Guidelines for employment impact assessment of renewable energy deployment - gross employment studies

Contribution to the special session: "Renewable energy policies – modeling challenges and economic results"

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Abstract:

The use of renewable energy (RE) sources plays a significant role in increasing the security of energy supply and mitigating climate change. Whereas this role is undisputed, there is an ongoing discussion about the employment impacts of promoting RE deployment. In the past years several studies have aimed at clarifying this issue, but the results differ widely, partly due to different methodological approaches and data sources. This paper presents the outcome from a project commissioned by IEA-RETD to develop and test methodological guidelines that intend to streamline employment impact studies and to increase transparency and comparability of results among studies. The paper focuses on guidelines for gross employment studies aiming at capturing employment in a country related to renewable energy use and presents two approaches that are able to capture RE related employment. The approaches are illustrated with examples and results from case studies for several IEA member countries.

Keywords: *Renewable Energy, Gross employment*

1. Introduction

Promoting the use of renewable energy (RE) is universally recognised as an important part of energy policy. The impact of RE promotion on employment is an important issue of public interest that has been analysed in a large number of studies. These studies were conducted using a large variety of methodological approaches to answer differing questions which made the discussion and comparison of the results difficult. Given this situation, the IEA-RETD has commissioned a project to develop methodological guidelines to assess the employment impact of renewable energy (RE) use with a focus on electricity generation from renewable sources. The purpose of these guidelines is to present a framework for assessing employment impacts of RE deployment in a structured and coherent way and to help increase transparency and comparability among these kinds of studies.

In the first phase of the project the existing employment assessment studies and the applied methods were reviewed (Breitschopf et al., 2011)[1]. Since the studies address rather different questions, it was concluded that the guidelines should distinguish between two principal types of employment assessment studies, "gross and net employment impact studies". For each type of study two methodological approaches are proposed in the RETD guidelines, in total four approaches (Breitschopf et al., 2012). This paper introduces the guidelines for gross employment studies and presents the results of exemplary calculations for several RETD member countries.

[1] published at http://iea-retd.org/archives/ongoing/employ

The structure of this paper is as follows. Chapter 2 introduces the objectives of gross employment studies and the two types of approaches. Aspects related to the definition and system boundary of the RE industry are mentioned in chapter 3. The guideline for the employment factor approach is introduced in chapter 4, that of the gross IO modelling approach in chapter 5. In chapter 6 the strengths and limitations of the approaches are discussed. Finally chapter 7 contains the results of the exemplary calculations for several RETD member countries.

2. Gross employment studies – objectives and approaches

Gross employment studies focus on employment in a country that is related to the use of renewable energy. The core is employment in the RE industry which can be seen as a cross-sectional industry that includes all economic activities specifically related to RE use (i.e. installation of new RE facilities, operation of RE facilities and supply of biomass). Furthermore, indirect employment in the upstream supplying industries is also considered. Thus, the study points out the relevance of the RE industry within the economy of a country with respect to employment. A study of this type also allows structural analysis of the RE industry, highlighting the importance of the different technologies (solar, wind, etc.) or the relevance of domestic RE use vs. exports as drivers of the RE industry's level of employment. This also allows an assessment of the specific strengths and weaknesses of the RE industry and may point to options for industry promotion. Apart from the current status, the development of the RE industry as a consequence of RE promotion can be monitored or forecast with the help of scenarios.

Net employment impact studies on the other hand analyse whether the (increased) promotion of RE deployment through policy measures will on balance have net employment benefits or costs for a country. Hence, the "impact" is expressed as change in employment due to policy measures whereas gross employment studies refer to the absolute number of RE related jobs in a country. The guidelines for net employment impact studies are presented in a separate conference paper.

Two approaches for gross employment studies are proposed in the RETD guidelines, the employment factor approach and the gross input-output modelling approach:

- Employment factor (EF) approach: from a methodological viewpoint, this is the simplest approach. It combines data on installed capacities and power generation for each RE technology with employment factors that reflect direct employment in the RE industry. The consideration of indirect employment in upstream industries is generally not included.
- Gross input-output (IO) model: In this approach, data on expenditures for domestic RE use and RE-related exports is combined with input-output modelling to calculate direct employment in the RE industry and indirect employment in upstream industries. It relies on the input-output table of a country that captures the economic interdependences between industries. IO modelling know-how is required for this approach.

3. 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. We propose the following definition:

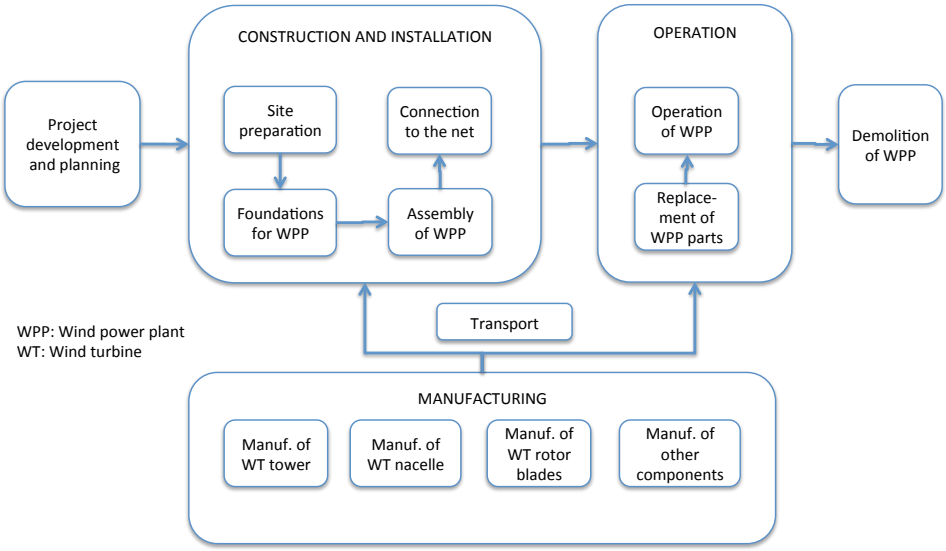
The RE industry includes all economic activities that are related to and are sufficiently characteristic or specific to RE use.

Whereas in economic statistics industries are usually grouped as enterprises that produce similar goods, the RE industry (RE industry) can be seen as a cross-sectional industry that includes economic activities that are closely related to the use of RE. The term "use of RE" ideally comprises the complete life cycle of RE facilities, where we can roughly distinguish the construction, the operation and the demolition phase. The life cycle consists of various activities (see figure 1 for an example of a wind power plant (WPP)):

- project development and planning,
- site preparation,
- manufacturing of the various components needed for the RE facility,
- construction and installation of the facility,
- operation and maintenance (O&M),
- replacement of parts during the operation phase, after their defined lifetime has been reached,
- and finally demolition of the RE facility.

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 wind turbine, manufacturing of other components needed to put the wind turbine into operation, as well as the connection of the wind turbine to the net. Before constructing the wind turbine on site, the various components have to be manufactured and transported to the site, i.e. the tower, the nacelle and the rotor blades. Each of these components is made of various sub-components that need to be manufactured. The further upstream we follow the supply chains, the less specific the components are with regard to the RE technology (e.g. steel for wind turbine towers may also be used for other products). At some point it is necessary to draw a boundary between activities counted as part of the RE industry and activities belonging to the rest of the economy.

Figure 1: Example of life cycle phases of a wind turbine and related activities



Source: own depiction

The RE industry thus includes several branches or enterprises which are involved in the life cycle of an RE technology:

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

This guideline focuses on RE technologies for electricity generation. A list of technologies can be found in the guidelines. Some of the listed technologies can only partly be considered as belonging to RE use. This includes 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 with a "RE share". The guidelines contains some detailed considerations of how to handle these technologies when calculating RE related employment.

4. Employment factor approach

The employment factor approach allows estimating the level of direct employment related to construction and operation of RE facilities in a country. From a methodological perspective, it is relatively straightforward. The approach is good at giving detailed outputs on the type of jobs created, and enables relatively quick monitoring of RE-related employment in a country or quick extrapolation for different energy scenarios. It generally does not include indirect effects.

Methodological approach

Basically, with an employment factor approach, the job impacts of RE deployment and use are estimated by multiplying physical activity data with employment factors. The employment factor relates employment to activity data. The approach is explained for the calculation of jobs in a country and a certain reference year. It can also be applied to any other region 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 and type of activity:

- For activities in the construction or demolition phase of RE facilities, the denominator usually is the new installed capacity or demolished in the reference year (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) would be appropriate.

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 persons with different workloads. Less common, but possible, is the use of working hours. The unit of the numerator also depends on the kind of activity:

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

Calculation steps

The employment factor approach includes the following steps. More detailed explanations of these steps can be found in the RETD guidelines.

(1) Determine the system boundaries of the RE industry in the respective country: Specify the RE technologies and, for each technology, the life cycle phases and activities to be considered in the employment analysis (see figure 1 for an example of a wind power plant life cycle and the main activities involved).

(2) Determine activity levels and employment factors

- Determine for each technology and each activity the value of the activity parameter, to which the employment factor is related. For activities that span across more than one year, the activity value should be divided by the duration of the activity (in years).
- The activity parameter usually refers to RE facilities in a country. Yet, for employment in the construction phase, the activity of domestic RE companies is relevant. Imported technology components for domestic RE facilities don't lead to domestic employment. On the other hand exports for RE facilities abroad do generate domestic employment. Therefore it is important to subtract imports and add exports when determining the activity levels.
- Determine the appropriate employment factor for each technology and each activity.

(3) Calculate employment and display results

- Calculate employment for each technology and each activity by multiplying the domestic activity level with the respective employment factor.
- Aggregate the calculated employment numbers 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 life-time of the RE facility and displayed in FTEs. For each reference year they can simply be added to give total employment in that year.
- Document the chosen system boundaries, the calculation steps and the results.

Data requirements and data sources

The following table gives an overview of the required data and possible data sources.

Table 1: Data requirements and data sources for the employment factor approach

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 • 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 (UN Comtrade) • 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

Table 1 (contd.): Data requirements and data sources for the employment factor approach

Data	Unit	Sources	Remarks
Employment factors	• FTE(-years) / MW • FTE(-years) / GWh	• Labour requirement analysis • Technology cost analysis • Enterprise surveys • Expert judgement	• Per technology and activity • Cost decline for future reference years

5. Gross IO modelling

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, that 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. We propose not to include induced effects in gross employment studies. These would represent the employment triggered by consumption expenditures of persons employed in the RE industry and in supplying industries. The guidelines assume that the readers are familiar with IO modelling and the standards of national accounting, since this knowledge is a precondition for applying this approach.

Methodological approach

Gross IO modelling combines technical-economic data on RE technologies with input-output modelling. One major starting point are the expenditures for capacity expansion, replacement and operation of RE facilities and the related cost components, 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.

Input-output tables are a key database for this approach. Extended with sectoral employment data they allow to calculate total employment multipliers needed for calculating indirect employment.

Calculation steps

(1) Determine system boundaries (similar to employment factor approach, see above)

(2) Determine expenditures for RE use: these include investment expenditures for new RE facilities, expenditures for the operation of existing RE facilities and possibly demolition expenditures for facilities that have reached their end of life.[2]

- Collect the physical capacity, input and output data necessary to calculate the expenditures for each technology in the reference year. For the calculation of investment costs, the new capacity installed is relevant. It can be calculated as the sum of net capacity increase and capacity replacement. For activities that span across more than one year, the activity value

[2] Since demolition is not relevant for most technologies in the current growth phase, it is excluded from the further description of the calculation steps

should be divided by the duration of the activity (in years). For the calculation of operating costs (including costs of biomass supply), data on total installed capacity and electricity generation in the reference year are needed.

- For each technology, collect specific installation costs, O&M costs and costs of biomass supply.
- Calculate the expenditures for installation, O&M and demolition for each technology by multiplying the physical data with the respective specific costs.

(3) Calculate domestic output by RE technology and industry

- 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) that can be related to certain economic activities. Thus data on cost structures of investment and O&M expenditures are needed for each technology and each life cycle phase (see data requirements below).
- Determine, at the cost component level, import shares which indicate the share of goods or services that are delivered from outside the country or region under consideration.
- Determine exports of RE-related products. These can only be partially identified from trade statistics (e.g. wind turbines, hydro turbines, fuel wood), since 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.
- Subtract imports from expenditures and add exports to obtain domestic output for each economic activity related to a cost component.
- Allocate the domestic output for each economic activity to the appropriate industries as represented in the input-output model. The allocation of expenditures to supplying industries can be seen as the interface between the technical-economic information and the IO model. Expenditures need to be transformed into output values used in the IO model.

(4) 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 in 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 hydro power 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 expert opinion.

(5) Calculate indirect employment in upstream industries of the RE industry: the respective matrix multiplication formula are given in the guidelines

- Calculate intermediate inputs by RE technology and industry
- Calculate total indirect employment by RE technology and industry by using a matrix of total employment multipliers derived from the national input-output table and sectoral employment data

(6) Aggregate the calculated employment numbers to display results, e.g. by technology and by life cycle phase.

(7) Document the chosen system boundaries, the calculation steps and the results.

Data requirements and data sources

The following table gives an overview of the required data and possible data sources.

Table 2: Data requirements and data sources for the gross IO modelling approach

Data	**Units**	**Sources**	**Remarks**
Capacities and energy generation: • Total installed capacity (year t and t-1) • Annual installed capacity • Annual power generation	MW, GWh	• Official national or international statistics (IEA)	
Specific costs: • Installation • O&M • (Demolition)	e.g. EUR/MW; EUR/GWh	• Specific techno-economic studies, feasibility studies • Enterprise information • Industry experts	• 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 structures: • Shares of cost components • Allocation to industries according to the IO model	%	• Techno-economic studies • Enterprise information • Industry experts	• Rarely published, • Adaptation of available data to country-specific situation
Employment and IO data: • National input-output table • Sectoral employment (compatible with IO table)	EUR, FTE/EUR	• Official statistics on IO table • Labour surveys	• Use most detailed and recent IO table available
Import shares and exports	%, EUR	• Trade statistics • Enterprise surveys • Industry associations • Technical literature • Industry experts	

6. Strengths and limitations of the approaches

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 are determined, using the approach is straightforward. Furthermore, the personal and financial resources needed to do such an assessment are not very large, if appropriate employment factors are available. Monitoring the RE industry or extrapolating results are easy to accomplish.

Unfortunately, there are only a few basic data sources that are used to derive employment factors, and the published employment factors for the same technologies vary greatly between the sources. In many cases, the generation of employment factors is poorly documented, so that definitions or the system boundaries of technologies are not always transparent. An 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) needs to be covered from other sources, e.g. market intelligence, company surveys or expert opinion.
- It is difficult to capture activities by specialised upstream suppliers (e.g. manufacturers of generators or gears for WPP) or equipment manufacturers (e.g. manufacturers of equipment for PV module production) that are not directly involved in RE deployment, since it is difficult to capture their economic output in physical units (MW, GWh) and since employment factors are generally not available.
- Indirect and induced impacts cannot be covered using this approach. Here results from the gross IO modelling approach could be transferred.

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. A limitation of this approach is caused by 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 or 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.

7. Results from country case studies

Employment numbers are currently being calculated for the RETD member countries with the gross IO modelling approach. They will be presented at the conference and integrated in this paper at a later stage.

8. References

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