequisite to using this approach. The following data are needed:

- physical data on installed capacities and electricity output by RE technology,
- specific installation, O&M (operation and maintenance) and biomass fuel costs for each technology, and
- an input-output model supplemented by employment data for the respective country.

The expenditures for investments in and operation of RE facilities are calculated using the first two datasets. Direct employment in the RE industry and indirect employment in the respective upstream industries (of RE industry) are determined using the IO model. As in the first approach, exports have to be determined separately.

Table 2-2: Comparison of the two approaches

Characteristics	Employment factor approach	Gross IO modelling
Effects included	Positive effects	Positive effects
Direct (RE equipment, components, services...)	Yes	Yes
Indirect effects (RE up-stream industries)	No	Yes
Exports	With additional sources, since data in physical units (jobs per export unit) are usually not avail-able	With additional sources
Imports	Import shares	Import shares
Specificity and accuracy of results	Depending on quality of employ-ment factors: low to high	Medium
Resource requirements	Depending on availability of ap-propriate employment factors: low to high	Medium
Data and model require-ments	RE capacity and generation data; technology-specific employment factors	RE capacity and generation data; technology-specific costs and cost structures; input-output model
Coherence with economic impacts (e.g. value added)	No	Yes

2.2.4 Characteristics of net employment approaches

Economy-wide employment impact studies aim to answer the question whether the (increased) deployment of RET through support policy measures will have net employment effects. The term “net” is used because both positive and negative effects (e.g. job losses) of RET deploy-ment are incorporated. Furthermore, the net employment approach assesses the economic impact of RET deployment on **all economic sectors** by including all effects of RE use i.e. ef-fects in the RE industry (direct effects), RE upstream industries (indirect effects) as well as ef-fects in other industries and consumption sectors (induced effects). In order to assess present and future net effects, two scenarios have to be developed: a baseline scenario that depicts the hypothetical energy supply structures, demand, prices etc. without RE support policies and an accelerated RET deployment scenario with strong RE policy support. The methodological challenges associated with developing scenarios are obvious and are discussed in Breitschopf et al 2011. The final results show the difference in the employment status between two economic situations – a low or zero RET deployment scenario compared to an advanced or accelerated RET deployment scenario. Hence, the “impact” is expressed as changes in employment compared to a baseline situation.

Two approaches are proposed for **economy-wide job impacts - net employment impact assessment**[5]:

- **Net Input-Output (IO) model**: The net IO approach captures some of the relevant impact mechanisms triggered by RE promotion policies. Data requirements include expenditures for RE use and displaced expenditures for non-RE use disaggregated by industry, as well as the impact of electricity prices on households and industries. The method combines two types of IO models to capture demand and price impacts. Net IO modelling entails some simplification of the economic reality, so data and modelling requirements are lower compared to the full economic model approach, but higher compared to the gross IO modelling approach. The focus here is on the net employment impacts of present RET deployment.

- **Full economic model**: Scientifically, the full economic model is the most comprehensive approach to capture all the present and future employment effects in all sectors and industries. In addition to the net IO approach, feedback loops, multiplier and accelerator effects are included and dependencies are modelled. Properly applied, this approach has a high potential to provide very comprehensive and exact data on employment impacts of RET deployment on the overall economy. This kind of model requires very specific knowledge, a large budget or financial resources and a large quantity of high-quality data. Several types of economic model can be used, including econometric models, applied general equilibrium models and system dynamics models. No step-by-step guidelines can be elaborated for this approach because the modelling steps and calculation methods vary strongly from model to model. However, the main features and inputs are briefly outlined in this report.

The two net impact approaches differ in several ways (Table 2-3). The main differences are in the time focus, model interactions or complexity. While the net IO modelling approach is more suited to analysing effects in the present (or the past or future for simple assessments), the full economic model focuses on prospective developments based on scenarios of future economic development and RET deployment. In addition, the full economic model captures the economic behaviour of all actors, like the reactions of households and industries to changes in prices and vice versa and depicts several interdependencies or feedback loops, while the IO model is based on fixed relations between industries without feedback loops. The net IO model only depicts the impacts of changes in production, consumption or prices on total output. However, both net models incorporate all relevant impact mechanisms of RET deployment, although their

5 See Review of employment impact assessment studies, Breitschopf et al. 2011.

depth and accuracy differs. For instance, the price effect in the net IO model is limited to a "one round" consumption impact. Table 2-3 shows the main features of each model and highlights the differences between them.

Table 2-3: Comparison of the two approaches

Characteristics	Net IO model	Full economic model
Profoundness and accuracy of results	Potentially medium – high. Depending on the level of detail of IO model and update status of IO coefficients	Potentially very high. Depending on the quality of the economic model, update status of IO coefficients and all other relevant data
Direct (RE industry) and indirect effects (RE upstream industry)	Yes	Yes
Induced effects (every sector of the economy)	Type 1 and 2, but limited to consumption (see Annex 1, A 1.3)	Type 1 and 2 Also: could take into account merit order effect, CO_2 prices, crowding-out of investments
Exports, imports	Yes – as a share of sector output or sectoral input	Yes – as share of sector output or input, trade module, etc.
Resource requirements (financial and human)	Medium - high	Very high
Data and model requirements	Medium RE capacity and generation data; technology-specific costs and cost structures; input-output model and coefficients	High RE capacity and generation data; technology-specific costs and cost structures; input-output coefficient, other economic, energy sector-specific and demographic data, macro model with trade module, energy sector module, etc.
Time horizon	Present(– future: simple assessment)	Future[6]
Scenario	Yes (limited baseline or counterfactual)	Yes (baseline)
Dynamic	Limited	Feedback loops, multiplier and accelerator, (endogenous) technical change.
Price and quantity changes	Limited Changes in prices or quantity are completely passed through to total output. Change is based on average coefficients	Yes Price or quantity changes are a result of output <u>and</u> price changes. Changes due to merit-order effect or CO_2 prices can be depicted
Economic relations	--> input-output relations between industry, final demand	--> input-output relations, national accounting, trade, job market, fis-

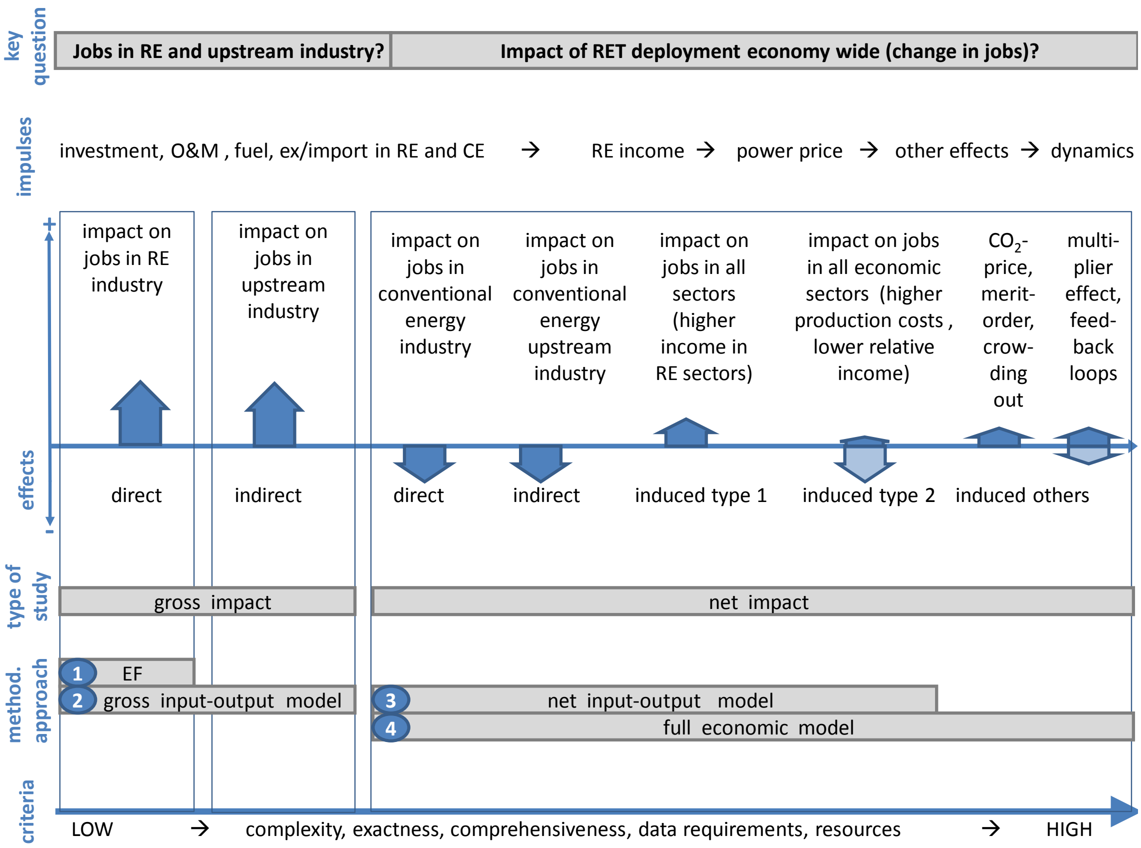
6 Pointless for impact assessments in the past.

Characteristics	Net IO model	Full economic model
	payment sector (linear - limitational)	cal, climate, energy sector, household consumption, policies, etc.

2.2.5 An overview of key questions and methodologies

For each type of impact assessment study, the policy questions, the respective economic impulses as well as the relevant effects or impact mechanisms together with the corresponding approaches are depicted in Figure 2-3 and in Annex 1 (A.1 and A.2).

Figure 2-3: The key questions and their implications for the inclusion of effects and the type of impact studies (net or gross)



Note: EF= employment factor approach

While indirect/direct effects refer to the RE industry and its upstream industries, induced effects are those which affect employment via prices or income and hence via consumption and production. As a result, a gross impact study relies on impulses that cause positive direct and indirect effects, while a net impact study also includes impulses that trigger direct/indirect positive and negative as well as induced effects.

Besides the direct, indirect and induced effects discussed here, other effects exist like environmental or health effects, merit-order effects (due to lower variable generation costs the order of generation plants being in production changes), crowding-out effects of investments outside the energy sector (due to increased RE investments less capital is available for other, non-RE investments), effects of CO_2 prices, etc., which are not explicitly taken into account in the step-by-step guidelines for the gross impact and net IO model approaches. In the step-by-step guidelines, the focus is on the economic effects – direct, indirect and induced effects – mentioned before.

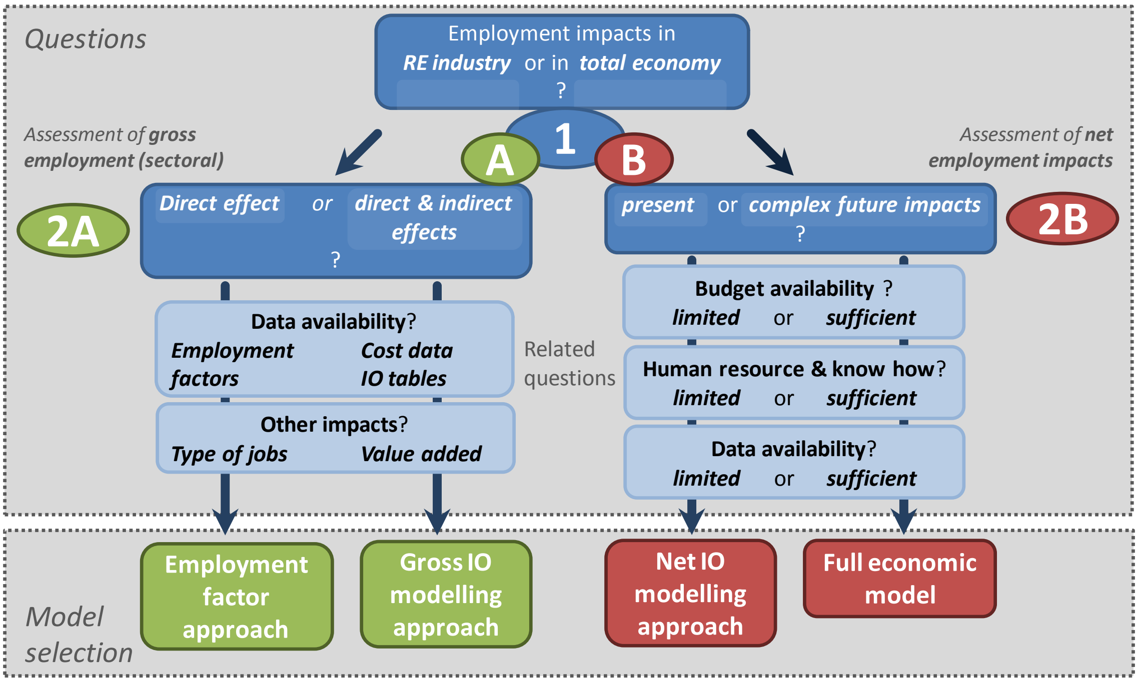
As a prerequisite for all kind of employment impact assessments, the system boundaries of the RE industry have to be clearly defined in order to conduct a transparent analysis (see Chapter 4 and also Annex 1, 6A.2).

Each approach also has its limitations and weaknesses. In general, one has to bear in mind that the outcome of impact assessment studies depends to a large extent on the assumptions made. The most important assumptions (export share, fossil fuel prices, technological change, supply of biomass), which significantly determine the outcome, together with the limitations of assessment studies are discussed in Annex 1, 6A.3.

3 Choosing an approach

This chapter has the objective to enable policy makers to choose the appropriate approach for assessing the employment impacts of RET deployment. Figure 3-1 illustrates the decision-making scheme, which consists of a set of key questions. Following the concept used in Figure 3-1, the key questions are then discussed in more detail.

Figure 3-1: Decision scheme – schematic illustration of key questions and related decisions



Source: own depiction

Central question: Assess employment in the *RE industry* or the *economy-wide* employment impacts of RET deployment?

The first and most crucial question is whether the aim is to assess the relevance and growth of employment in the RE industry alone, or whether the focus is on the net employment impact of RET deployment in the total economy?

--> If the focus is on the total number of jobs in the RE industry and its supplier industries, or on a structural analysis of the RE industry, then an RE sector employment study (gross impact study) should be conducted (follow A).

--> If the focus is on the impact of RET deployment on economy-wide employment, then a net employment impact study should be performed (follow B).

A

<u>*Follow-up questions (if assessing RE-sector jobs)*</u>

2A

Assess *direct employment* or *direct & indirect employment*?

The second question to be answered is whether the aim is to assess only the number of jobs in the RET industry (direct employment), or also in its upstream industries (indirect employment)?

--> If indirect (upstream industry) and direct employment (RET industry) is of interest, then the gross IO modelling approach is recommended.
--> If only direct employment in the RE industry is to be analysed, both approaches are feasible.

Related questions: Data availability and further impacts?

The choice of approach should take into account whether reliable employment factors are available for the relevant RE technologies in the respective country. The EF method can provide more detailed information about the types of jobs created (technology and activity specific). And, this approach will be more appropriate for countries that do not have up-to-date and detailed input-output tables (e.g. for some developing countries). If good employment factors are not available, it may be too costly to generate them.
The IO modelling approach is preferable if sound cost data are available or coherence with the calculation of other economic impacts is desired (e.g. with value added in the RE industry), since this approach is more comprehensive.

--> If recent data on employment factors are available, then the EF approach is recommended.

--> If recent IO tables and cost data are available, then the gross IO approach is recommended.

--> If recent data for both approaches are available, then decide which policy question is to be answered:
i) direct effects and type of jobs → EF approach,
ii) direct and indirect effects and other impacts (value added) → gross IO approach.

B *Follow-up questions (if assessing net employment impacts)*

2B **Focus on *present or future impacts*?**

Is it intended to assess present impacts, or future impacts? An assessment of present impacts can be done using the net IO model. For a comprehensive assessment of future impacts, the full economic model is the most appropriate approach. The depiction of future impacts with an IO model is limited due to the fixed relations between industries that are based on empirical (past and present) values. Further limits are the missing interactions between prices and quantities, fixed structures in consumption, trade, etc.

--> If present impacts are of interest, then the net IO approach is recommended.

*--> In general, if a comprehensive assessment of future impacts is of interest **and** there are no data or budget limits, then the full economic model is recommended.*

Related questions: Availability of budget, human resources and know-how as well as data

A net impact assessment requires know-how, human and financial resources, and high quality data to differing degrees.[7] All these aspects are decisive and mutually dependent, e.g. if there is only limited data but a large budget, resources could be spent on collecting further data via an industry survey, for example.

Since net IO modelling includes more simplifications than full economic modelling, the limited economic mechanisms of the net IO modelling approach should also be included in the decision.

--> In general, if data, budget or human resources are limited, then the net IO-approach is recommended.

7 For example: The Panta Rhei model has been used in Germany, which consists of more than 40,000 equations describing the inter-industry flows between 59 economic sectors. Another example is the Astra model, which has been applied to assess the impact of RET deployment on jobs and economic growth in the EU. This consists of nine modules (e.g. trade, infrastructure, population, etc.) with time series from 1990 onwards. These two full economic models are highly complex systems requiring large amounts of macroeconomic as well as energy sector-specific data. To build up such a model from the scratch and assess the impacts requires about 3 person years, while a gross IO approach requires about 6 person months.

4 Guidelines for gross impact studies

The two approaches proposed for the assessment of employment impacts in the RE industry are explained in detail in the following chapters. They are illustrated with an example of the wind industry. However, first the system boundaries of the RE industry are briefly depicted.

4.1 System boundaries of the RE industry

Studies analysing the employment impacts of RE use need to be based on transparent system boundaries of the RE industry. The following definition is proposed:

The RE industry includes all economic activities that are related to and are characteristic for or specific to RE use.

Whereas in economic statistics, enterprises producing similar goods are usually grouped into industries, the RE industry can be seen as a cross-cutting industry whose economic activities are closely related to the use of RE. The term “use of RE” ideally comprises the complete life cycle of RE facilities, which can be roughly split into the manufacturing, construction, the operation and the demolition phase.[8] The life cycle consists of various activities (see Annex 1, 6A.2 and Figure 4-1 for the example of a wind power plant (WPP)):

- project development and planning,
- site preparation,
- manufacturing the various components needed for the RE facility,
- construction and installation,
- operation and maintenance,
- replacement of parts after their defined lifetime is over,
- and finally demolition of the RE facility.

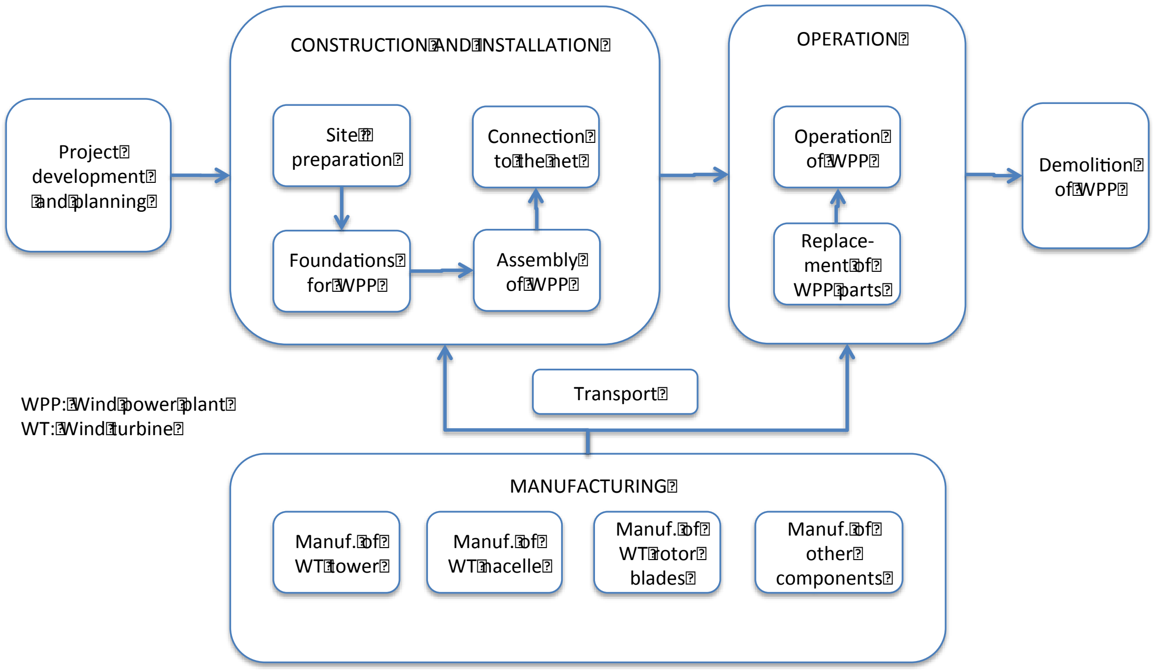
Recent developments have shown that the importance of power storage facilities is growing in line with RET deployment. Even though they do not belong to the core RE industry, RE-power storage facilities could be included as technologies connected to RE use if they are needed due to or used to better integrate the increased amount of intermittent, variable electricity generation from RE sources.

Each of these activities is supported by a supply chain of other activities which are more or less characteristic of RE use. Installation of a wind turbine, for example, requires a foundation, construction of the turbine, manufacturing of other components needed to operate the wind turbine, as well as connecting the wind turbine to the electricity grid. Before assembling the wind turbine on-site, the various components have to be manufactured and transported to the site, i.e. the

8 Here further phases like extraction of raw materials, disposal of waste products etc. are not explicitly mentioned but are subsumed as activities within manufacturing or demolition.

tower, the nacelle and the rotor blades. Each of these components is made of different sub-components which have to be manufactured. The further upstream we follow the supply chains, the less specific the components become with regard to RE technology (e.g. the steel used for wind turbine towers could also be used for other products). At some point it is necessary to draw a boundary between activities which are counted as part of RE (upstream) industry and activities belonging to the rest of the economy.

Figure 4-1: Example of life cycle and supply chains of constructing a wind turbine



Source: own depiction

The RE industry includes several types of enterprises which are involved in the life cycle of an RE technology, e.g.:

- developers and operators of RE plants,
- manufacturers of RE technology goods, not only of final products, but also of specific components or investment goods,
- service companies for engineering, planning or other technical services,
- construction and installation companies, and
- trading enterprises.

The guidelines focus on RE technologies for electricity generation. A list of technologies can be found in Annex 1, 6A.2. Some of the listed technologies can only partly be considered as belonging to RE use. These include, e.g. pumped storage power plants, biomass co-firing and municipal solid waste incineration. Therefore the economic impacts related to the construction and operation of these facilities should only partly be included, e.g. by multiplying the results by a “RE share”. The Annex contains some guidelines on how to handle these technologies when calculating the economic impacts.

4.2 Employment factor approach

4.2.1 General remarks

The employment factor approach can estimate the level of direct employment related to the construction and operation of RE facilities in a country. From a methodological perspective, it is relatively straightforward. The approach is good at giving detailed information on the types of job created, and enables relatively fast monitoring of RE-related employment in a country or rapid extrapolation for different energy scenarios. For example a study done by Rutovitz and Usher 2010 (p. 3) for Greenpeace International applies this approach for the current and future years: http://www.isf.uts.edu.au/publications/rutovitzusher2010jobsmethodology.pdf. However, this approach does not usually include indirect effects and should be focused on the present situation.

4.2.2 Methodological approach

Basically, with an employment factor approach, the job impacts of RET deployment and use are estimated by multiplying physical activity data by employment factors (e.g. employed persons or full time equivalents per MW or MWh). The employment factor relates employment to activity data. The approach is explained here for calculating jobs in a country and a certain reference year, but it can also be applied to any other regional level or time period.

The employment factors

The employment factor relates the level of employment needed to perform a certain activity to the output of that activity. The **denominator** of the employment factor is a physical activity parameter that depends on the life cycle phase of the technology and type of activity:

- For activities in the construction or demolition phase of RE facilities, the denominator is usually the additionally installed or demolished capacity (typically measured in MW).
- For activities in the operational phase of RE facilities, the total installed capacity is often used (in MW). Another choice could be the total electricity generation (MWh).
- For activities related to fuel supply, electricity generation (in MWh) is the usual choice.

For the **numerator** of the employment factor, the number of full-time equivalents (FTE) is preferable to the number of employed persons, since the former unit can be utilised to adequately incorporate employees with different workloads. Less common, but also possible, is the use of working hours. The unit of the numerator also depends on the kind of activity involved:

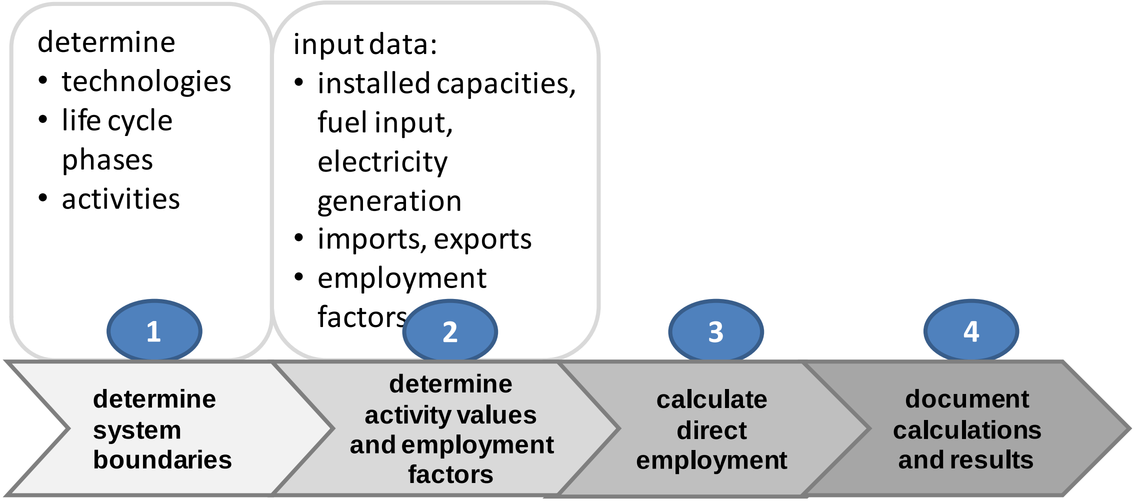
- Since activities in the construction or demolition phase are temporary, the numerator is measured with the unit FTE-years (e.g. 0.5 FTE-years per MW installed capacity).

- In contrast, activities in the operational phase are permanent during the operating lifetime of the RE facilities. Therefore, they are expressed as permanent FTEs (e.g. 5 FTE per MW installed capacity or per GWh power generation).

4.2.3 Calculation steps

The employment factor approach contains the following steps. Sources for generating the required data are described in the next chapter.

Figure 4-2: Calculation scheme for the EF approach



Determine system boundaries

1. Determine the system boundaries of the RE industry in the respective country (Chapter 4.1 and Annex 1, 6A.2):
    - Specify the technologies to be analysed: all technologies for generating electricity that are relevant for the specific country should be included.
    - Specify, for each technology, the life cycle phases and activities to be considered in the employment analysis. All relevant activities should be included. Activities for manufacturing goods where relevant shares are imported or exported should be considered separately. The level of disaggregation depends upon the relevance of activities and data availability.
    - Examples: the life cycle phases construction, operation and demolition may be relevant for wind power plants. These life cycle phases can be further broken down into activities that are relevant for employment in the respective country (see Figure 1-3 for an example of a wind power plant and the main activities involved).

2 Determine activity levels and employment factors

1. Determine for each technology and each activity and for each reference year the value of the **activity parameter**, to which the employment factor is related (e.g. for the activity “planning”, the additionally installed capacity, or, for the activity “operation”, the total capacity installed). For activities that span more than one year, the activity level should be divided by the duration of the activity (in years).
2. Determine the appropriate employment factor for each technology and each activity.
3. Determine the share of domestic output for each activity by adjusting for imports into the country and exports out of the country. The domestic share relates domestic output to the respective activity value. The domestic share is larger than 100% if exports exceed imports.
    - Regarding imports, determine the imported share for each activity, resp. the good or service that is supplied by the activity.
    - Regarding exports, determine either the level of products intended for export or the number of jobs directly linked to the export activity. It may for instance be easier to collect data about the number of jobs linked to manufacturing the exported wind turbine towers rather than obtain data on the installed capacity related to the exported towers. Export data can be extracted from national trade statistics for selected RE goods, although not in the physical units (MW, GWh) used in the employment factor approach.
    - An alternative is to directly determine the relation of domestic output to the value of the activity parameter for each activity. E.g. if the newly installed capacity of PV modules is 50 MW and domestic production of PV modules is 100 MW, the domestic output relation is 200%.
4. For each technology and each activity determine the domestic activity level by multiplying the activity value by the domestic share. Export-related employment can also be added directly in a later step. In this case, the domestic share does not include exports.

3 Calculate employment and display results

1. Calculate employment for each technology and each activity by multiplying the domestic activity level by the respective employment factor. Directly add export-related employment where necessary.
2. Aggregate the calculated employment figures to display results, e.g. by technology and by life cycle phase. Jobs in the construction phase are temporary and displayed in FTE years. Jobs in the operation phase are permanent for the lifetime of the RE facility and displayed in FTEs. For each reference year they can simply be added together to give total employment.
3. Document the chosen system boundaries, the calculation steps and the results.

4.2.4 Data requirements and data sources

Physical activity data

The necessary activity data depend on the RE technology. They may include for each reference year and RE technology:

- total installed capacity (by activity considered, e.g. in MW)
- net capacity increase (calculated as installed capacity in the reference year minus installed capacity in the previous year, e.g. in MW)
- capacity replacement (e.g. in MW); this may not always be identifiable from the existing statistics, but may require separate calculations and assumptions about replacement patterns
- electricity generation (e.g. in GWh), and
- biomass fuel input (e.g. in GWh).

Electricity generation data are usually available in the countries' official energy statistics. If these are not detailed enough, other sources should be consulted, e.g. industry associations. Where capacity data are not available, they can be calculated from electricity generation by assuming generic full load hours per year. Since the focus of the guidelines is on electricity generation, CHP plants should also be recorded with their installed electrical capacity.

Import- and export-related data

Import- and export-related data are needed for specific products generated by activities in the RE industry. Possible sources include trade statistics, data from industry associations, studies or expert estimations.

Only a fraction of RE-related products can be identified in the official trade statistics (e.g. hydropower turbines or wind turbines). RE products are often merged with other products even at the most detailed level of commodity classification (e.g. PV cells and modules are subsumed with certain semiconductor devices). Steenblik (2005) and (2006) gives an overview of products covered in foreign trade statistics. Furthermore, trade statistics usually record the weight and monetary value of traded goods, but not capacity- or energy-related units. It may therefore be difficult to merge trade statistics data with the physical data used in the employment factor approach.

For these reasons, it may be more useful to conduct interviews with exporting companies in order to convert export values into the required physical units, or to collect export-related job data directly from the exporting companies. The most important exporting companies will probably be known to the respective industry associations.

Employment factors

Technology-specific employment factors can be determined from various sources,

- from detailed labour requirement analyses of RE technologies (e.g. Singh et al. 2001), although these are rather scarce,
- from cost analyses of technologies, where labour costs are translated into the number of full-time equivalent jobs (e.g. Peterson/Poore, 2001),
- from surveys of RE companies, by relating employment to output in physical terms (MW, GWh), or from
- experts' estimations.

The employment factors should be technology-specific and valid for the considered country and reference period. They should be estimated separately for the various life cycle phases and activities. Ideally, the employment factors are available for every activity included in the RE industry system boundaries. Employment factors should be available at a level of detail that enables imports and exports of RE-related products to be taken into account. For instance, for the employment impact of PV systems, it is important to know which share of the PV modules installed is supplied by domestic companies, and which share is imported. Therefore the level of detail of the employment factors needs to reflect the import and export ratios in the RE industry.

Employment factors decline as technologies mature, so it is important to adjust factors over time. This is particularly relevant for energy scenarios which project over multiple years. Generally, specific information on the EF will not be available, so it is recommended to apply the decline in costs to the EF.

The following table gives an overview of the data needed for each RE technology per activity in the technology life cycle:

Table 4-1: Overview of data requirements

Data	Unit	Sources	Remarks
Capacity data: • Total installed capacity (year t and t-1) • Capacity replacement	e.g. MW	• Official statistics (IEA, national statistical offices) • Other RE-related sources	Per technology Adjusted by activity duration, if relevant
Energy output data: • Total output • Full load hours	e.g. GWh	• Official statistics, e.g. www5.statcan.gc.ca/cansim/a33?RT=TABLE&themeID=4012&spMode=tables&lang=eng (Canada) • Other RE-related sources	Per technology
Biomass input	e.g. GWh	• Official statistics • Other RE-related sources	Per technology
Export and import data:	Various units that need to be converted into MW / GWh	• Official trade statistics (e.g. UN Comtrade; Canada: www.ic.gc.ca/eic/site/tdo-dcd.nsf/eng/Home) • Steenblik 2005 and 2006: overview of products covered in foreign trade statistics • Technical literature, market intelligence , enterprise data	Per technology and RE product Official statistics cover only fractions of traded RE-related products Often RE products are merged with other products in one trade group
Employment factors	• FTE(-years) / MW • FTE(-years) / GWh	• Labour requirement analyses • Technology cost analyses • Enterprise surveys • Expert judgements	Per technology and activity Necessary to take import and export of RE products into account
Learning curve or cost declines	% per year	• Industry information	Per technology

4.2.5 Example: Employment factor approach

The employment factor approach is illustrated based on the example of onshore wind power plants in a country with significant exports in this technology. The capacity data, import and export shares are fictitious. Employment factors are not available at the required level of detail. Existing studies that use the employment factor approach only distinguish between the construction phase (including manufacturing of major components) and the operation phase. The employment factors listed in Wei et al. (2010) range between 2.6 and 11 job-years per MW for the construction phase and between 0.14 and 0.4 jobs per MW for the operation phase. Therefore, for this example employment factors have been estimated based on cost data and industry averages for output per employee used in the example for the gross IO modelling approach. The rough estimates are within the range in Wei et al. (2010) with 7.0 job-years per MW for the construction phase and 0.2 jobs per MW for the operation phase.

The following table contains the data needed for the calculation. The activities considered are listed in the first column. They make up a simplified version of the WWP life cycle excluding demolition, which is currently not relevant. The second column contains the activity parameters relevant for calculating employment and the third column displays the respective values. Net capacity increase is chosen for all activities of the construction phase. The replacement of existing capacities is neglected, because this is of minor relevance in the current growth phase of wind power plants. For operation of WPP, total installed capacity is chosen as the activity parameter. The domestic shares related to the activities are listed in the fourth column. The fifth column contains the employment factors.

Table 4-2: Overview of required data

			Domestic share (incl. net exports)	Employment factor	
Activities	**Activity level parameter**	**Activity value**		**Value**	**Unit**
	€ m	€ m			€ m
Project development and planning	Net capacity increase	1,500 MW	100%	0.8	(FTE * a) / MW
Manufacture of WT towers	Net capacity increase	1,500 MW	80%	1.2	(FTE * a) / MW
Manufacture of WT nacelles	Net capacity increase	1,500 MW	110%	1.3	(FTE * a) / MW
Manufacture of WT rotor blades	Net capacity increase	1,500 MW	180%	0.7	(FTE * a) / MW
Construction and installation of WPP	Net capacity increase	1,500 MW	100%	3.0	(FTE * a) / MW
Operation of WPP	Total installed capacity	10,000 MW	100%	0.2	FTE / MW

By multiplying the activity values by the domestic output shares and the employment factors and adding up the results, a total of 14,765 FTEs related to wind power use is obtained. Of this total, 12,765 FTE are required in WPP construction and 2,000 FTE in WPP operation.

4.2.6 Discussion of the employment factor approach

Advantages

The employment factor approach potentially has the advantage of being detailed, technology-specific and accurate. The employment factors can be based on data from actual RE facilities or feasibility studies, or from enterprises in the RE industry. Technical studies to derive the employment factors may be resource-consuming. Once the employment factors have been determined, using the approach is straightforward. Furthermore, the personnel and financial resources needed for such an assessment are relatively low, if suitable employment factors are available. Monitoring the RE industry or extrapolating results are easy to accomplish.

Limitations

Unfortunately, there are only a few basic data sources that are used to derive job factors, and the job factors for the same technologies vary greatly between the sources. In many cases, the employment factors are poorly documented, so that definitions or the system boundaries of technologies are not always transparent. Improved documentation would also make it easier to apply employment factors to other reference years or countries.

Other limitations include the following:

- The level of RE technology exports (measured as installed capacity) has to be covered using other sources, e.g. market intelligence, company surveys or expert estimations.
- It is difficult to capture activities by suppliers (e.g. manufacturers of generators or gears for WPP) or equipment manufacturers (e.g. manufacturers of items not directly involved in RET deployment), because it is difficult to capture their economic output in physical units (MW, GWh) and because employment factors are generally not available.
- Indirect and induced impacts cannot be covered using this approach, but results from the gross IO modelling approach could be transferred.

4.3 Gross input-output (IO) modelling approach

4.3.1 General remarks

Gross IO modelling is widely used to estimate the economic and employment impacts of RE use. It allows gross employment in the RE industry to be estimated within a consistent framework, which also enables economic impacts to be calculated with the same methodological approach (e.g. gross value added as a contribution to GDP). This is the only gross employment assessment approach which can take indirect impacts into account. It is proposed not to include induced effects in gross employment studies. These represent the employment triggered by consumption expenditures of persons employed in the RE industry and in supplying industries. The gross IO approach differs greatly from the EF approach regarding its methodology.

The following guidelines assume that readers are familiar with IO modelling and the standards of national accounting, since this knowledge is a precondition for applying this approach. Some additional information on IO tables and models is provided in Annex 1, 6A.3. So far, studies that have applied the gross IO approach are: EmployRES: http://ec.europa.eu/energy/renewables/studies/renewables_en.htm the MULTIREG model for gross effects; RE employ!, an IO-approach for gross effects: http://www.erneuerbare-energien.de/english/renewable_energy/data_service/graphics/ doc/39831.php.

4.3.2 Methodological approach

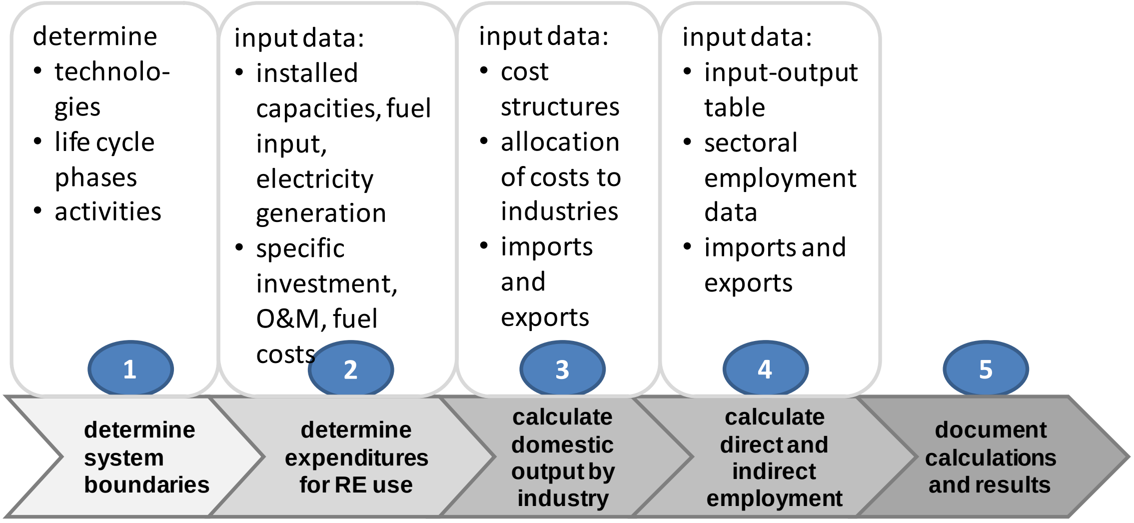
Gross IO modelling combines technical-economic data on RE technologies with input-output modelling. The expenditures for capacity expansion, the replacement and operation of RE facilities and the related cost components are major inputs that are derived from technical-economic analysis. IO modelling is used to determine the level of employment directly engaged in the related economic activities and indirectly in the supplying industries. A major assumption of this approach is that the industries included in the IO model are adequate proxies for the companies of the RE industry with regard to input structures or employment per unit of output. The impact of this assumption can be reduced by including additional, technology-specific information in the IO model, e.g. by incorporating new RE-related industries.

The approach includes the following main steps,

- determining system boundaries,
- determining expenditures for RE use,
- calculating domestic output by RE technology and industry, and
- calculating direct and indirect employment.

In the following paragraphs, these steps are explained in more detail. Note that the calculations can be done at various levels of detail. Simplifications and further differentiation are both possible. Underlying the level of detail proposed in the following is the idea that calculations should be as detailed as possible and aggregated when displaying the final results. It should be possible to distinguish impacts by technology and by life cycle phase (e.g. installation, operation, demolition) and to distinguish between impacts from installing and operating domestic RE facilities and impacts from exports of RE related goods.

Figure 4-3: Calculation scheme for the gross IO model approach



4.3.3 Calculation steps

1

Determine system boundaries

1. Determine the **system boundaries** of the RE industry in the respective country (Chapter 4.1 and Annex 1, 6A.2):

   - Specify the <u>technologies</u> to be analysed: all the relevant technologies for generating electricity that are significant in the specific country should be included.
   - Specify for each technology the life <u>cycle phases and activities</u> to be considered in the employment analysis. All relevant activities should be included. Activities should be considered separately for those manufacturing goods of which significant shares are imported or exported. The level of disaggregation depends upon the degree of relevance and data availability.
   - <u>Example</u>: For wind power plants, the life cycle phases of construction, operation and demolition may be relevant. These life cycle phases can be further broken down into activities which are relevant for employment in the respective country (see Figure 1-3 for an example of a wind power plant and the main activities involved).

2

Determine expenditures for RE use

1. **Collect the physical data** necessary to calculate the investment costs, O&M costs and demolition costs for RE use for each technology in the reference year.

   - The <u>new capacity installed</u> in the reference year is needed to calculate the investment costs. This can be calculated as the sum of_net capacity increase (i.e. the difference between total installed capacity in the reference year minus total installed capacity in the previous year) and capacity replacement. Capacity replacement has to be estimated based on the total installed capacity and the average lifetime of the technology involved. For activities that span more than one year, the activity value should be divided by the duration of the activity (in years).

- The total installed capacity and electricity generation in the reference year are needed to calculate the operating costs (including costs of biomass supply).

2. For each technology, **collect specific installation costs, O&M costs and costs of biomass** supply. Specific installation costs usually refer to the new capacity installed (e.g. euro per unit of MW installed). Specific O&M costs have a fixed cost component that depends on the total capacity installed and may have a variable component that depends on electricity output. Costs of biomass supply can usually be related to biomass input or electricity output.
3. **Calculate the expenditures** for installation, O&M and demolition for each technology: multiply the physical data by the respective specific costs (unit costs).

3 Calculate domestic output by RE technology and industry

1. **Distribute the expenditures to cost components** (e.g. planning, the PV module, the inverter and the rest of the system in the case of PV technology) which can be related to certain economic activities. Thus data on cost components are needed for each technology and each life cycle phase (see data requirements below). If no specific information is available, use cost structure of similar industries, e.g. from the input-output table.
2. **Determine**, at the cost component level, the **import shares** which indicate the share of goods or services supplied from outside the country or region being considered. Subtract imports from expenditures to obtain domestic output for each economic activity related to a cost component.
3. **Allocate the domestic output** for each economic activity to the appropriate industry as represented in the input-output model. Since the industries of the IO model are much more aggregated than the activities related to the cost components, it is important to choose the industry which typifies the activity. Compile a vector of domestic output by industry for each life cycle phase of each technology. Put all the vectors into a matrix of direct domestic output (for domestic RE use) by industry.

   The allocation of expenditures to supplying industries can be seen as representing the interface between the technical-economic data and the IO model. Expenditures need to be transformed into the output values used in the IO model. This may require some calculation, e.g. from expenditures in purchasers' prices to output in basic prices, according to national accounting concepts. Some of these issues are mentioned in Annex 1, 6A.3.
4. **Determine the exports of RE-related products**. These can only be partially identified in the trade statistics (e.g. wind turbines, hydro turbines, energy wood), because, in most cases, the commodity classification of trade statistics is not detailed enough to capture

RE products (e.g. PV cells or modules are grouped together with other similar products). Therefore, it is necessary to base RE exports on other sources, e.g. a survey of enterprises, or data and estimates from industry associations or experts. Allocate the exported goods to industries as represented in the input-output model.

5. **Add the matrix of exports** by industry to the matrix of domestic output for domestic RE use. The resulting matrix should have the structure of the following table. Direct operation of RE facilities is aggregated into one “industry” for technical reasons. In principle, the level of differentiation of the matrix columns can be freely chosen and thus adapted to data availability. So, e.g. for domestic RE use, activities could be further differentiated into the technology life cycle phases. On the other hand, comprehensive data on exports may not be available beyond the technology level.

Table 4-3: Example of a matrix of domestic output by technology life cycle phase and by industry

	Domestic RE use					**Exports**		
	Wind power plants		. . .	**Waste incineration**		**Wind power plants**	. . .	**Waste incineration**
Industries (according to IOT)	**Installation**	**Operation**	. . .	**Installation**	**Operation**		. . .	
	€ m	€ m	. . .	€ m	€ m	€ m	. . .	€ m
Direct operation of RE facilities								
Agriculture								
...								
Services for private households								

4 Calculate direct and indirect employment and display results

Direct and indirect employment is calculated in two steps. This offers the possibility to integrate results on direct employment from other reliable sources (e.g. industry surveys)

1. **Calculate direct employment** in the RE industry:

   - Calculate direct employment for operating RE facilities directly from labour costs by assuming an average compensation per FTE.

- Calculate direct employment for any other activity by multiplying domestic output with an industry-specific direct employment factor that relates employment to industry output (in monetary units). The employment factor can be calculated from the extended input-output table of the respective country.
- Note that these employment factors are industry average values that may introduce a bias into the results. To increase technological specificity, at this point, it is also possible to include technology-specific data on direct employment (e.g. the number of full-time equivalents needed to operate the hydropower plants or FTE working in the wind technology industry). These data can be based on physical activity data and employment factors as in the employment factor approach, on enterprise surveys or estimates from industry associations or experts.
- The resulting direct employment matrix should have the same structure as the matrix shown above.

2. **Calculate indirect employment** in upstream industries of the RE industry:

Intermediate inputs of the RE industry are the starting point for calculating total indirect employment in the complete supply chain (or upstream industries) of the RE industry

- Calculate intermediate input totals by RE technology and industry with the following matrix multiplication:

$$IT^{RE} = (I - \hat{v})\, Y^{RE}$$

with IT^{RE}: matrix of intermediate input totals
I: identity matrix
$\hat{v}$: diagonal matrix with value added coefficients on the diagonal, calculated per industry as value added divided by gross output
Y^{RE}: matrix of domestic output by RE technology and industry (without the row for direct operation of RE facilities, Table 4-3).

- Calculate intermediate inputs by RE technology and industry II^{RE} with the following formula:

$$II^{RE} = A^{II}\, IT^{RE}$$

with A^{II}: matrix of intermediate input shares, calculated from the transactions matrix of the IO table per column as an intermediate input divided by the total of intermediate inputs in purchasers' prices.

Note that the column totals in the matrix II^{RE}, representing intermediate input totals, will deviate from the column totals in the matrix IT^{RE} due to the exclusion of net commodity taxes and imported inputs.

- Calculate total indirect employment by RE technology and industry F^{RE} with the following formula:

$$F^{RE} = E\, II^{RE}$$

with E: matrix of total labour requirement multipliers (see Annex 1, 6A.4.1).
The resulting matrix again has the same structure as Table 4-3.

3. **Aggregate** the calculated employment figures to display results, e.g. by technology and by life cycle phase. Jobs in the construction phase are temporary and displayed in FTE years. Jobs in the operation phase are permanent for the lifetime of the RE facility and displayed in FTEs. For each reference year they can simply be added together to give total employment.
4. **Document** the chosen system boundaries, the calculation steps and the results.

4.3.4 Data requirements and data sources

The necessary data include the following:

Capacity and electricity generation data for RE technologies

The necessary activity includes, for each reference year and RE technology,

- total installed capacity (e.g. in MW),
- net capacity addition (calculated as installed capacity in the reference year minus installed capacity in the previous year, e.g. in MW),
- capacity replacement (e.g. in MW); this may not always be identifiable from the existing statistics, but may require separate calculations and assumptions about replacement patterns (e.g. lifetime of a technology),
- electricity generation (e.g. in GWh), and
- biomass fuel input (e.g. in GWh).

Electricity generation data are usually available in the countries' official RE statistics. If these are not detailed enough, other sources, e.g. industry associations, should be consulted. Where capacity data are not available, they may be estimated from electricity generation by assuming technology-specific values for full load hours per year. Since the focus of these guidelines is on electricity generation, CHP plants should be recorded with their installed electrical capacity.

Specific costs

For every technology, cost data are required with regard to the installation of new facilities, operation and maintenance and finally demolition. Installation costs or operating costs can be found in specific techno-economic or feasibility studies. In general, the required data are available for most of the relevant technologies, since the cost of RE use has been extensively studied. Data may be scarce for technologies that are less relevant today. Data availability will also probably vary among countries. Here it will be necessary to check whether data from other countries can be applied, possibly with certain adjustments to reflect the country-specific situation.

Cost structures

For each technology, data on cost structures break down the above mentioned costs into distinct cost components. Ideally, the cost components can be linked to goods or services produced by industries according to the IO model. Data for cost components and cost structures can also be found in specific technical-economic studies, although they are generally not as available as data on specific costs. Information about cost structures is often used for economic impact assessments of technologies with IO models, but the cost structures used in these studies are not fully documented. Therefore, it will be necessary to use the available data and adapt it to the respective country.

Import- and export-related data

Import- and export-related data are needed for specific products from the RE industry. This includes final products, but also intermediate goods. Possible sources are trade statistics, data from industry associations, studies or expert estimates.

In official trade statistics, only a fraction of RE-related products can be identified (e.g. hydropower turbines or wind turbines). Often, RE products are merged with other products, even at the most detailed level of commodity classification (e.g. PV cells and modules are subsumed together with certain semiconductor devices). Steenblik (2005) and (2006) give an overview of the products covered in foreign trade statistics.

For goods not covered by trade statistics, it will be necessary to collect data from other sources. The most promising approach will depend upon data availability and the resources available for data collection. Import shares for goods used in the construction or operation of RE facilities could be collected from enterprises that operate RE facilities, industry associations, technical literature or experts. Data on exports can be directly collected from the exporting companies, or again from industry associations, the technical literature or from industry experts. The most significant exporting companies will probably be known to the respective industry associations.

Input-output model and employment data

The main database for an input-output model is the national input-output table. In most countries, IO tables are regularly published by the statistical offices. The level of aggregation of the table is one determinant of the quality of results. Therefore the most detailed IO table available should be used.

Additional employment data are necessary for employment impact studies. Ideally, these should be compatible with the IO table with regard to industry classifications and definitions of national accounting. Some countries publish employment data together with their IO tables. If these data are not available, other sources of employment data (e.g. from labour surveys) need to be evaluated.

Table 4-4: Overview of data requirements and data sources

Data	Sources	Remarks
Capacity and energy generation data: • Total installed capacity (year t and t-1) • Annual installed capacity • Annual power generation	• Official national or international statistics (IEA)	Comparability between countries versus detailed information at country level
Cost data: • Installation • O&M • (Demolition)	• Specific techno-economic studies, feasibility studies • Enterprise information • Expert opinion	Per technology Per country Per activity Not always available for all technologies or countries Adaptation of data from other countries if no country-specific data are available
Cost structure: • Shares of cost components • Allocation to industries according to the IO model	• Techno-economic studies • Enterprise information • Expert opinion	Rarely published Adaptation of available data to country-specific situation
Employment and IO data: • National input-output table • Employment coefficients (compatible with IO table)	• Official statistics on IO table • Labour surveys	Use most detailed and recent IO table available
Data on import shares and exports	• Trade statistics • Enterprise surveys • Industry associations • Technical literature • Industry experts	

4.3.5 Example: Gross input-output approach

The gross IO modelling approach is illustrated using an example for onshore wind power plants in a country with significant exports in this technology field. The capacity data, import and export shares are fictitious, whereas the cost data are taken from the GreenX database (referring to Germany) and cost structures are taken from various existing studies. The input-output calculations were done with the IO table of Germany. The following simplifying assumptions are made for the example:

- New installed capacity is assumed to be equal to net capacity increase. Capacity replacement is neglected, because it is of minor relevance in the current phase of wind energy deployment.
- Instead of full-time equivalents, the number of employed persons is used as the employment indicator, since no data on FTE by industry is readily available for Germany.

The following data were used for the example:

- Assumptions about new installed capacity and total installed capacity of wind power plants (WPP)
- Specific costs per kW for the installation of new WPP and for O&M of the existing WPP
- Breakdown of installation costs and O&M costs into cost components, which were allocated to industries of the IOT
- Import and export shares for selected RE products (WPP towers, WPP nacelles and WPP rotor blades)
- Input-output table for Germany for the reference year 2007 from Eurostat with additional information on the number of employed persons
- Data on the number of employees and employee compensation by industry from the KLEMS database (http:// www.euklems.net).

The steps described above are illustrated below.

Step 1: Determine system boundaries

The life cycle of a wind power plant is subdivided into the following activities that are included in the wind-related segment of the renewable energy industry. Wind turbine manufacturing does not necessarily take place in one factory. WT nacelles, rotor blades and towers are usually manufactured at their respective factories and then transported to the operation site, where they are assembled.

Construction phase

- Project development and planning of wind power plant
- Manufacture of wind turbine towers
- Manufacture of wind turbine nacelles
- Manufacture of wind turbine rotor blades
- Construction and installation of the wind power plant

Operation phase

- Operation of wind power plant
- External maintenance of wind power plant
- Manufacture of spare parts

Due to its minor relevance, the demolition phase is neglected in this example.

Step 2: Determine expenditures for RE use

Collect physical data on new installed capacities and total capacity installed as well as specific costs. The following table contains the data for the reference year 2009. Specific installation and O&M costs were taken from the GreenX database. The specific capital cost contains the depreciation of the wind power plant, interest on debt capital and return on equity. It was calculated assuming a capital interest rate of 7% and an economic lifetime of 20 years. In economic terms, the capital cost is part of the value added of the plant owner.

Table 4-5: Capacity and cost data for wind power plants

Variable	Unit	Value
Total installed capacity	MW	10,000
New installed capacity	MW	1,500
Specific installation cost	EUR/kW	1,553
Specific O&M cost	EUR/kW	37
Specific capital cost	EUR/kW	147

The following expenditures for construction and operation of wind power plants are arrived by multiplying the capacity and cost data:

- Construction expenditures: 2,830 m EUR
- Operation expenditures: 370 m EUR
- Capital costs: 1,470 m EUR
- Total expenditure: 4,670 m EUR

Step 3: Calculate domestic output by RE technology and industry

This includes the following sub-steps:

- Distribute the expenditures to cost components: The cost components of construction, operation and capital costs are displayed in the following table with their cost shares.
- At the cost component level, determine import shares and compute the domestic output for each activity.
- Allocate activities to industries of the IOT.
- Determine exports of RE related products: In the example exports of WT towers, WT nacelles and WT rotor blades with different export shares are assumed.
- Compile a matrix of domestic output and exports by life cycle phase and industry.

Table 4-6 shows the data and assumptions used in this step. Import and export shares are given as percentages of newly installed capacity in the example country.

Table 4-6: Cost components and cost shares, import and export shares

Cost components	Cost shares	Import shares	Export shares	Allocation to industries of IOT
Construction of WPP	100%			
Planning	4%	0%	0%	Business services (74)
Manufacture of WT towers	15%	20%	30%	Man. of metal structures (28)
Manufacture of WT na-celles	37%	20%	100%	Machinery (28)
Manufacture of WT rotor blades	15%	30%	80%	Plastics processing (25)
Transport	4%	0%	0%	Ground transport (60)
Site preparation	3%	0%	0%	Construction works (45)
Foundations of WPP	6%	0%	0%	Construction works (45)
Assembly of WPP	6%	0%	0%	Machinery (28)
Connection to the net	10%	0%	0%	Electrical industry (31)
Operation of WPP	100%			
Labour cost	20%	0%	0%	Value added of operator
External maintenance and repair	35%	0%	0%	Machinery (28)
Other costs (insurance, electricity, services)	30%	0%	0%	Insurance (66), electricity (65), busi-ness services (74)
Land rent	15%	0%	0%	Value added of operator
Capital cost	100%			
Value added of operator	90%	0%	0%	Value added of operator
Bank services (as part of interest)	10%	0%	0%	Financial services (65)

Table 4-7 shows an excerpt of the matrix of domestic output and exports. The total output for domestic RE use amounts to 1,982 m EUR for construction of new WPP and 1,834 for operation of the existing WPP stock. Exports of WPP components equal 1,246 m EUR.

This step consists of the following sub-steps:

- Calculate direct employment in WPP operation: Employment is calculated from labour costs and average employee compensation in the power supply industry.
- Calculate direct employment in other parts of the RE industry: Employment is calculated from the data in the direct output matrix and industry average employment factors that are derived from the IOT.
- Calculate indirect employment in upstream industries of the RE industry: Employment is generated according to the formula in Chapter 4.3.3.

Table 4-7: Compilation of direct output for domestic RE use and export (excerpt)

		Domestic RE use			Exports
		Wind power plants		. . .	Wind power plants
NACE	**Industries** (according to IOT)	**Construction**	**Operation**	. . .	
		€ m	€ m	. . .	€ m
-	Direct operation of RE facilities	1,473			
	…				
25	Plastics processing	245	0		279
28	Manuf. of metal structures	419	0		105
29	Machinery	689	129		862
31	Electrical machinery	233			
	....				
	Total	1,982	1,834		1,246

Step 4: Calculate direct and indirect employment and display results

The following table displays the results of the calculations. Total expenditures for the construction and operation of domestic wind power plants equal 4.16 billion euros. Since the country is a net exporter of wind power technology, its total domestic output is larger at 5.1 billion euros. There are 23,943 persons directly employed in the wind power industry and 19,718 indirectly employed persons, resulting in a total of 43,661 persons employed due to wind power use in the example. The contribution of domestic wind power plants vs. exports is also displayed in the table.

Table 4-8: Capacity and cost data for wind power plants

Variable	Unit	Construction of domestic WPP	Operation of domestic WPP	Export	Total
Expenditure	m EUR	2,329	1,834	0	4,163
Domestic output	m EUR	1,982	1,834	1,246	5,062
Direct employment	EP	13,737	3,517	6,689	23,943
Indirect employment	EP	10,820	2,118	6,779	19,718
Total employment	EP	24,557	5,636	13,468	43,661

4.3.6 Discussion of gross input-output approach

Advantages

Gross IO modelling combines technology-specific data on capacities, costs and cost structures with economic modelling. A major advantage is that it allows 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). Furthermore, this is the only gross approach able to take indirect impacts fully into account.

Limitations

One limitation of this approach is the assumption that the industries included in the IO model are adequate proxies for the companies of the RE industry and its supply chain with regard to cost structures, import relations and employment per unit of output. This aggregation bias can be reduced by partly including additional, technology-specific information in the estimation of direct employment, e.g. according to the employment factor approach or with data from enterprise surveys or industry experts. Enterprise data are also important to estimate the export-related employment.

5 Guidelines for net impact studies

Net impact studies relate to **changes in jobs** that result from the **difference between employment under low or zero RET deployment and advanced RET deployment** – this and the inclusion of the electricity price effect are the key differences between gross and net approaches. To model employment under two different RET deployments, assumptions have to be made about the socio-economic and energy sector development. A hypothetical situation is created, which shows the development "which would result if there is no RET deployment or no RE support policy". In this guidelines, a prospective (foresight) scenario is called a baseline scenario; a retrospective one is called a counterfactual scenario; and the counterfactual scenario reflects an RET deployment without RE support policies, so competitive RET can be included in the power generation technology portfolio.[9]

5.1 Net input-output (IO) modelling approach

5.1.1 General remarks

The net IO modelling approach suggested here allows the most significant effects of recent RET deployment to be captured without having to apply a full economic model. The net employment impacts (endogenous variables) are measured either as changes in

- number of jobs per year,
- full-time equivalents (FTE) per year or
- working hours (h) per year.

To also capture (negative) effects outside the RE industry, this approach compares two situations which differ in their RET deployment - the current one and a hypothetical one. In this guide, the hypothetical situation refers to a situation without RE promotion policies, the so called "counterfactual" situation, which retrospectively depicts a hypothetical electricity generation portfolio based on conventional and, if competitive, on RE technologies installed without any policy support.[10] This assessment depicted in the guidelines here focuses on the present situation, although a prospective scenario (baseline) could also be developed and applied to assess impacts[11] – albeit limited ones - of future RET deployment.

With regard to the IO model, the following guidelines assume that readers are familiar with IO modelling, since this knowledge is a precondition for applying this approach. Some additional

9 It is not possible to give examples for the two approaches because, so far, no studies have been conducted which apply the net input-output approach depicted, and no guidelines have been prepared for the full economic model.

10 The assumption of a zero RET deployment scenario is useful if someone is interested in the total overall impact of RET deployment.

11 Limited because current IO-relations (linear relations, no technological change, etc.) are applied for future interactions.

information on IO tables and models is provided in Annex 1, 6A.3ff. So far no study exists that has assessed RE employment impacts based on this approach.

5.1.2 Methodological approach

The net IO modelling approach tries to capture some of the most important impact mechanisms related to substituting conventional energy use by RE use. The impulses (exogenous variables) and related effects are:

- expenditures for investment and operation of RE-based electricity generation and for replacements due to demand in RE-related industries → direct and indirect effects,
- (displaced) expenditures for investment and operation of CE-based electricity generation due to demand in CE-related industries → direct and indirect effects,
- changes in household income due to employment in RE- or CE-related industries → induced effect type 1 and
- changes in electricity prices caused by the switch to RE use. The price changes are borne by electricity consumers and affect consumption and other production industries → induced effect type 2.

The suggested approach combines two input-output models, a (partially) closed quantity model and a (partially) closed price model.

- The **price model** (see Annex 1, 6A.4.2) calculates the impact of a price change[12] on the prices of sectoral outputs. In this IO-price model, household consumption and labour (primary input) are "endogenised", while the electricity sector and all other primary inputs are considered to be exogenous inputs.

  It is assumed that any price increase lowers the real purchasing power of final consumers and thus reduces the final demand for all goods and services. The change in final demand for goods and services is estimated based on assumptions about the price reactions of household consumption (e.g. by assuming certain price elasticities). Although this should be calculated for the total final demand (investments, net exports, consumption, etc.), in this guidelines, it is referred only to changes in household consumption.

- The **quantity model** (see Annex 1, A.5) is used to calculate both the impact of the shift in investment and operation expenditures from CE technologies to RE technologies, and the impact of consumption changes on total output and employment in the economy (Chapter 4.3). Household consumption is "endogenised" as depicted in Miller and Blaire (1985).

The calculation procedure is applied twice: in a situation without RE policies (counterfactual) and with strong support for RET deployment. The difference in employment between the two

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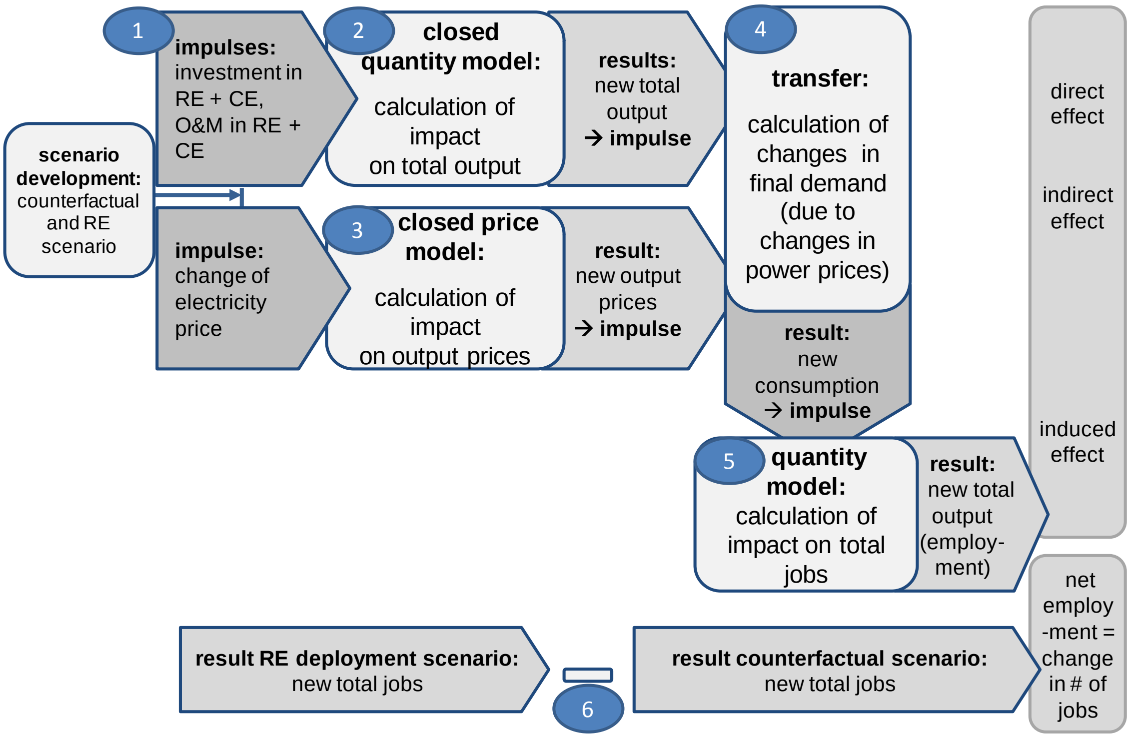
12 The price change can be assessed via the feed-in levy on current electricity prices or, if available, via electricity market models.

outcomes represents the net employment effect of RE promotion. These basic steps are depicted in Figure 5-1.

Figure 5-1: Calculation scheme for the net IO model approach



The approach comprises six steps:

1. Compile the final demand impulses from investment, O&M, exports/imports and fuel (a “no-RE- policy” scenario is developed here, meaning only competitive RE generation technologies are applied).

2. Calculate the direct, indirect and induced effects of type 1 by running the quantity IO model.

3. Compile the price impulses and calculate the electricity price impact on other prices by running the price IO model.

4. Calculate the impact of price changes on changes in consumption.

5. Assess employment by running the quantity IO model.

6. Get the impact on employment by taking the difference between the outcomes of the two scenarios.

This approach captures the main impact mechanisms, but contains simplifications in the following areas:

- Both the quantity and the price model assume linear production functions. There is no price-quantity interaction in either model. Changing intermediate demand in the quantity model does not lead to price changes, and price changes for intermediate goods in the price model do not lead to reactions in the demand for these goods.

- The effects of electricity prices (price IO model) are depicted only for final consumption.
- The effects of changes in investments (quantity IO model) and prices (price IO model) on output are modelled as consecutive (re)actions and not as simultaneous reactions.

5.1.3 Calculation steps

1

Compile the impulses from expenditures: define scenarios and calculate initial input data for the quantity model.

1 Compile and prepare data for the impulses (investment, O&M, fuel, net export) of the **RET deployment situation** to be analysed. Technologies, activities, exports and imports should be specified as described in Chapter 4.3.2. How impulses are calculated or how to allocate (cost) components to sectors is also depicted in this Chapter 4.3.2 (steps 1-4):

- Y_I: Investment impulse: --> see Chapter 4.3.2.
- $Z_{O\&M}$: O&M impulse: --> see Chapter 4.3.2.
- Z_{fuel}: Biofuel supply: --> see Chapter 4.3.2.
- $Y_{Ex,\ Im}$: Export/imports: --> see Chapter 4.3.2.

2 Assess the impulses (investment, O&M, fuel, net export) for the **counterfactual scenario** (here: it is assumed that there is no politically induced RET deployment, only competitive RE generation technologies are in place) under the same exogenous specifications concerning economic growth, prices, consumption, investment etc. (if possible) as the RET deployment scenario. First, define the point in time horizon at which the “no support policy” should be applied, e.g. from 2005. Then calculate:

- <u>Investment impulse</u>: to assess the investment impulse of CE, necessary hypothetical investments in CE that would replace the RET deployment since 2005 have to be estimated. Therefore, calculate:

  ✓ *Investment* $_{conventional}$ = *capacity* $_{coal}$ * *cost per capacity* $_{coal}$ + ... + *capacity* $_{oil}$ * *cost per capacity* $_{oil}$

  investment in €; capacity in MW, cost per capacity in €/MW

  To estimate the total investments in conventional generation technologies, the specific costs per capacity (€/MW) as well as the generation capacity (MW) is needed. Multiplying capacities by their respective costs yields investment ex-

penditures in conventional generation technologies. The hypothetical conventional capacity is the sum of the hypothetical capacities of each conventional generation technology.
The hypothetical generation capacity for each conventional technology can be derived by:

$$Generation_{coal} = \Sigma_{RE} (generation_{RE} * substitution\ share_{RE\ coal})$$
$$Capacity_{coal} = generation_{coal} / FLH_{coal}$$

where RE stands for RE technologies e.g. wind, solar, biomass, ... FLH: full load hours; generation in MWh final energy

The substitution share reflects to which extent e.g. wind, solar or biomass power replaces power from coal plants. Adding up the product resulting from the share and generation of each RE technology gives the replaced generation, namely the hypothetical coal generation. Dividing the replaced coal generation (sum) by the full load hours (FLH) of an average coal power plant gives the hypothetical generation capacity of coal power plants. This calculation has to be done for each conventional technology.
To derive the RE generation of each technology (if unknown), calculate:

$$Generation_{RE} = installed\ capacity_{RE} * average\ FLH_{RE}$$

where RE stands for RE technologies. generation RE in MWh; installed capacity in MW; FLH in hours (h)

To assess the generated power of each RE technology, data are needed on the total RE capacity which was installed due to political support (all RE relying on feed-in tariffs, quota systems, favourable taxation, ...) and the long-term average full load hours (FLH) of each RE technology. The FLH vary by technology, but also by location, e.g. the wind potential in some regions in Egypt is up to four times higher than in some regions of Germany.

- O&M impulse: The hypothetical O&M expenditures (for CE) are calculated by multiplying either generation or investment by the specific O&M costs for CE. They can be indicated either
  - ✓ in euro (€) per replaced generation (MWh), for which the equation from above can be applied:
  - ✓ $Generation_{coal} = \Sigma_{RE} (generation_{RE} * substitution\ share_{RE\ coal}) * cost\ share_{O\&M\ coal}$,
  - ✓ or as a share of the initial investment % of investment) installed, which is reflected by the above calculated “investment $_{conventional}$” multiplied by the cost share for O&M.
- Exports/imports and domestic production of fuels and technologies:
  - ✓ To get the hypothetical imports or domestic output, biomass fuel supply (in MWh) has to be replaced by conventional fuels that are either imported or domestically produced. Imports and domestic production should be calculated according to

their substitution relation and import shares. Changes in domestic production and imports enter the IO model via final demand y (investment and net export). The equation for each fossil energy source (coal, lignite, gas, oil) is shown for the example of coal:

$Import_{coal} = biomass\ fuel\ supply * substitution\ share_{coal} * import\ share_{coal}$

$Domestic\ output\ z_{i\ coal} = biomass\ fuel\ supply * substitution\ share_{coal} * (1- import\ share_{coal})$

where fuel supply is expressed in MWh

- ✓ Calculate also imports and domestic output of coal or any other fossil energy source that has been replaced in power generation by wind power, hydropower, solar or geothermal energy for each fossil fuel by:

$Import_{coal} = generation_{coal} * import\ share_{coal}.$

$Domestic\ output_{coal} = generation_{coal} * (1 – import\ share_{coal})$

$Generation_{coal} = \Sigma_{RE}\ (generation_{RE} * substitution\ share_{RE\ coal})$

with RE standing for wind power, hydropower, solar and geothermal energy; convert generation coal to primary energy

- ✓ Calculate the exports of conventional technologies (in €) based on current ratios of exports (exports to total domestic output) and the imports of conventional technologies based on imports (imports to total domestic output) multiplied by cost shares of O&M per technology (all shares are assumed to be constant over time). Exports and imports enter the IO model via final demand as “net exports” (Miller and Blaire 1985, p7ff):

$Export_{convent\ tech.} = current\ export\ ratio_{coal\ tech} * total\ domestic\ output_{coal\ tech.} + ...$

$Import_{convent\ tech.} = (current\ import\ ratio_{coal\ tech} * total\ domestic\ output_{coal\ tech.} + ...) * cost\ share_{O\&M}$

2 **Calculate the direct, indirect and induced effects:** run the partially closed quantity IO model

The partially closed IO quantity model is applied to map the impact of changes in final demand y (without household consumption) on total output. The following matrix equation is used:

$$x = (I – A)^{-1}\ y$$

where

x represents the sum of total output per sector (vector) including households' output that is defined to be "the total value of its [household's] sale of labour services to the various sectors, that is, total earnings" (Miller and Blair, 1985),

A the matrix of intermediate input coefficients (including household consumption and earnings), and

y (vector) the sum of final demand (net exports, government spending, investment and O&M) without household consumption (see Miller and Blair 1995, p 25ff). Exports and imports are taken into account as "net exports".

Impulses from investments and net exports are included in final demand (y). Changes in expenditures for O&M and fuel supply (e.g. domestic production) are treated as additional final demand (y). Check Chapter 4.3.2 to see how to proceed. The impacts on output induced by changes in final demand can then be assessed using the closed IO-quantity model for each scenario (counterfactual and advanced RET deployment scenario) independently. Changes in value added or income and, hence, the induced effect of type 1 are also depicted due to moving household consumption from the final demand vector to the endogenous sector (intermediate inputs matrix).

To obtain the resulting household consumption per sector yc_{old} (vector), the resulting final output for household X_c must be multiplied by the sectoral coefficients for consumption a_c:

$$yc_{old} = a_c * X_c$$

where

$\mathbf{yc_{old}}$ is household consumption with the impulses from final demand,

$\boldsymbol{X_c}$ is the total output from households (earnings) and

$\mathbf{a_c}$ is the sectoral coefficient for consumption.

It should be noted that the time horizon should be the same in both scenarios, i.e. when analysing RE investments since 2005, the counterfactual scenario should only include hypothetical investment impulses from conventional generation from 2005 onwards.

3 **Compile the price impulse and assess induced effects of type 2:** compile data for electricity price and run the price IO model

If an electricity market model is available which assesses electricity price changes caused by RE, then these price changes could be used, otherwise:

A **Collect data** on: electricity prices, RE levies, taxes, power generation, price and quantity of tradable green certificates (TGC). The merit-order effect and CO_2 certificate prices could be indirectly included by applying the market price for electricity..

B In order to calculate the **price impulses** for the RET deployment scenario and the counterfactual scenario, the IO coefficients of the most recent year available in national statistics (here afterwards called "update year") have to be compared with the time horizon in the model. With a time horizon for the two scenarios from 2005 to 2010, three cases can be distinguished:

a) Update year (2005) of IO coefficients is equal to lower boundary of the model's time horizon (2005 – 2010) (Case A):
In this case, the price impulse of RET deployment (in the RET deployment scenario) consists of the additional generation costs for RE (the merit-order effect is not taken into account here while the CO_2 price could be included by comparing renewable and conventional generation costs) since 2005. The price impulse for a counterfactual scenario (no RE support since 2005) is then equal to zero.

b) Update year (2010) of IO coefficients is equal to the upper boundary of the model's time horizon (2005 – 2010) (Case B):
In this case, the price impulse for the counterfactual scenario has to be estimated back to 2005, since the current IO coefficients have already captured the price effects of RET deployment. The price impulse of the counterfactual scenario is then the negative value of the additional generation costs for RE.

c) Update year (2008) of IO coefficients is within the scenarios' time horizon (2005 – 2010):In this case, differences between the two price impulses have to be taken: for RET deployment from 2008 to 2010 (Case A) and for conventional generation from 2005 to 2008 (Case B).

The calculation of the price impulses (additional generation costs) depends on the policy scheme in force and has to be conducted for the RET deployment and/or the counterfactual scenario. In a feed-in system, consumers pay a (fixed) levy on the electricity price, while in a quota system the certificate price reflects the additional generation costs that have to be allocated to total power generation. The calculations are given in the following table:

Table 5-1: Calculation of price impulse

Case A) **Price impulse (P_e) under RET deployment =**	**Case B)** **Price impulse (P_e) under a counterfactual scenario =**
FIT scheme: Price impulse $_{FIT}$ = additional costs = = RE-levy * tax rate	*FIT scheme:* Price impulse $_{FIT}$ = – (RE-levy) * tax rate
Quota: Price impulse $_{Quota}$ = additional costs = sum of TGC values / total power generation	*Quota:* Price impulse $_{Quota}$ = – [(sum of TGC values) / total power generation]

TGC: annual required tradable green certificates; FIT: feed-in tariff; the merit-order effect is not integrated due to lack of data.

The electricity price change is the key input to the closed price input-output model; the outputs are the resulting price changes of all other sectors. The IO model is partially closed, that is, labour is included as an endogenous variable, while electricity generation is considered to be an exogenous input since the question is: How do changes in electricity prices affect prices in all other industries and in primary input labour (compare Miller and Blaire 1985 p25ff and Moosmüller 2004 p 295 ff)? The model is based on the matrix equation:

$$p_{new} = (I - A')^{-1} (vP_v + a_eP_e)$$

where

p_{new} (vector) represents the new sectoral commodity and labour prices,
P_v the price of all other primary inputs except labour,
v the primary input coefficient except for labour,
P_e (scalar) the price for electricity and
a_e the input coefficient of the electricity sector.

In this price model, the exogenous variables are the prices of primary inputs (except labour) and electricity, and the endogenous variables are the prices of all industry goods except electricity. In the quantity model, in contrast, the exogenous variable is final demand (without household consumption) and the endogenous variable is total output (quantity).

Using the prices (impulses) for electricity as inputs to the price IO model, the new prices p_{new} are obtained. How the new prices for all goods translate into changes in final or rather household consumption will be depicted in step 4.

4 Calculate the effect of electricity prices on household consumption

Changes in relative income (due to changes in prices or wages) translate into changes in consumption, savings or exports in such a way that even the structure of each final demand activity might change. Since substitution, income and price elasticities are very (country, income, ...) specific, a simple approach is to set income elasticities = 1 and price elasticities = -1.

> To assess the **price effect**, changes in the consumption structure and savings rate of households as well as in total income are assumed to be zero. This means, for instance, that a change in prices affects the consumption of all goods proportionately – energy consumption included. This can be expressed by the formula:
>
> $p_{old} * yc_{old} = p_{new} * yc_{new}$
>
> An increase in output prices reduces consumption or rather final demand and a fall in prices leads to an increase in final demand.
>
> The calculation of the price impact is as follows:
>
> $yc_{new} = yc_{old} * (p_{old} / p_{new})$ for each output of sector i,
>
> where
>
> **yc_{new}** represents the new consumption of households after adaptation to new prices

p_{new} while
$\mathbf{yc_{old}}$ is the former consumption of households before the electricity price change (with old prices p_{old}) before step 4 and
$\mathbf{p_{old}}$ are the prices of all industry goods before the electricity price changed.

Since only changes between yc_{old} and yc_{new} will be included in the final demand vector y_{new}, the difference between these two must be calculated for each sector:

$$\Delta yc = yc_{old} - yc_{new}$$

5 **Calculate the impact on employment by running the IO quantity model**

In the closed quantity IO model, not only investment and export impulses, but also consumption changes Δyc are added to final demand y_{new}. Therefore the following formula can be applied:

$$x = (I - A)^{-1}\, y_{new}$$

where
$\mathbf{y_{new}}$ as the final demand vector represents the sum of a) change in consumption spending (households) Δyc_i, b) net exports y_{netEx}, c) investments and O&M expenditures y_I, (government expenditures y_{gov} are kept constant). Household consumption yc_{old} (not the change) and earnings are included in the coefficient matrix (as in step 2).

The calculation of the vector x total outcome is based on the new final demand y_{new}. It shows what the total output will be under promoted RET deployment and under a counterfactual scenario.

After multiplying the output by labour coefficients (labour requirements per unit of output), employment E is obtained.

6 **Get the net employment:** take the difference between the outcomes of the two scenarios

The difference between the employment under RET deployment and under a counterfactual scenario gives the net employment impact:

$$E_{net} = E_{i\ counterfactual} - E_{i\ RE\ deployment}$$

5.1.4 Data requirements and data sources

The data required for the net approach encompass primary data from the latest IO tables as well as data on current RET deployment impulses and on counterfactual scenario impulses. They are depicted in the following table.

Table 5-2: Required data

Data	Sources	Remarks
Input-output table: • IO coefficients • Labour coefficients	• Chapter 4.3.4 (national statistics)	Latest available IO tables with detailed (sub)sectors
Impulses for direct and indirect effects: • Investment in RE • O&M in RE • Biofuel supply in RE • Export/import of RE	• Chapter 4.3.4 (national statistics)	
Impulse for induced effect: • Current electricity price and other input or factor prices • Total power generation • Value of annual required tradable green certificates	• National statistics on current power prices, CO_2 prices, e.g. EUROSTAT for EU • Merit-order effect • RE levy (e.g. EEG-levy in Germany) • Prices of tradable green certificates	Reminder: taxes on electricity increase price

Counterfactual scenario:
• Investment in CE:
  ○ Substitution factors for fossil-based energy by RE,
  ○ RE capacity and full load hours RE
  ○ Full load hours of CE
  ○ Costs of conventional generation plants
• O&M in CE
• Fuels supply in CE
• Exports/imports of CE, fossil resources
	• National statistics, reports, IEA: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat
	• UN Comtrade database: http://comtrade.un.org/
	• Substitution shares see Klobasa 2011 (for Germany), own assumptions based on current power generation structure
	• Full load hours (FLH) or potentials: RE statistics, e.g. Eurostat for EU; photovoltaic geographical Information system (PVGIS) http://re.jrc.ec.europa.eu/pvgis/; The world of wind atlases, http://www.windatlas.dk/; domestic generation data;
	The global atlas of wind and solar power: http://irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=35&CatID=109&SubcatID=163
	• Cost curves, investments, potential, Held 2011; IRENA: http://www.irena.org/; BNEF: http://www.bnef.com/bnef/press-publications/
		Hypothetical investment, O&M costs etc. Assessment is based on average RE generation data, costs and substitutional relations between RE and CE generation

CE: conventional energy (sector); CT conventional generation technology; RE renewable energy (sector)

5.1.5 Discussion of net input-output approach

The net IO model includes all the relevant impulses and impact mechanisms but its coverage regarding induced effects is restricted to a singular impact on final demand – on consumption. The approach fails to take into account feedback loops and interactions between actors, prices, quantities and markets. Furthermore, it neglects the social benefits or externalities caused by RE such as a decrease in pollution, protection of resources, health etc. Induced effects are captured as changes in consumption, but not as cost structures of industries. Technical changes due to advanced RET deployment are completely omitted as are productivity changes due to the limited time horizon of this approach. Further, the coefficient of the IO model depicts average changes although the effects reflect marginal responses to additional impulses.

The main advantages of this approach are its analysis of detailed sectoral impacts and in-depth examination of structural changes and impacts in the short term, without the complexity and high data requirements of a full economic model. Therefore, it is more suitable for an analysis of present effects, for a detailed depiction at the sectoral level and an approximate assessment of net effects which includes induced effects to a certain degree without the need for comprehensive macroeconomic modelling. It could also be applied to depict future impacts in a simple (limited) way. The main features of an IO model are summarised in the table below.

Table 5-3: Features of an IO model

	IO model
Use/Application	Analyses changes in/ consequences for economic structure with a high degree of sectoral detail
Time horizon	Short-term analysis (only static IO are considered here)
Drivers	Changes in sectoral demand and household income due to RE and electricity price
Methods	Simple mathematical operations, fixed input-output relations
Parameters	Calculation based on given input-output relation = constant IO coefficients --> no substitution and non-constant returns on scale
Crucial issues	Adaptation of sectoral data and structures to properties of RE technologies. Inputs from final demand via investments and from price changes via consumption
Weaknesses	Fixed IO- relations (linear-limitational technology), no interactions between prices and quantities, no depiction of markets, no incorporation of changes in consumer preferences and technologies. Limited induced effects through changes in consumption due to electricity price changes
Applicability for net employment impact assessment	Depiction of consequences for sectoral structures Incorporation of a (simple) induced effect of electricity prices via the consumption vector

5.2 Full economic model

5.2.1 General remarks

The full economic model[13] is used to assess the future net effects of RET deployment. As in the net IO model approach, the net employment impacts are measured as changes in:

- number of jobs, or
- full-time equivalents (FTE), and / or
- working hours (h).

A full economic model can also assess changes in economic welfare using another impact indicator which are generally expressed in absolute terms (billion €) or in relative terms (% of (default) GDP). So far, studies that have applied a full economic model to assess employment impacts are: EmployRES: http://ec.europa.eu/energy/renewables/studies/renewables_en.htm; RE employ: http://www.erneuerbare-energien.de/english/renewable_energy/data_service/graphics/ doc/39831.php.

5.2.2 Methodological approach

There have been quite a number of employment impact assessments made using a full economic model. The models used differ in many features (see Table A.5–1: in Annex 1, 6A.5), but also share some principal similarities:

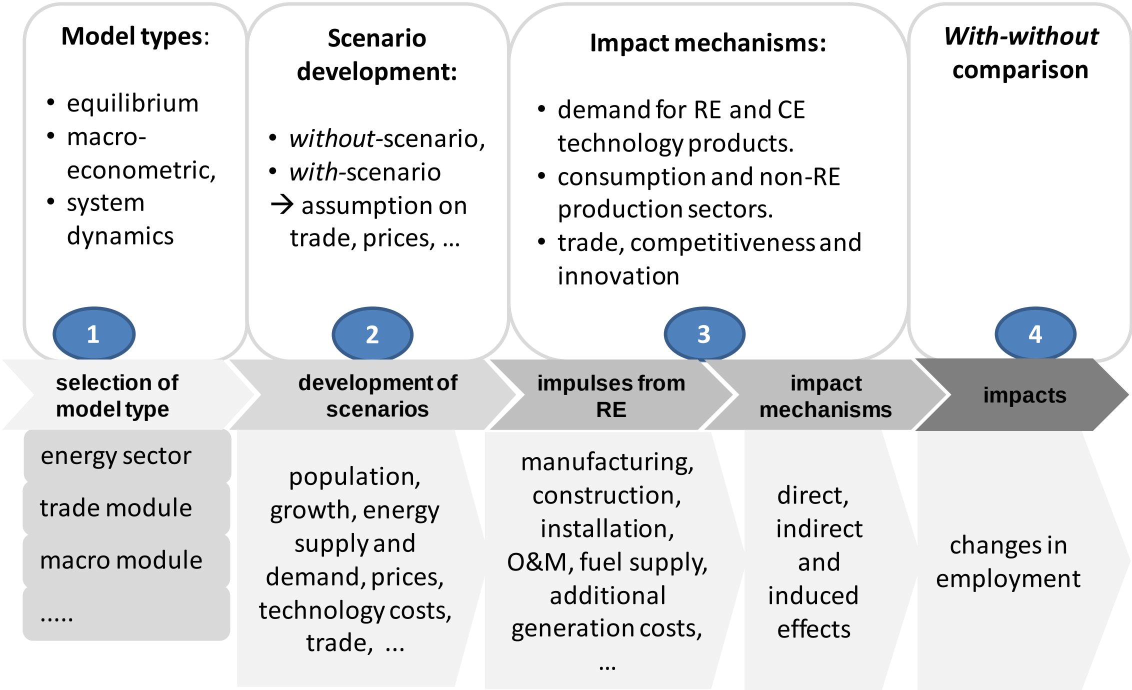
- The effects are modelled along a **functional chain,** where activities in the RE business sector cause impulses which trigger economic reactions (impact mechanisms) which then result in employment effects (see Annex 1, 6A.1.1).
- Full economic models contain modules with **bottom-up and top-down** approaches. The energy sector module reflects a bottom-up analysis and delivers detailed technology-specific and sectoral data on energy supply (structures, costs, etc.) under a given policy. The macroeconomic and trade modules, on the other hand, as top-down approaches rely on highly aggregated data and incorporate trade relations, input-output tables and national accounting.
- A "**with" and "without" comparison** is necessary to depict net effects. The "with case" refers to an advanced RET deployment scenario. The "without" can refer to one of two options: a) Assuming zero RET deployment is useful if the aim is to investigate the overall impact of RET deployment. b) The no RE policy scenario is useful when analysing the employment impact of RE policies.

13 This part of the chapter is intended only as an overview, not as step-by-step guidelines for a full economic model approach.

Assessing net impacts using a full economic model involves several steps: first, select the model if there is a choice; second, develop at least two scenarios; third, derive the impulses and "run" the impact mechanisms and finally make a "with" and "without" comparison. This general procedure is depicted in Figure 5-2.

In order to assess net impacts, a large amount of data is necessary and assumptions need to be made, for example, on fossil prices, population growth, housing area, power generation structure, taxes, generation capacities, generation, exports and the related costs of power generation, etc.

Figure 5-2: General procedure in a net impact study



5.2.3 Calculation of effects – An overview of how to proceed

1 Select a model

In the discussion about the employment effects of RET deployment, three **types of models** are commonly applied: general equilibrium models, macro-econometric models, and system dynamics models. Up to now, a few net employment impact assessment studies[14] exists, but

14 E.g. Lehr et al. 2011 (BMU-job study) and Lehr et al. 2012; Ragwitz et al. 2009 (EmployRES).

only one that compares the outcomes of two different model types triggered by the same impulses. The outcome of the two models is quite similar, on average, but the reactions occur at different speeds (Ragwitz et al. 2009). With regard to models used to analyse the impacts of climate policy, Walz and Schleich (2009) see only slightly differing outcomes, for example, “macro-econometric models tend to assess the effects of climate protection policy slightly less pessimistically than equilibrium models.” Overall, there are slight differences in impacts between the different models, but they depend on a set of model features like economic theory, parameter derivation, closeness, approaches etc. and not solely on the type of the model used (see Table A.5–1: in 6A.5). The models’ features are briefly outlined in the following.

One principal feature or characteristic of any model is its subject of investigation/ **the reason for the analysis.** Models are used to answer questions such as: What is the most efficient solution to reach a given target? Or, what are the results of RET deployment? To answer the latter, a simulation model is used which builds on the exogenously given activity options and discloses their effect on the economy. This approach is applied to the impact assessment studies made with macro-econometric, equilibrium or system dynamics models[15].

Another main feature is whether a **top-down or a bottom-up approach** is used? While the former relies on aggregated production functions, the latter takes the technological perspective and can integrate specific technological characteristics. In impact modelling, we rely on a top-down approach at the macro-economic level, while the impulses generated are often derived from a bottom-up approach.

The **theory** on which a model is based on can be neoclassical, Keynesian, evolutionary, or endogenous growth-oriented. All three model types - macro-econometric, equilibrium or system dynamics models - can build on all four theoretical foundations. Neoclassical approaches assume rational behaviour and transparent markets, whereas an evolutionary orientation places more emphasis on bounded rationality and non-equilibrium processes leading to transformations of the economy. Certainly, the theoretical orientation influences the outcome of the model, but it is difficult to estimate its impact since it can be compensated by the equations and restrictions applied, the determination of parameter values, etc.

Deriving model **parameters** can either be based on econometrical estimations or calibrations so that initial outcomes can be reproduced by the model. The first method relies on historical data and may be less suitable for assessments in the distant future, while the second approach seems better suited to future assessments.

With regard to **exogenous or endogenous** variables, the income cycle can either be open, so that the demand of private households is exogenously given, or features closed loops where demand is endogenously derived. The latter allows the price effect to be reflected in the consumption vector. In some models it is possible to capture changes in prices for input coefficients or a double dividend for taxes, as well as depicting inefficiencies and first mover advantages, while in other models this is not feasible (or endogenously modelled).

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15 The first type of question refers to optimisation problems and models.

Table 5-4: Overview of model types and their general characteristics

	Macro-econometric model	(Computable) general equilibrium model	System dynamics based model
Use/ Application	Predicts overall level of economic activity (using macroeconomic figures). Analyses transitional impacts e.g. employment, ...	Examines impact of changes in relative prices on economic outcome.	Analyses impacts of price or demand changes on economic activities.
Time horizon	Short- to medium-term predictions	Long-term predictions	Long-term analyses
Drivers	Changes in aggregated quantities, prices	Changes in prices	Changes in prices, quantities
Methods	Considers and solves behavioural and definition equations simultaneously. IO table and national accounting included.	Strong microeconomic foundation with (partial) market equilibriums. Supply and demand functions. CES production and utility function. Contains IO tables.	Consists of non-linear differential equations. Uses positive and negative feedback loops. Includes IO tables and national accounting. Contains attributes of econometric models and applies equilibrium approaches as well.
Parameters	Estimation based on historical data --> fixed relations --> non-optimisation of individual behaviour	Calibrated = replicates data of base year	Estimation and calibration
Crucial issues	Macroeconomic data availability. Time series data. Specification of functional forms.	Exogenous parameters	Complexity
Weaknesses	Great effort involved in model specification. Simplistic functional forms may lead to inconsistencies.	Slightly more emphasis on negative effects since increases in efficiency are hardly taken into account. In some approaches, economic aspects outside the defined field of analysis are kept constant (partial analysis). Assumes optimisation behaviour of economic agents and efficient markets which is not realistic.	Mixed theoretical foundation. Complex structures due to manifold feedback loops
Applicability to net employment impact assessment	Tends to assess effects slightly less pessimistically than equilibrium models. Suited for short-medium term analyses. Depiction of encompassing macroeconomic effects. Depiction of transitional	Depiction of long-term aspects. Depiction of a particular market or a few sectors without including significant spill-overs.	Integration of several sectors and fields of RE use (transportation, heat, power)

	Macro-econometric model	(Computable) general equilibrium model	System dynamics based model
	impacts on unemployment, growth, ...		

Source: own compilation, based on Walz and Schleich 2009, Krail 2009, Forum für Energiemodelle 1999, Bhattacharyya 1996, Frankhauser and McCoy 1995

The different models commonly applied for net impact assessment studies do not have fixed characteristics, but can integrate different features. For example, the parameters in a macro-econometric model can be estimated or calibrated, or the model can integrate neoclassical and/ or evolutionary aspects. In the following table, a brief overview of the **general characteristics of model types** and their potential influence on the employment effects assessed is given.

All the three models types described in the table above are suitable for assessing the effects of RET deployment. Their features might be (and are) adapted to specific research questions, for instance, the parameters could be estimated and/or calibrated in an macroeconomic model to allow long-term assessments as well. Therefore, it is recommended using the model that is available for the country or region (at universities, (supra) national research institutes/centres), looking at its features and bearing in mind its possible influence on the final results.

2 The challenge – develop scenarios

Scenarios for employment impact assessments with a full economic model are constructed to depict the future development of energy demand and prices and to assess - based on this development – the future impacts of different policies or RET deployment. They are tools used to indicate feasible developments, but do not forecast developments. In order to assess net impacts, a situation “with” and one “without” RE support policy or RET deployment are compared. These are often called “zero RET deployment” or “zero RE policy” (counterfactual or baseline scenario)[16] and “advanced RET deployment”. When assessing employment impacts, several advanced RET deployment scenarios could be developed to show how strongly the net employment impact depends on assumptions about prices, export relations, and generation technology structures.

Fundamental issues when applying and developing scenarios are:

- The main drivers of energy demand are demographic and economic development as well as energy intensity. Global RET deployment depends on energy demand or prices as well as on policies, and is projected by international agencies like the IEA.
- A minimum of two scenarios are necessary: a baseline scenario and an advanced RET deployment scenario.

16 In the net IO approach, a counterfactual or baseline scenario reflects a hypothetical situation without RE promotion policies or without any RET deployment at all.

- The baseline scenario has to be realistic, either reflecting a situation without RET deployment or the actual RET and CE deployment without additional RE policies, while the accelerated/advanced RET deployment scenario should be based on potential RE policy measures, price developments and potential global deployment. The potential RET deployment effects of RE policies are greater, the further back in time, i.e. the more "historical" the baseline scenario is, e.g. referring to a situation in 1995, 2000 or 2005. The assumption of a zero RET deployment scenario is useful if one is interested in the total overall impact of RET deployment.
- It is crucial to analyse the model's sensitivity with regard to the assumptions made. To reveal the influence of the assumptions made about prices, trade relations etc, it is useful to develop different advanced RET deployment scenarios in which, under a given RET deployment level (e.g. 50% of power from RE), other factors are varied, e.g. prices for fossil fuels, trade relations, market shares, supply structures, etc. Note that only one of these factors can/should be varied at one time.
- The predicted world market prices of fossil energies should be based on generally accepted projections, e.g. IEA scenarios. Socio-economic projections should be based on internationally acknowledged data or publications e.g. OECD.
- The future exports or market shares of RE technologies should be based on realistic assumptions (constant or decreasing shares due to increasing global trade and growing emerging economies) and developed in a transparent procedure (see Breitschopf et al, 2011).

3 Determine impulses and establish the impact mechanisms

To obtain a comprehensive assessment of net employment, it is recommended taking the main impulses and impact mechanisms into account. These include the impact mechanisms via the demand for products of the RE industry, the consumption of households and trade. Further, all effects should be modelled with multiplier effects; for instance, increased income in RE industries triggers increased consumption which in turn leads to higher production and income in the consumption sector, which increases the spending of those employed in the consumption sector etc. The crucial effects that should be included in the model are listed in the following table. For information on how to derive impulses, see Chapter 4.3.

Other induced effects like the crowding-out of other investments, environmental or health effects could be included in this model but are not considered here (due to the focus on economic effects).

Table 5-5: Relevant effects to be included

Effects	Positive or negative	Impulses (input data)
Direct effect	+, -	Investment (MCI) O&M Fuel supply Exports/imports R&D, demolition, administration
Indirect effect	+, -	*see above*
Induced effect type 1	+ - (in case income in CE industries decreases)	Income from RE industries Income from CE industries
Induced effect type 2	+ specific generation costs with RE fall below those of CE (RE < CE) - generation cost RE > CE	Price for electricity (cost effect in industry, budget effect in households) taking into account taxes, price for CO_2, merit-order effect, ...
Effects on innovation, productivity, ...	+. -	Endogenous (if possible)

Note: MCI: manufacturing, construction, installation; O&M: operation & maintenance

4 **The “with" and "without” comparison**

Finally, in order to obtain the net impact, it is necessary to compare a situation with RET deployment (or RE promotion policy) with one with no RET deployment or RE support policies. The outcomes from the baseline scenario are subtracted from the outcomes of one or more RET deployment scenarios. The resulting figure is the change in overall employment in all economic sectors - the net employment effect. Normally the baseline as well as the advanced deployment scenario start at some point in the past, e.g. in 2000 with a given level of RET deployment and extend to 2020 or beyond. The further back in the past the scenarios are, the larger the increase in RET deployment and, hence, the larger the effects.

5.2.4 Data requirements and data sources

The quantity and quality of data needed for an impact assessment based on a full economic model are very high. The data should cover the time period under consideration, e.g. 2000 – 2020 and several countries if being performed for a region like the EU. Examples of the data required are listed in the following table.

Table 5-6: Selection of data required for an economic impact assessment

Data	Unit	Sources
Prices and allocation: Crude oil CO_2 Gas for households, industry, ... Electricity for households, industry, ... Fuel for households, industry, transportation	€ / ... e.g. bbl t kWh kWh l	IEA energy outlook; OECD
Socio-economic data: Population per age group Birth, mortality rate, migration Private households GDP Production value Number of passengers, commercial vehicles, Transportation of goods and persons	 # # € € #; km	National statistics on population, energy, ...
Efficiency indicators: Primary energy consumption (PEC) Share in PEC of each energy source GDP per PEC Final energy consumption (FEC) per household Gross value added per FEC for industry Production value per FEC Transportation per FEC	 GJ/capita % €/GJ GJ/# €/GJ €/GJ km/GJ	National statistics; European Statistics: Eurostat, ...
Emissions: GHG emission factors Substitution factors	 G/kwh %	National statistics, publications of national ministries (environmental, commerce, ...), UNFCCC communications
Policies: Social insurance Tax rates, depreciation rates Operating terms of nuclear power plants, ...		Publications by government ministries; OECD reports
Macroeconomic data: Input-output coefficients National accounting Trade data Labour force data (quantity and qualification)		National and supranational statistics, e.g. Eurostat, UN Comtrade, national energy balance, ...
Statistics on: Housing: real estate prices, existing and new construction, ... Transportation: # of cars, fuel input, average transportation, ... Energy: primary and final energy use, ...		National and supranational statistics, e.g. Eurostat, UN Comtrade, national energy balance, ...

5.2.5 Discussion of the full economic modelling approach

No guidelines are given for the full economic model, since this is extremely complex, consisting of various modules, relations, input data, is based on different theories and hence offers a broad range of options for modelling or assessing impacts.

The full economic model allows modellers to include all the relevant economic effects of RET deployment, feedback loops or interactions between variables, actors, sectors and markets. Although the type and characteristics of a model influence the outcome, they are negligible in comparison to the potential impacts of impulses (investment, O&M, prices etc.), the selection of activities and scenarios.

Hence, if a full economic model (often available at universities or national research centres/institutes), socio-economic and energy data are available for the country or region under consideration, then the RE employment impacts should be modelled with such a model. This model should also be applied if the objective is to make as thorough and comprehensive an assessment as possible and if there are no budget or data limits.

Crucial aspects when working with a full economic model are:

- Scenario development: base socio-economic and energy data on projections of internationally acknowledged organisations.
- Baseline scenario: be aware of the fact that the more historically based the baseline scenario is, the larger the impacts.
- System boundaries: define clearly which activities (along the functional chain) and technologies are included.
- Impulses: include all relevant impulses or effects (see Annex 1.1 to 1.3 and Breitschopf et al. 2011).
- Prices and taxes: base price changes for consumers on the actual prices (at constant prices) they are paying and not on the specific generation costs. Tax rates, social insurance etc. should be appropriately depicted in the model.
- Exports and market shares: use realistic market shares or export shares. The higher the shares, the higher the (positive) employment impacts in the manufacturing sector.

6 Contribution of reviewers

Prior to the publication of the guidelines, external experts were asked to review the guidelines. The review process took place from December 2011 to January 2012. The following external experts received a draft version of the guidelines:

- Christian Lutz
- Jay Rutovitz
- Werner Rothengatter
- Andrea Stocker
- Fabrizio Calevaro
- Simon Bawakyillenuo

The experts were asked for their feedback on the overall structure of the guidelines, e.g. level of detail, transparency, clarity (goals and steps) and comprehensibility (How do you judge the level of prerequisite knowledge needed to work with the guidelines? What type of knowledge do you feel is necessary?). Another issue was the usability of the guidelines for specific countries or regions (specific issues/ adjustments).

Overall, the feedback has been positive and encouraging, but there were, however, some parts of improvements suggested by the reviewer. Some quotes from the reviewers:

"Please find attached my comments on this very important and excellent work." Andrea Stocker

"In effect, these guidelines will be a shot in the arm for many renewable energy advocates and academics in renewable energy studies in Ghana, because utilising these guidelines will aid them to influence renewable energy policies." Simon Bawakyillenuo

" .... I highly appreciate the work of the research team, their analysis is up to date, explanations are clear and the suggested sequence of analysis including the data input needed is well described. Therefore my main comments will not focus on modifying some details ... rather than commenting .... some sort of an IEA quality certificate." Werner Rothengatter

"I think [the transparency and clarity of the guidelines] is really good." Christian Lutz

The major concern was, that the target group was not defined clearly enough throughout the document. Therefore, the purpose and rational of the guidelines, and the targeted audience, has been more explicitly described in this final version of the guidelines. An overview and summary chapter for policy makers have been added to this version of the guidelines, but the guidelines are not meant to be a handbook or manual for impact assessment studies.

Most of the reviewers considered the guidelines to be sufficiently detailed, comprehensible and transparent. To enhance understanding, the experts suggested including more illustrations of the elaborated employment impact approaches. In this final version, examples are included for the employment factor and gross input-output approaches.[17]

Furthermore, the reviewers' as well as authors' main concern is to keep the guidelines as simple as possible, and as detailed as necessary. The authors tried to address this challenge by presenting an overview of the main questions or topics that can be answered or evaluated by the selected approaches at the beginning of the guidelines followed by a detailed description of how to proceed.

The full economic model has not been elaborated in more detail, although some of the reviewers encouraged this. It is the authors' opinion that a final recommendation cannot be given about which model type will be best suited since this depends on budget, data and human resource considerations and modelling details.

The issue of translating the complex issues associated with calculating employment effects into clear, understandable and applicable guidelines has been one of the major challenges throughout the entire EMPLOY project.

We would like to express our sincere thanks to all reviewers for their very valuable and comprehensive feedback. Many of the similar points they made have been discussed in detail and incorporated into the guidelines, while their diverging suggestions, perspectives and views emphasise the complexity of the issue.

[17] No studies have yet been conducted using the net IO approach and no step-by-step guidelines have been elaborated for the full economic model approach.

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Annex 1: Background information

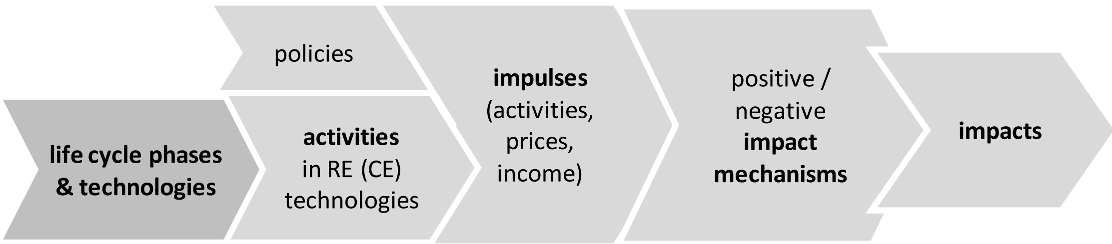
For further information on RE employment impact studies please also see the review report (Breitschopf et al. 2011) that can be downloaded under:
http://iea-retd.org/archives/ongoing/employ, Task 1.

A.1 The functional chain: From impulses to effects

The deployment of RET causes **impulses** (exogenous variables) in the economy that have their origins in activities like manufacturing, construction and installation (MCI), as well as the operation and maintenance (O&M) of RE power plants, fuel generation and supply, research and development – all based on life cycle phases of a power plant. The impulses are captured as expenditures in the respective sectors and are translated via an impact mechanism[18] into **impacts measured** as the **number of jobs** or as **changes in employment**.

This **functional chain** – from activities through impulses and impact mechanisms to impacts - is crucial to understanding the impact assessment approaches. For example, the installation of a wind power plant requires the manufacturing of a turbine (activity). This generates a demand for intermediate products that is passed through to upstream industries by expenditures in the manufacturing sector (impulses from RE). The expenditures for the wind turbine stimulate production and hence income in RE-related industries (impact mechanism) resulting in an increase in the number of employees there (impact). In a different example of an impulse from RE (policy), using RE to generate electricity leads to higher electricity prices which reduce the relative income of households so that their spending for consumption (all goods) drops, leading to lower economic production in the consumer goods industry (impact mechanism) and hence to a decrease in the number of jobs (impact). This functional chain is depicted in Figure A.1–1: . To learn more about impacts, read Annex 1, A.1.1 and A.1.2.

Figure A.1–1: From RE activities to RE impacts - A causal chain



Impact mechanisms translate economic impulses or shocks into economic impacts, e.g. into changes in employment or economic growth. Impact mechanisms are distinguished by their impact pathway, e.g. via demand for RE industry, consumption and production, and classify

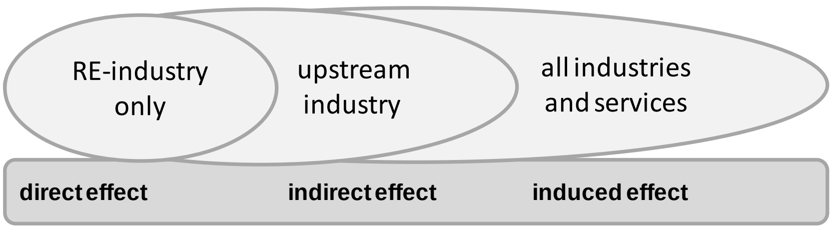
18 For example, impact mechanisms describe how and through which activities and sectors impulses from RE are translated into an economic impact. For example: RE investment (impulse) triggers demand in the RE and RE-related industries (mechanism) and finally results in an increase in employment (impact).

them according to their respective positive or negative economic impulse described in points 1 to 3 in Annex A.1.1. In contrast to impacts, **effects** refer to **how the impulses affect the economy** or **via which impact mechanism** they result in an impact – there can be positive or negative effects. The effects of the different impulses add up to a final impact on employment. The main impact mechanisms applied or discussed in net studies are described in detail in Breitschopf and Nathani (2011).

Direct effects affect the economy via production in RE-related industry. They include only the effects on jobs within the RE industry or conventional energy industry, like construction or machine manufacturing, O&M and provision of biofuels, while **indirect effects** comprise the effects on jobs in upstream industries like steel processing or chemical production as well. They are related via intermediate products to the RE technology.

Induced effects include impacts on jobs in sectors beyond the RE or conventional power generation industry and their upstream industries, namely impacts on consumer goods industries and the related upstream industries. Induced effects occur via income, or power prices and they affect consumption and production. This is illustrated in Figure A.1–2: below, where direct effects refer to jobs in the RE industry, indirect effects include effects in the respective upstream sectors of the RE industry and induced effects encompass all effects via power price and consumption in all industry and service sectors. To learn more about effects, read Annex A.1.2.

Figure A.1–2: Outline of direct, indirect and induced effects



In the context of impact assessment studies, one usually talks about **positive and negative effects (or impacts)**. Positive (negative) effects contribute to an increase (decrease) in the number of jobs in some branches or industries.

For example, an RE investment reflects a positive (direct and indirect) effect since it leads to an increase of employment in the RE industry, while avoided investment in the fossil energy sector is a negative effect, because it lowers investment in the conventional power generation industry and hence causes a loss of jobs in this branch.

The induced effect (Type 1) - an increase in income from the RE industry - is positive since higher income is supposed to augment final demand and hence overall production and employment. However, a decrease of income in the CE industry due to lower production could negatively affect total employment. The induced effect (Type 2) caused by electricity prices is negative if electricity from RE is more expensive than power from fossil sources. This is the case if the (higher) generation cost of electricity from RE is not compensated for by taxes on fossil energy resources, or costs for CO_2 emissions allowances and the merit-order effect[19] of RE. The main positive and negative effects are listed in Table A.1–1: .

Table A.1–1: Overview of positive and negative effects caused by economic impulses

Positive effects → job increases	Negative effects → job losses
Increase in investment in RET (RE industry and upstream industry)	Displaced investment in conventional generation technology (CE industry and upstream industry)
Increase in O&M in RE generation (RE industry and upstream industry)	Displaced O&M in conventional power generation (CE industry and upstream industry)
Increase in fuel demand (biomass) (RE industry and upstream industry)	Decrease in fossil fuel demand (CE industry and upstream industry)
Increase in trade of RE technology and fuel (biomass) (RE industry and upstream industry)	Decrease in trade of conventional technology and fossil fuels (CE industry and upstream industry)
Higher household income from employment in RE industry	Lower household income from employment in CE industry
Decreased electricity price for households and industry due to merit-order effect, etc*	Increased electricity price for households (budget effect) and industry (cost effect) due to additional generation cost of RE-based power generation

* So far, electricity from RE is usually more expensive than electricity from fossil energy sources

A.1.1 Impulses and impact mechanisms

Impulses like price changes, investments, O&M expenditures etc. are regarded as activating an economic mechanism which results in economic effects. Impulses lead to positive and negative effects. The key impulses (of activities) in net studies that are triggered by certain policies (or external shocks) and that activate economic mechanisms can be grouped into different types:

2. Impulses which have an immediate impact on demand for CE- and RE-related manufacturing, intermediate input, construction and services. These can be positive in the sense of additional investments, O&M, and fuel, or negative in the sense of avoided investments.

    - Investment impulse: occurs only during investment period and has an investment effect.

    - O&M impulse: occurs over the lifetime of the generation plant and has an O&M effect.

19 The merit-order effect of RE is a decrease in the power price due to a higher supply of electricity (shift of the supply curve to the right) from sources with low marginal costs (RE). (Sensfuß 2011, ISI et al. 2010).

- Fuel demand impulse: occurs over the lifetime of the generation plant and has a fuel effect.

2. Impulses with no immediate impact on demand but with an impact via prices or income on other (not RE-related) production and consumption sectors affecting the final demand for consumption goods as well as for investment and intermediate inputs:

   - Price impulses (at constant prices) felt as a budget effect (households) or cost effect (industry) due to additional direct and indirect generation costs, generally called price effects.

   - Other price impulses: merit order (MO effect), CO_2 prices as costs or as credits (at constant prices).

   - RE income impulse, e.g. additional income (household income at constant prices) in RE sector leads to a higher demand of households with RE sector employment (often indirectly included in model set-up), often called RE income effect. Accordingly, if employment in conventional generation technology (CT) industries decreases and hence income shrinks for those households employed in the CT sector, there is an avoided income impulse.

3. Impulses from international (trade) relations affecting demand for RE investments and competitiveness:

   - Trade impulse: increasing exports of technologies augment the investment effect and imports of technology augment the O&M effect.

   - Trade impulse for fuels: avoided imports of fossil fuels, additional imports of RE-fuels.

A.1.2 Effects in net impact studies

Economic impulses lead to diverse impacts of RET deployment, e.g. on employment, measured by the number of jobs, for instance. However, when discussing employment indicators, it is important to define employment because referring to employment or jobs without indicating the duration involved could be misleading. Therefore it is suggested using job or employment to refer to a full-time job or full-time equivalent, or a job-year, all of which are equivalent to a full-time job for one year and one person. When describing employment effects, one distinguishes between positive and negative, direct, indirect and induced (of Types 1 and 2) effects that are all triggered by RE activities and impulses.

3. Direct employment effect: This refers to employment caused directly by planning, developing, managing, manufacturing, constructing, installing (MCI), operating and maintaining (O&M) different components of a RE technology or a power plant, ignoring effects on upstream industries. The data can be collected directly from the existing facilities, manufacturers, project developers, etc. in the respective phases of operation. This is a positive effect, while avoided investment in the conventional power generation in-

dustry reflects a negative direct effect since fewer jobs are required as a result in this industry.

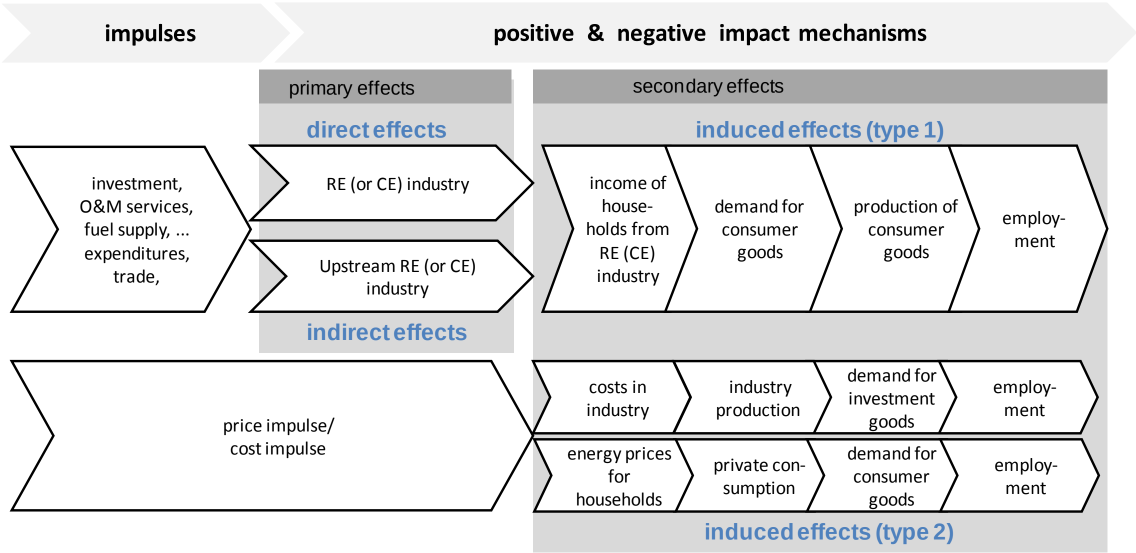
4. Indirect employment effect: This includes employment in upstream industries that supply and support the RE activities. This could be the demand for intermediary inputs like steel, synthetics, software, etc. for RE plants, or for equipment, facilities, maintenance and operation. These industries are not directly linked to any RE activity field. Both the direct and indirect effects are called primary effects, while the indirect effects stem from the intermediate input demand. This effect is positive in upstream industries related to the RE sector, but negative in those supplying the conventional power generation sector.

5. Induced employment effect: This is reported in net studies as well as in some gross studies as the effect on employment in industries not related to RE MCI, O&M or fuel etc. It is considered to be a secondary effect that occurs along two impact paths:

    - Type 1 drives a positive impact and is induced by additional (direct and indirect) employment and hence expenditure-induced effects in households (at constant prices) employed in RE industry and services. This leads to increased consumption, which, in turn, results in more investments in all industries and services, affecting all incomes positively etc.[20] However, if household income decreases due to lower production in the CE industry, then this effect has also a negative impact on employment.
    - Type 2 sets a negative impact in motion if it is initiated by higher prices for power (energy), leading to additional costs for electricity use in industry and households. This entails changes in consumption or production leading to lower demand, either for consumer goods and services, or for investment and intermediate goods and services. This in turn affects production, income and again consumption, etc. In case, power generation based on RE leads to a reduction of electricity prices paid by households and industries, this effect is positive.
    - Besides the induced effects of type 1 and 2, there are other effects like the crowding-out of investments in sectors beyond the energy sector. In addition, non-economic effects like environmental effects, health effects, etc. due to deploying RE could have an induced impact on employment. These effects are not considered here.

20 Theoretically, avoided income in CT industry could have a negative effect on the consumption of households employed in CT.

Figure A.1–3: Types of effects

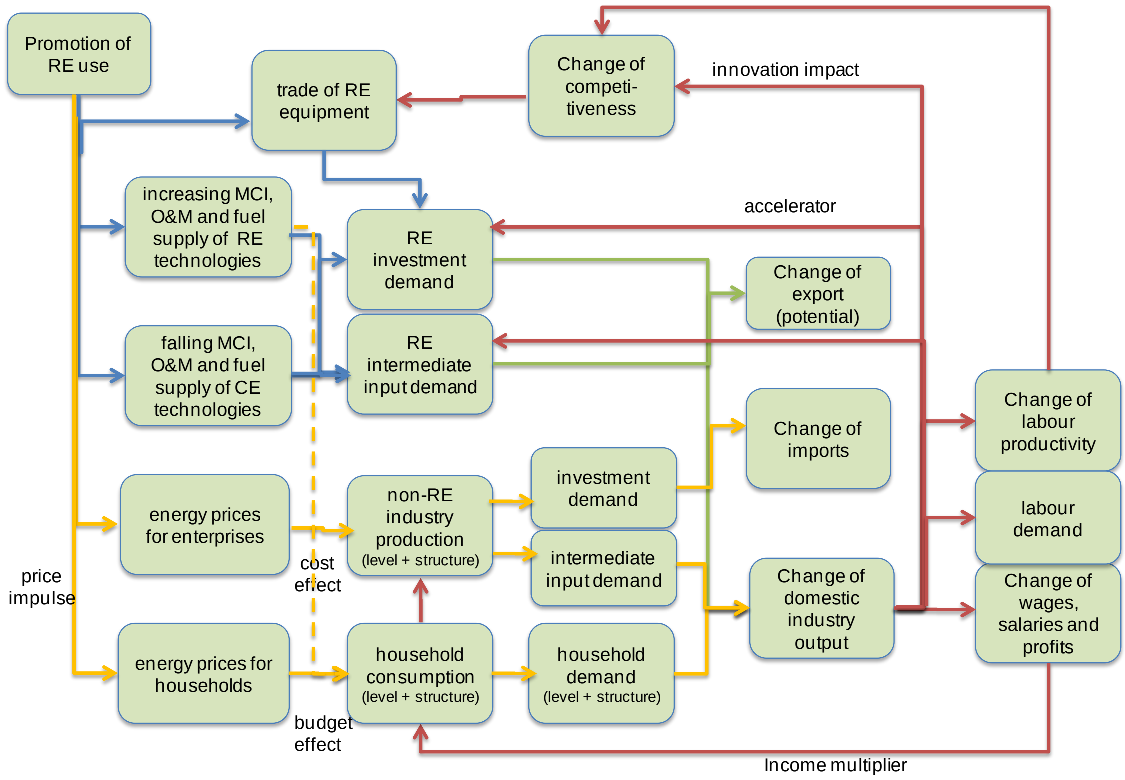


Source: own depiction on the basis of Haas et al. 2006

Gross employment assessments generally cover direct, indirect and (very rarely) induced (Type 1) effects, while net impact studies generally also include induced Type 2 effects.

Figure A.1–3: gives an overview of the classification of the different effects resulting from the impulses while Figure A.1–4: illustrates the complex interdependencies of impulses, impact mechanisms and impacts. The blue lines represent direct and indirect effects; the yellow lines Type 2 induced effects; the red line dynamic aspects; the green line Type 1 induced effects. Some net studies cover only a few impulses and impacts, while others are more comprehensive.

Figure A.1–4: Impulses, impacts and interdependencies of net impact assessment approaches



A.2 System boundaries, activities and technologies

A.2.1 Renewable Energy Technologies for Electricity Generation

These guidelines focus on RE technologies for electricity generation. According to the Energy Statistics Manual jointly published by the OECD, the IEA and Eurostat (2004), RE sources include

- → solar energy,
- → wind energy,
- → geothermal energy,
- → hydropower,
- → ocean resources (tidal and wave energy),
- → solid and liquid biomass and biogas, including biomass fractions of municipal solid waste and industrial waste.

Technologies for generating electricity from these sources can be subdivided into pure power generation plants and combined heat and power (CHP) plants. It is proposed to include CHP plants. To what extent CHP plants should be considered (RE ratio) in studies of the economic impacts of electricity generation technologies is discussed below. Thus technologies for generating electricity from RE sources are linked to the following electricity generation systems:

- → photovoltaic systems,
- → solar thermal electricity generation plants (CSP),
- → wind power plants,
- → geothermal power and CHP plants,
- → hydropower plants, distinguishing between small hydro (< 10 MW) and large hydro (>= 10 MW)
- → tidal and wave power plants,
- → biomass power and CHP plants, which can be further disaggregated into
  - biomass power and CHP plants
  - co-firing of biomass in fossil power and CHP plants,
  - waste incineration plants (especially the biodegradable fraction of municipal solid waste (MSW)) and
  - biogas power and CHP plants with biogas including agricultural biogas, landfill gas and sewage gas.

Special considerations

Renewable energy ratio of RE technologies

The sole function of most of these power generation systems is to generate useful energy from renewable sources. However, it is not possible to allocate all the technologies completely to RE use for various reasons. Here a “renewable energy ratio” should be used to include these technologies within the RE system boundaries. In the following, some technologies are presented for which RE ratios are needed.

Pumped storage hydropower plants can be thought of as having two functions,

- → to generate electricity from naturally inflowing water and
- → to store electricity from the grid by using power to pump water from a lower elevation reservoir to a higher elevation reservoir and then release it at a later time to generate electricity.

The question is whether to include pure storage of power into the system boundaries of RE use. From an environmental viewpoint, it is proposed not to include pumped storage capacities – i.e. as the energy source stored is, by definition, electricity (which can stem from various energy carriers already accounted for elsewhere). This is in accordance with the international energy statistics which only include hydropower generation net of pumped storage in RE supply data (e.g. definitions in WEO from IEA 2011).

Waste incineration plants have two functions, the disposal of waste and energy use. Only the energy use part should be considered as part of the RE sector. This part can, for example, be quantified as the additional costs or expenditures related to generating energy in a waste incineration plant. Furthermore, the waste incinerated contains a biodegradable and a non-biodegradable fraction. It is proposed to consider only the biodegradable fraction. Biodegradable waste is also incinerated in other plants, e.g. cement kilns. Similar to waste incineration, the electricity generation from biomass is not the main purpose of these plants, but only a secondary one. Thus the economic impacts related to the construction and operation of these plants should only partly be included in the RE system boundaries. It is proposed using the biodegradable share in total energy input multiplied by the costs related to electricity generation in the respective plants.

Co-firing of biomass in typically large-scale thermal power and CHP plants refers to the use of biomass fuels besides conventional fuels (coal, gas) for generating electricity (and heat). Co-firing is a comparatively cheap technological option, as generally only small additional investments are necessary. Obviously, it implies the use of RE only as a supplement to conventional fuels. Here, the additional investments dedicated to the complementary biomass co-firing unit together with the share of biomass fuels in total energy input appear adequate to determine the ratio dedicated to RE.

Auxiliary technologies

Some studies of the economic or employment impacts of RE use include certain auxiliary technologies such as storage technologies, fuel cells, technologies for hydrogen use or elements of (smart) power grids. They argue that these technologies often complement a large-scale use of RE. It is proposed to exclude these auxiliary technologies from the core RE industry for reasons of comparability.

Combined heat and power plants

CHP plants use thermal energy from RE sources to simultaneously generate electricity and heat. There are many different designs. In some CHP plants, electricity is the main output, whereas in other plants heat is the main output and electricity a by-product. This heterogeneity makes it difficult to handle CHP plants in studies focusing on electricity generation. In general, most CHP plants can be thought of as comprising three main elements: a power generation component, a heat exchanging device for heat extraction and a district heating network to distribute the heat to the users. It is proposed to exclude the heating network, as a similar approach is commonly applied for electricity (i.e. the handover point represents the feed-in of electricity to the grid).

A.3 Critical issues or limitations of impact assessment studies

Any assessment relies to a certain extent on some crucial input parameters and assumptions, especially when analysing future impacts. Therefore, these parameters or assumptions need special attention:

For **RE sector impact studies** (gross impact studies) where the assessment is mainly based on installed capacities, the following parameters are critical:

- **Generation by technology:** generation varies from year to year, therefore the derivation of capacities or labour input by technologies for O&M should be based on an average value.
- **Exports**: the larger the amount of exports, the higher the employment share in the manufacturing sector (temporary employment). Impact assessments based on installed capacities tend to underestimate the impacts from investments if exports are not taken into account (or overestimate them if the assumed export share is too high).
- **Imports:** the larger the import share of installed RE generation plants, the lower the employment in the domestic manufacturing sector, but the higher the employment in the O&M sector for RE plants. Hence, investment-based impact assessments tend to overestimate investment impacts (temporary jobs) and underestimate O&M impacts (permanent jobs) if import shares are not taken into account.
- **Productivity**: A change in labour productivity affects employment; the higher the labour productivity, the lower the number of jobs per unit of installed capacity or output. To adjust for differences in productivity between regions, the ratio of labour productivity between regions could be used, although this should be calibrated with local data if possible (see Rutovitz and Atherton, 2009, Rutovitz, 2010[21]).

For **economy-wide impact** studies (net impact studies) relying on installed capacities, the crucial parameters and assumptions in addition to those for gross studies are:

- **Prices for fossil energy** (sources): the higher the prices for fossil energy, the lower the negative impact of the additional generation costs of RE (price effect) and, hence, of the negative impact on jobs, e.g. in the consumer goods industry. To avoid unrealistic effects, the assumptions about fossil energy price developments should be clearly described and be based on a commonly accepted price scenario (e.g. IEA WEO).
- **Costs for RET for electricity generation**: It is assumed that, due to the increasing diffusion of (new) RE generating technologies, the costs of these technologies will decrease in

21 *South African energy sector jobs to 2030.* (2010) Jay Rutovitz. Prepared for Greenpeace Africa by the Institute for Sustainable Futures, University of Technology, Sydney.

a given ratio (learning curves) and, hence, reduce the additional generating costs (price effect). This in turn mitigates the negative price effect, namely, the negative impact on jobs. Therefore, any assumptions about the worldwide diffusion of RE technologies and the ratio between diffusion and cost decreases are crucial.

- Internalisation of **CO_2 emissions**: Impact studies include the costs of CO_2 emissions (prices for CO_2 emission allowances) to different degrees. The higher the included CO_2 price, the lower the additional generation costs, and, hence, the lower the negative impacts on jobs in the total economy. Up to now, CO_2 is the most dominant environmental effect so that other environmental or health impacts are not taken into account (ISI et al. 2010).

- There is a large impact from **supplying biomass fuel**. One share of biomass fuel is a residual or by-product, while other shares are not officially produced (shadow market). Therefore, special attention needs to be addressed to the origin of data on (domestic) fuel supply or assumptions about the share of biomass fuel that is officially registered, as well as assumptions about the labour coefficients for producing biomass fuel.

- **Economic and demographic growth,** as well as improved **energy efficiency,** influence the demand for energy, which, in turn, affects prices. Therefore, assumptions about growth and efficiency changes are also crucial. They should be based on assessments of internationally acknowledged organizations or institutions.

- **Type of model**: The model type or characteristics as well as the parameters' development might affect the results slightly, but such variations cannot be ruled out completely.

A.4 Input-output model

This chapter contains some selected information on input-output tables and input-output models. Additional information can be found in, e.g. Miller/Blair (2009).

A.4.1 The quantity input-output model

Box A-1: Some concepts and definitions of input-output modelling

Box: Some concepts and definitions of input-output modelling

The costs of RE use are derived from company data that need to be translated into output data according to the concepts of national accounting that are used in IO analysis. The following offers a brief introduction to some of these concepts and definitions. More detailed information can be found in the conceptual framework of the System of National Accounts (UN 1993)

Output: value of industry output, roughly calculated as turnover corrected for changes in stock of final products and minus expenditures for merchandise. The output of some industries is calculated differently:

- Trade companies: output here refers to gross margin, i.e. turnover minus purchase cost of merchandise.
- Banks: here, it is important to mention that the income from interest does not fully count as part of output. Interest payments are split into two parts, the larger part being a transfer payment between the capital-giving party and the capital-taking party and the smaller part a service for the bank.
- Insurances: similarly, income from insurance premiums is split into two parts: a distributive part covering the insurance claims and a service fee for the insurance. If, e.g. operation of a wind power plant is insured, it is important not to treat the complete insurance premium as the output of insurances, but only the service fee part.

Intermediate inputs: goods and services purchased from other companies needed for a company's own production activity. Does not include purchase of merchandise meant for sale; also does not include the purchase of investment/capital goods.

Gross value added: balance between output and intermediate inputs; comprises compensation of employees, depreciation, taxes and operating surplus.

The main database for an input-output model is an input-output table that distinguishes a number of industries in a country's economy and displays the flow of goods and services between these industries, and from the industries to private households and the other components of final demand in monetary units. For each industry, the supply of goods to other industries and final demand is represented in a row in the IO table (IOT). The columns contain data on the cost or input structures of every industry, as well as information on gross value added. Gross value added is often further disaggregated into compensation of employees (wages), depreciation, net production taxes and operating surplus. There are different types of IO tables (see e.g. Miller/Blair 2009, p10ff for further details). Usually the symmetric IOT is used for the kind of multiplier calculations presented in these guidelines.[22]

Table A.4–1: Structure of an input-output table

	Intermediate demand	**Final demand**				
	Industries 1 . . . n	Private household consump-tion	Gov. consum-ption	Invest-ment	Ex-ports	Total out-put x
Goods produced by domestic industries 1 ... n	Z	F				
Imported goods						
Gross value added v						
Total input						
Employment						

The information on the interdependencies between industries and some additional assumptions allow us to calculate the total production in an economy induced by a certain demand for goods with a linear model. In technical terms, this model is called the open static Leontief quantity model. With this model, it is possible to calculate multipliers for each industry which yield the total output in the economy triggered by one unit of final demand for that specific industry’s goods.

To explain how to calculate the multipliers, mathematical notation are used, following Miller and Blair (2009):

The matrix containing the intermediate use of goods by industries is called the transactions matrix Z. The vector x denotes the output vector. With Y being the final demand matrix and i^Z resp. i^Y being unity vectors used for summing across columns, the relation between these variables is the following: output x is equal to the sum of intermediate demand and final demand.

$$x = Z i^Z + F i^F$$

22 In symmetric IOT sometimes the term homogeneous branches is used instead of industries. For reasons of simplicity we solely use the term industries in the context of IOT.

The input coefficient matrix A is calculated by dividing the intermediate inputs by output:

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

The matrix C; called the total requirements matrix (or the Leontief inverse); is then calculated as

$$C = (I - A)^{-1}$$

Each element c_{ij} of this matrix contains a multiplier that denotes total (direct and indirect) output in industry i triggered by a unit of demand for the good j. The column sums of the Leontief inverse denote total output in the economy triggered by a unit of demand for the good j. These output multipliers can be extended to the labour required. With e being a labour coefficient vector showing labour requirements (in full-time equivalents) per unit of gross output, the matrix of total labour requirement multipliers is calculated as

$$E = \hat{e}\,(I - A)^{-1}$$

A.4.2 The price input-output model

The input-output table reflects the monetary value of the inputs and outputs that are assembled on the basis of recorded transaction quantities z_{ij} and prices P_i. In a price model, it is assumed that the unit price P is: P= 1. The input-output table of a price model is depicted in Table A.4–2: [23] (see Moosmueller 2004, p 295ff).

All inputs of the processing industries and the payment sectors (labour, depreciation, etc.) add up to the sum of the k_{th} column which is equal to the sum of the i_{th} row: $P_iX_i = P_kX_k$ for i = k. Therefore one can write for each column k:

$\Sigma_i(a_{ik}X_kp_i) + v_kX_kP_v = x_ip_i$

with a_{ik} *and* v_k *as input-output coefficients for intermediate inputs* a_{ik} *and primary inputs* v_k*.* P_v *represents the price for the primary input.*

Dividing this equation by X_k, applying the matrix notation and rearranging the equation, one gets:

$p = (I – A')^{-1}\, vP_v$

with A as the intermediate coefficient matrix, v as the vector of primary coefficients, I as the identity matrix and P_v *as the price for primary input v.*

Any change in P_v results in a change of P_i (= Vector p) for all outputs. By including household consumption (not all primary inputs or final demand) and earnings into the coefficient matrix, consumption yc becomes endogenous. Furthermore, electricity prices P_e have to be exogenous to be able to calculate their impact. Therefore, the electricity sector will be excluded from

23 See Miller and Blair 2009 p41ff for details on the price model.

the coefficient matrix and becomes exogenous (see Miller and Blair 1985 p 27ff). The equation for each column k becomes:

$$\Sigma_i (a_{i\text{-}e+c,k\text{-}e+c} X_{i\text{-}e+c}\, p_{i\text{-}e+c}) + v'_k X_k P_{v'} + a_e X_e P_e = x_i p_i$$

where "-e+c" refers to the input coefficients now including the sector household consumption c and excluding the sector electricity e in the rows and columns. Pv' and v' represent the price and coefficient of primary input without consumption, P_e and a_e the price and input coefficient for electricity, respectively.

Rearranging this equation and solving it for p yields:

$$p = (I - A')^{-1} (v'P_{v'} + a_e P_e)$$

where A' represents the coefficient matrix with the sector household consumption and without the sector electricity, a_e the input coefficient and P_e (scalar) the price for electricity.

Table A.4–2: Scheme of a (price) input-output table

	Intermediate demand $z_i P_i$	**Final demand F P_i**				**$X_{i.} P_i$**
	Industries z_{i1} P_1.... z_{in} P_n	Private household consump-tion	Gov. con-sump-tion	In-vest-ment	Ex-port	**Total out-put**
Goods produced by do-mestic industries $z_k P_k$ z_{1k} P_j ... z_{nk} P_j	Zij P					
Imports						
Taxes, ...						
Labour V_k						
...						
Total input $X_{.k} P_k$						

A.5 Comprehensive economic models

Table A.5–1: Features of economic models

Model types	Equilibrium models, macro-econometric models and system dynamics models
Theory	• Neoclassical theory • Evolutionary theory • Keynesian (demand) approach, • Endogenous growth theory
Goal	• Optimisation • Simulation of past, present, future to show effects of e.g. policies
Application	• Depicting changes with high degree of sectoral detail • Predicting overall level of economic activity • Analysing impact of changes in relative prices
Approach	• Top-down & bottom-up • (Sequential) dynamic, static • Based on fixed relations or endogenously/exogenously adapted relations • Simulation of situation sequential or simultaneous • Interactions between systems' elements or economic agents via feedback loops (positive and negative)
Assumptions	• Efficient markets (market clearance) --> no inefficiency • Optimisation-oriented (firms, households) • Bounded rationality
Functions/equations	• Supply and demand functions, production and utility function with CES • Definition equation, behavioural equations --> highly aggregated data, simplistic equations could lead to inaccuracies or inconsistencies • System with a set of elements and a set of relations per element --> determination of system borders and exogenous variables
Parameter determi-nation	• Calibration (replicating dates of base period) • Exogenously determined • Econometric estimation (based on historical data)
Depiction of ineffi-ciencies	• No – yes • Can be measured with suitable variables (especially for taxation)
Closeness	• Exogenously/endogenously determined macroeconomic data e.g. exogenous demand or factor income determines final demand
Expectation	• Expectation based on past and recent realisations • Inter-temporal optimisation (based on perfect foresight) • Exogenous modelling of technologies and preferences
Reality content (re-garding time period)	• Short-term, short to medium term, long-term
Drivers/Focus on	• Price effect • Demand effect
Further aspects	• Depiction of first mover advantage • (Partly) endogenous technical change • Double dividend, ...

Annex 2: Gross employment figures

In Annex 2 the RE employment impacts for the IEA-RETD countries and Tunisia are depicted that result from an increased RET deployment in these countries. The assessment is based on the gross IO-model described in these guidelines and depicts the results for all IEA-RETD countries in country fact sheets. Besides, detailed input and output data is available in a separate excel file for each IEA-RETD country.

For the country fact sheets and data, please see the separate documentation: the Annex 2 report and the county specific excel sheets. All available at: http://iea-retd.org/employ.