Employment assessment of energy transition scenarios

Technical file #12

Information and recommendations for scenario producers

This document is part of a set of 12 technical files. These files have been produced by *The Shift Project* after nearly 2 years of research and experts consultations on the different aspects of energy transition and the future studies around these aspects.

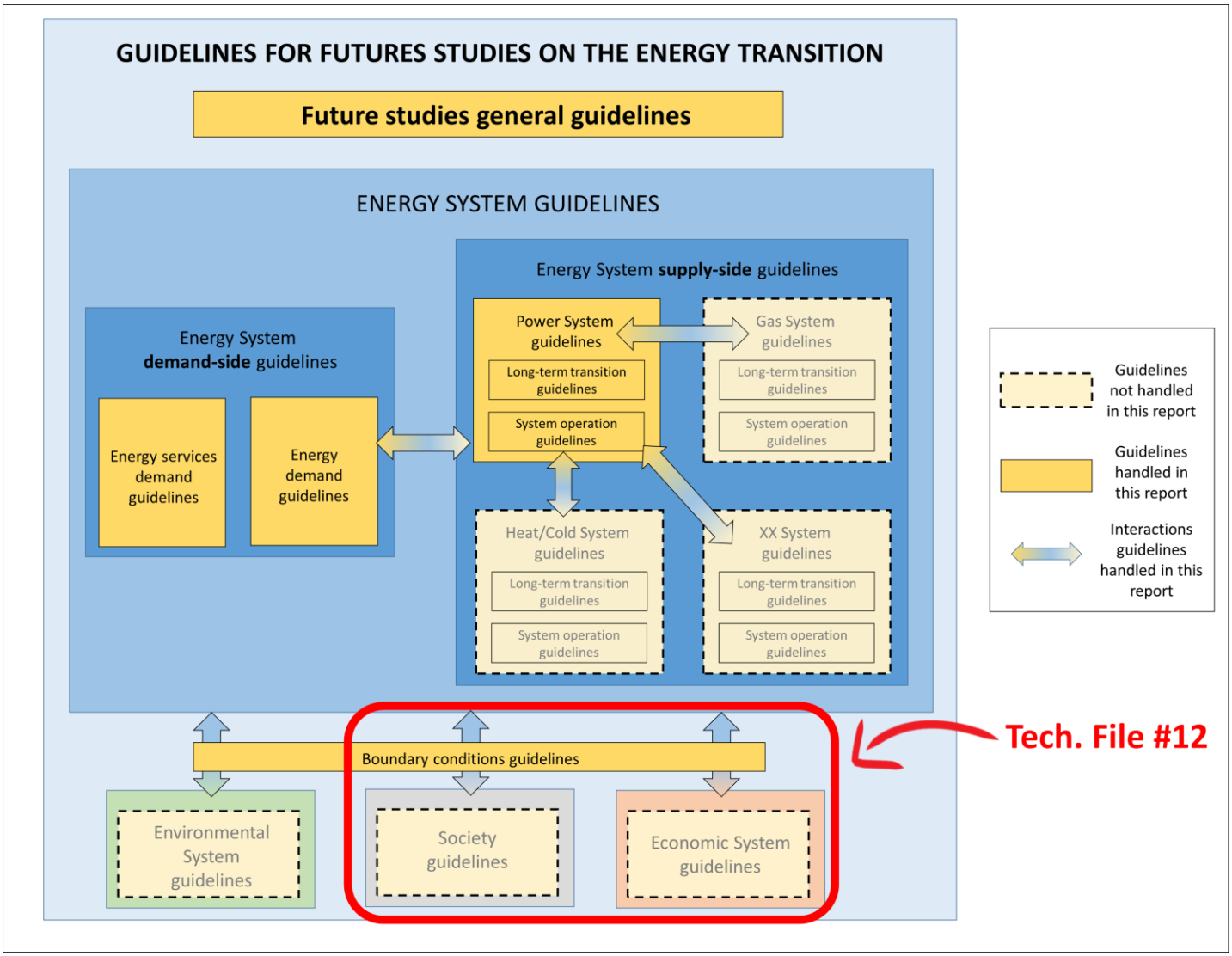
Our project, "Power Systems 2050 – Guidelines for future studies on energy and power transitions," started in January 2018, involved approximately 60 experts through interviews and workshops, reviewed more than 300 works, including about 20 future studies. The objectives and approach of this project are discussed in the executive summary of the framework.

Several aspects of the energy transition are handled in these technical files. However, **on the energy supply-side only the power system has been studied**. The main reason for this choice is that we had to start from somewhere with limited resources, and the power system seemed to be a key system to study in the energy transition context, towards a low-carbon economy, as shown by the growing number of future studies focusing on this system. However, the guidelines we propose could be completed by analyzes on the other energy supply-side systems (the gas system, oil system, heat system and so on).

Each technical file tackles several aspects of future studies for the power (and energy) transition. Here is the complete list of the technical files produced during the project:

#	Technical file title
1	Future studies on energy transition
2	Energy transition models
3	Boundary conditions for energy transition scenarios
4	Long-term evolution of energy consumption in energy transition scenarios
5	Lifestyles and consumption behaviors in energy transition scenarios
6	Long-term evolution of the power system supply-side in energy transition scenarios
7	Power system operation in energy transition scenarios
8	Impact assessment in energy transition scenarios
9	Transition desirability in energy transition scenarios
10	Environmental assessment of energy transition scenarios
11	Economic evaluation of energy transition scenarios
12	**Employment assessment of energy transition scenarios**

Altogether, these files cover the fields described on the following map of the guidelines for future studies on the energy transition. The document you are reading covers the red-circled topics.



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Reading keys

Explanation box, containing key information for a better overall understanding of the subjects.

Recommendations for scenario producers:

These boxes contain the recommendations for scenario producers.

The word "should" means that scenario producers, if they are to follow the guidelines, must substantiate the corresponding point. The words "may" or "might" relates to suggestions, ideas to help the scenario producer respond to the point.

Questions in italic are examples of questions scenario producers might ask to substantiate the points. They are here in an illustration purpose.

Phrases in italic in the text are words which are being defined and will be subsequently used in the framework.

Phrases which are highlighted in yellow refer to other technical documents of this series.

I. Discussing key aspects on employment transition

1. Discussing job *need* rather than *impact* on jobs

In future studies, employment assessment usually comes after the definition of a pathway. Therefore the term "job impact" is often used, as if the changes in the energy system unilaterally impacted employment. However in the real world **open job positions and skilled workers are needed before** these big changes can actually happen. These are prerequisites. This is why we prefer to use the "job need" designation.

2. Employment is a key indicator for political decision makers

Employment is a key indicator for political decision makers if they want to involve people in a strategic choice. Assessing this aspect enables to better prepare the training for people, the infrastructures, training the instructors, for the right economic sectors in the right regions. Many future studies already assess employment while some others don't.

As pointed out by (Perrier & Quirion, 2017b), although this indicator is less systematically studied than cost indicators, **it may have an equivalent importance in the public debate**. A policy with a real or perceived negative impact on employment could be disqualified.

This importance given to the employment assessment of scenarios can partly be explained by the high unemployment rates currently experienced in some countries (sometimes for decades), as unemployment can raise strong desirability issues.

3. Enlarging discussions from purely quantitative global net employment needs to qualitative global job management issues

When assessing employment, several indicators are useful to enlighten public debate.

Quantitatively speaking, the **global net employment need** is a useful indicator as it enables to easily compare two scenarios. *Which trajectory has the highest need for employment? Are the two values close or very different?* Stakeholders can then decide which situation they prefer according to whether they prefer more or fewer jobs in such or such sector in the future.

Quantifying employment needs requires in the first place to define a "job." A job is usually associated with a "working person". But that person could very well be at work 10 hours a day, 6 days a week since the age of 10, or 35 hours a week for 40 years.

Global net employment need is not the only indicator that matters, and not necessarily the most important one.

Indeed, a transition in employment is above all a need in **global job management**. Global job management is required both to handle the need for skills in the case of job creations and for people management in the case of job destructions. In that respect, the **qualification level and skill level of jobs** is an important driver of the dynamics of the work structure change: the higher the skills and qualification of a job, the more inertia in the creation of that job (a longer training is required), and the more inertia in its destruction (acceptance issues are greater).

The **sectoral distribution** of the creation and destruction of jobs, as well as their **geographical distribution** are key elements to better inform this global job management. It is this level of details that enables to build a detailed and concrete narrative, making it possible to discuss the desirability of the proposed trajectory with the stakeholders.

Job stability is another important element with regards to acceptability of the work structure transition.

We do not tackle the key issue of the repartition of jobs among the population in this section. Some aspects of it are handled in the section about desirability. In this section we rather discuss the implications of an energy transition on employment.

Recommendations for scenario producers

A study strategy about employment needs assessment should be made explicit. If the subject is covered, the following aspects should be considered (detailed recommendations are provided in the dedicated sections):

- Quantitative employment needs along the scenarios. What is called a "job" in the employment assessment should be defined. It should be ultimately expressed as a total number of hours of work, typically by providing a workload per year and a corresponding number of years. *What is the workload of a full-time equivalent (FTE) job? How many FTE over how many years are required?* E.g., if building a new section of cycle path requires 3000 hours of work, it requires 2 FTEs of 1500h/year for 1 year.
- Qualitative insights about global job management evaluation. This concerns both the need for skills in the case of job creations and people management in the case of job destructions. This can be enlightened thanks to an evaluation of sectoral and geographical distribution of the creation and destruction of jobs, and an evaluation of the skill and qualification level of the considered jobs.
- Insights about the stability of the jobs along the scenarios.

In the end, all these elements should be used to build a concrete and intelligible narrative for stakeholders so as to discuss the enabling conditions and the overall desirability of the proposed trajectory.

These different elements will be discussed in this following parts: first, considerations on global job management are presented and then methodologies on quantitative assessments of employment needs are discussed.

II. Considering global job management in scenarios

Transitions described in scenarios may lead to a job **decline in some sectors** and to **job creations in other sectors**. Proposed transitions may also alter the location of jobs.

Therefore, depending on the **speed of the transition**, emerging sectors requiring labor may hit hiring bottlenecks and disappearing sectors may encounter acceptance issues from their workers. Considerations on global job management, including considerations on job stability, qualification levels and geographical repartition of jobs are provided in this section.

A. Describing skills management for job creation

1. Job need is skills need

We previously explained why 'job need' term could be preferred over 'job impact'. One other added-value of this designation is that it becomes more obvious skills requirement underlies every transition since job need appeals for skills need and more generally for industrial experience (which includes the experience in engineering, production or manufacturing, and the proper organizational culture and infrastructure supporting them).

As (IRENA, 2018) explains it, meeting the human resource requirements of sectors in rapid expansion is an enabling condition for a job transition. It requires to consider **education and training policies** to meet the demand for the skills needs of these sectors.

Indeed, (CEDD, 2013) supports the fact that paying attention to the supply of work and skills is necessary to avoid "bottlenecks". (European Commission, 2011) also insist on this idea: education and training need to be addressed **at an early stage** in order to avoid unemployment in some sectors and labour shortages in others. Change rates for each concerned industry in specific country / region is indeed a key element.

Employment needs management also depends on the **age pyramid** of the concerned population. For example, it is more complicated to mobilize a skilled workforce in a country where a majority of the population is no longer of working age than in a country with a majority of young people.

Taking into account these constraints in the labor markets can have strong impacts in scenarios results: introducing "rigidities" of the labor market in comparison with a "very flexible" situation can have significant impacts on the final results of some studies (Guivarch, 2011).

2. Level of professional skills

Proposed transitions may also induce changes in the required global skill levels, which can in turn have various social consequences.

For example, an energy transition can increase investments in new technologies, which can in turn lead to more demand for people with highly specialized skills. Such a change can have various impacts: jobs requiring specialized skills are usually associated with higher wages, with a higher job quality, but may also lead to a reduced access to employment for women and young people (Cambridge Econometrics, 2011). All these aspects raise desirability issues.

Specialized skills are also associated with a longer education time and thus higher inertia for the skills demand to be met.

Also skills are lost if they are not practiced for a long time. This may be an issue for scenarios showing camel back-shaped curves for skill requirements. For instance, the very fast installation of wind turbines for a decade, followed by maintenance only and then by a full replacement of the installed park at its end of life (requiring installation skills again), would generate such issues for skills management.

B. Describing the global management for job destruction

Just as job need and skill need are an inseparable duo, job destruction cannot go without human resource management so as to prevent citizens to be left-behind, to avoid long duration unemployment and *in fine* to avoid acceptability issues. Inadequate management leads to acceptability issues: the expectation of job destruction can generate strong resistance if not well managed. In other words, when jobs are destroyed support is needed. These are again enabling conditions for a job transition.

Thus, putting special effort on **workers re-training** to enable professional reconversion is a key element. (IRENA, 2018) underlines that an assessment of the occupational patterns and skill profiles in declining industries is necessary to that extent. They then illustrate what concrete measures professional reconversion may require in terms of job security: "Because reskilling and other adjustments is not always certain to succeed, there is also a need to **provide interim support**, such as unemployment insurance and other social protection measures."

These are strong desirability issues of a scenario.

Furthermore, management for job destruction can also be linked to the **age pyramid** of the concerned population. For example, the phase-out of a specific sector is eased when the majority of the workers are old and therefore close to retirement. This has an impact on the 'social cost' of the transition.

C. Discussing the stability of employment

Another notion that may be important is the **stability of employment**. From a total net employment assessment perspective, ten jobs during one year provide the same amount of working hours as one job for ten years. However, this is very different from a job precariousness perspective. Therefore a strong transition on a small timeframe doesn't have the same counterparties as a transition more spread over time.

D. Discussing the geographical repartition of job creation and destruction

As well as sectoral repartition of job creation and destruction, **geographical repartition** is another key element since **all regions do not undergo the same employment transitions**, especially in scenarios with high shares of locally produced energy. This enables to better inform global job management needs and can raise desirability issues.

Such changes in the geographical location of job needs are linked to the availability of skills in the territory or to workers geographical mobility, to the presence of housing infrastructure to host them, and to the ability to properly manage family situations (hosting family members, finding other jobs for family members in the area, places to study and so on).

As summarized in (IRENA, 2018): "The geographic distribution of energy sector jobs gained and lost are unlikely to be aligned. This could introduce challenges for maintaining employment among fossil fuel workers if the focus is only put on retraining within the energy sector. […] **Additional measures such as social protection programs and adequate transition support are critical**." (also see section on desirability)

Geographical location of jobs depend on the nature of the considered jobs. Some jobs are non-relocatable, such as the on-site installation of renewable energies. These jobs directly require to discuss the points we just tackled on geographical mobility of workers and/or local presence of skills for these jobs.

Other jobs are relocatable. In this case, responding to the human resource need is less restrictive because moving jobs and companies in regions hosting skilled workers (inside or outside the geographical scope of the study) is possible.

Beyond the presence of skills and local industry, job location/relocation also depends on the following elements:

- **Competitiveness** of the local industry. In a globalized world based on free movement of goods, services and capital, price has a great influence on industry location choices: if the same good can be produced in

a cheaper way elsewhere, relocation is often considered as a consistent option. This depends in particular on the capacity of the given region to take and keep a lead in the concerned sectors (Centre d'analyse stratégique, 2012; ECF, 2010).

- **Political choices**. Policies can influence job location through subsidies, taxes, bans and obligations, tariffs and so on. This depends on the choices made in the scenario (Centre d'analyse stratégique, 2012).

Note: the cost items described in the section about economic evaluation (OPEX and balance of trade) highly depend on job location: developing a sector locally leads to local job creations (hence to a greater OPEX) and tends to increase exports (hence to a greater balance of trade) while developing it elsewhere does not lead to local job creation and tends to increase imports.

Recommendations for scenario producers

A study strategy about taking into account global job management should be made explicit.

The following aspects should be considered for each scenario, especially when the proposed scenario includes important variations in skills requirement:

- Considered industries: some growing industries may require large needs for skills while other may not. Declining industries may require job destruction management.
- Age pyramid within the considered industries.
- Underlying needs for education and training, as well as skill maintenance*. How to train people? At what pace? How to maintain these skills over time knowing the know-how fades away after years/decades if the skill is not used?*
- Level of professional skills with regards to job quality and access to employment should also be qualitatively addressed. *Will the scenario require higher skilled jobs? What are the consequences on job quality? Would some part of the population be more likely to be excluded from these types of employments?*
- Job location: evolving activities (either growing or declining) may be located in specific regions, requiring to plan for skills being present at the right place. The following aspects should be discussed
    - Regions undergoing significant changes in the number of jobs they host. *Which regions will be most strongly impacted by the transition to employment? To what extent?*
    - Nature of the considered jobs (relocatable or not)
    - Drivers of job location (economic drivers, policies, also see section on boundary conditions)
    - Workers geographical mobility
    - Infrastructure and organization to host new workers (presence of housing, ability to properly manage family situations and so on)
- Policy measures. Policies impacting job location, or policies to support employment transition such as social protection programs, education and training policies may be discussed.
- Desirability issues. Improperly managed job destruction or strong changes in the location of jobs with regards to the mobility capacity of workers, could raise such issues. All the preceding aspects participate in the discussion about desirability issues. *Are some professional reconversions planned? What type of accompanying measures are implemented? In case no accompanying measure is implemented, how are desirability issues handled? How to retrain workers to enable professional reconversion? Are they close to retirement anyway? Which type of support would be needed? Unemployment insurance? Other social protection measures?*

III. Quantitatively assessing employment needs

(Quirion, 2013) and (Breitschopf, Nathani, & Resch, 2012) are the two main sources presenting a review of existing quantitative employment assessment methods used for writing this employment section.

They both explore pros and cons of the several methods they present. (Breitschopf et al., 2012) provides a "methodological guidelines for estimating the employment impacts of using renewable energies for electricity generation" while (Quirion, 2013) provides a review of existing methods, especially those used in future studies, before evaluating the employment need of the study (NégaWatt, 2011).

A. *Gross assessment* informs specific actor's perspectives, *net assessment* can inform system perspective

Energy policies may create jobs in some sectors and destroy jobs in others. Therefore one should first distinguish two main types of employment assessment: **gross assessment** and **net assessment**.

A **gross assessment** focuses **on job creation only or on job destruction only** while **net assessment** takes **both effects** into account.

Assessing a gross effect only may appear as a limitation but it actually **depends on the question** that is being answered (Breitschopf et al., 2012)**.**

Indeed, gross effect can be useful from a specific actor's perspective. (Centre d'analyse stratégique, 2012) gives the example of a study from AREVA evaluating the destruction of employment related to a nuclear phase-out, and another example of a study from SER assessing job creation in the renewable energy industry related to an increase of renewable energy sources (RES) in the mix. In both cases, this kind of gross assessment provides **insights for one specific industry** and is therefore useful from this specific industry's perspective, both for work unions and business owners of the sector.

However, gross effect alone is **not adapted to inform public decision from a system perspective** (see Economic Evaluation section for a detailed *system perspective* definition)

Indeed, when estimating the **global employment need** of a scenario, **net assessment** is better adapted[1] (Criqui, 2013; Quirion, 2013).

We will focus only on net assessment methods in this employment section.

B. Depth of exploration in the value chain to assess employment need

Methods to assess employment needs divide those needs into four main categories.

1. Employment needs in the energy sectors evolve during the transition

Energy transitions may require and affect jobs in different sectors.

Direct jobs are those in the industry sector which is directly mobilized for the proposed transition, typically industry concerned by the core system of the future study (the energy sector, the power sector…). It can include jobs in fuel production, transformation, transport, distribution, construction of infrastructure for the energy system, operations and maintenance of these infrastructure and so on, as well as jobs in production of equipment / appliances which consume energy.

[1] However, not all the net employment assessment methods enable to enlighten system perspective, as explained in the next part.

Indirect jobs generally include jobs in secondary industries which supply the primary industry sector. This is all the supply chain and may include, for example, catering and accommodation. (Rutovitz, Dominish, & Downes, 2015).

In other words direct jobs are those in the branches directly solicited for the transition while indirect jobs are those appearing (or disappearing) within the suppliers of these branches, and their own suppliers, etc.

Effects of the transition on these jobs (called *direct effect* and *indirect effect*) are of a ***technical*** nature: they occur within the energy sector and do not involve any macroeconomic mechanism.

2. Employment needs in other economic sectors evolve during the transition

Transitions of the energy system may induce effects on other jobs, called *induced effects*.

These effects on employment are of a **macroeconomic** nature (see section on economic evaluation, II.C).

From one study to another, the term "induced effect" often takes on different definitions[2], and may sometimes not even be clearly defined. Therefore we will refer here to induced effects as all the effects on employment of a macroeconomic nature that can be calculated alone, that is, independently of other effects.

Once calculated, these effects can be added up 'manually' to direct and indirect effects without going through the use of a macroeconomic model ("full model" approach), as detailed later.

We will later explore several examples of studies assessing induced effects. From one study to another, these effects are sometimes similar, sometimes different, or they can partially overlap.[4]

One example of induced effect: the 'expenses-induced' effect

To give an example, (Quirion, 2013) takes into account an induced effect corresponding to the **jobs created or destroyed by the change in expenses of all economic agents** (households, private actors, the State ...) To remove any ambiguity we will use the "expenses-induced" designation for this type of induced effect. When comparing a transition scenario to a reference scenario, there are two possibilities for these economic agents:

- They can either benefit from cost reductions (e.g. if they consume less energy for heating after insulating of their houses). In that case all the money that is not saved is **reused**, which **increases consumption** in other sectors of the economy (a type of rebound effect). This leads to job creation. These jobs are called here expenses-induced jobs.
- Or, they can have to pay for additional costs. It causes the opposite effect: consumption reduces in other sectors which has a negative impact on employment.

Thus, this effect is not technical but rather macroeconomic. **Expenses-induced effect can be significant**.

Box 1: The expenses-induced effect

The last effects on employment are what we call here *all other macroeconomic effects*, such as merit order effects, multiplier effect, or effects occurring when economy is close to full employment, or when a policy improves the balance of trade, etc. Some of these macroeconomic feedback loops are detailed in the next section.

[2] "Induced effect" designates for example jobs resulting from spending wages earned in the primary energy industries in (Rutovitz, Dominish, & Downes, 2015), while it refers to all the jobs created or destroyed by any macroeconomic mechanism in (Centre d'analyse stratégique, 2012), etc.

[4] This is why we indicate 'some induced jobs' in summary equations and tables.

C. A frame to properly discuss quantitative methods for assessing employment needs

Now that these four types of effects are defined we can express the total net employment need with the following equation:

Total net employment need = Δ direct jobs + Δ indirect jobs + Δ some induced jobs + Δ jobs due to other macroeconomic effects

With Δ = job creation – job destruction (otherwise this would be a gross assessment rather than a net assessment).

Not all employment assessment methods take all these effects into account. As we will see, these methods tends to **gradually add effects** in their assessment which allows to progressively expand the scope of the branches of the economy taken into account.

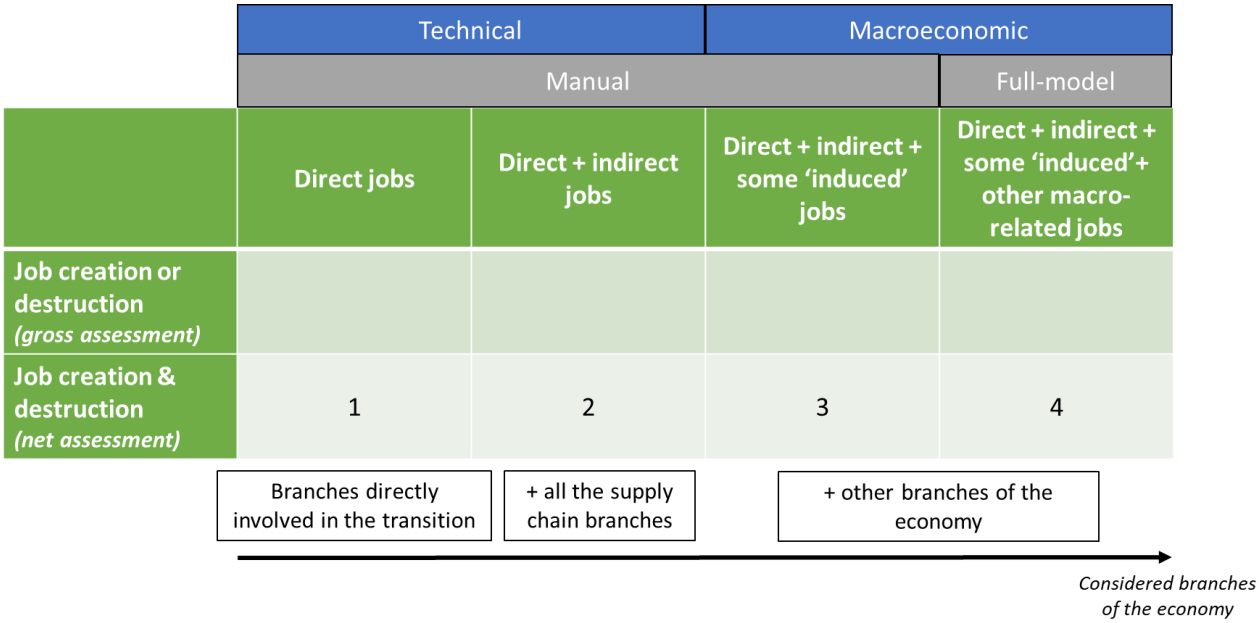


Figure 1: Table representing the different types of methods used for quantitative employment assessments. The further to the right in the table, the more sectors of the economy are included in the assessment and the more effects are taken into account, but the more complex the evaluation becomes. For example, the first column only includes jobs directly involved in the energy transition; the last column enables to take all effects into account but requires the use of macroeconomic models which are difficult to grasp. The two lines distinguish the gross assessment method and the net assessment method. Methods used in future studies can be categorized in this table.
Source: author.

Future studies typically distinguish the methods they use along the following categories:

- technical vs macroeconomic approach, describing the comprehensiveness of the sectors of the economy which are included in the assessment;
- manual or full-model approach, describing the technique to compute job evolution.

These categories are described in the following parts.

1. Technical vs Macroeconomic approaches

Depending on **the scope of the considered branches of the economy**, future studies distinguish two approaches: technical ones and macroeconomic ones (also see section on economic evaluation on this distinction).

The first column provides insights on branches directly linked to the transition. The second column takes in addition all the involved supply chain branches into account. These two types of methods are called **'technical'** because they focus on the **energy sector only** by excluding any macroeconomic effects.

Future studies within our scope and using a technical approaches **focus on the energy sector supply-side** (e.g., oil, coal, nuclear, solar, etc), so they cannot inform a system perspective, which would require to include in addition demand-side (production of cars, TV sets, mobile phones and so on).

Rather, technical approaches on the supply-side only are useful to provide **insights for a set of specific actors**. Unlike gross employment assessment, they make it possible to shed light on both the job creation and job destruction, and thus inform more broadly the various specific actors' perspectives. A dedicated narrative can enable to enlighten the related global job management needs.

Unlike technical methods, the third and fourth columns also assess the employment needs in **other branches of the economy**. They are called **'macroeconomic'** approaches, whether the method is 'manual' (column 3) or 'full-model' (column 4). These approaches include demand-side sectors of the economy. Hence they can inform a system perspective.

In order to properly inform a system perspective, employment assessment inventories (whether technical or macroeconomic) must include activities leading to the proper operation of both supply-side and demand-side of the energy system.

2. 'Manual' vs Full-model approaches

A second distinction between these methods is usually made to describe **the way in which the calculations are carried out**.

A 'manual' process can be followed to assess direct, indirect and some induced jobs. In this process, the employment need for each sector is calculated thanks to employment factors. The different effects (direct, indirect and some induced effects) can be calculated separately.

Alternatively, a macroeconomic model can be used. This type of method is called here 'full-model' approach.

There is therefore **a trade-off between clarity and completeness**. On the one hand, full-model approach simulates all macroeconomic effects (as represented by the theory behind the model) hence seems to provide information on a larger spectrum of the economy. On the other hand, manual methods have the advantage of being inherently transparent and relatively simple to understand. Main drivers of the results are typically more easily identified with such method. It makes it easier to **build a narrative** around the transition in employment, and thus facilitate **discussion with stakeholders**. Manual methods can be grasped more easily and can therefore be transparently reused for more disaggregated evaluations such as employment need assessment of a transition on a local scale for example, as with the tool (« Outil TETE - Transition Ecologique Territoires Emplois », 2018)

Each method also has other specific advantages and limitations, which are explored in the next section. For example, they all enlighten sectoral distribution of job creation and destruction but not with the same disaggregation level. Sectoral distribution is crucial information with regards to global job management so as to inform the debate with stakeholders.

D. Quantitative methods for a regional evaluation

None of the methods presented in this section seems to directly allow a geographical distribution evaluation of job creation and destruction. However, there are several possibilities to inform this aspect of an employment transition. Such a regional evaluation is performed in (European Commission, 2018; Greenpeace, 2015; IRENA, 2018).

A first method is to **apply the chosen employment assessment method for each given geographical region**. This is for example performed by (Greenpeace, 2015). The study indeed applies their net direct employment assessment method for ten different regions of the world.

Another possibility to illustrate this regional distribution is to **define how the main sectors are distributed across the different regions.** Thus, by identifying the sectors that will be strongly impacted by the transition to employment, it makes it possible to visualize which regions will be consequently impacted. This is performed for example in (European Commission, 2018).

E. General practices on employment assessment in future studies

No matter the type of future study, none of those we reviewed evaluate job need of their scenarios in their core modelling. Instead, the **studies assessing job needs within our scope perform an extra evaluation to this end**. E.g., a modelling of the Institute for Sustainable Futures at the University of Technology Sydney supplements the Energy [R]evolution from Greenpeace (Greenpeace, 2015), (Quirion, 2013) supplements the négaWatt study (Association négaWatt, 2013), ThreeMe model is used for a macroeconomic assessment (ADEME, 2013) of the Visions by ADEME (ADEME, 2012), (Cambridge Econometrics, 2011) modelling is used for a macroeconomic assessment of (European Commission, 2011), etc.

Furthermore, there is no direct link *a priori* between the type of future study and the chosen employment assessment method.

Recommendations to scenario producers

Scenario producers should clearly define the quantitative indicators they selected about employment evolution during their scenarios. They should substantiate their choice of indicator(s) with regards to their study strategy. The following aspects should be covered:

- Depth of the assessment in the economy: what type of jobs are included in the assessment (direct, indirect, induced, all sectors?)
- Inventory of the assessment: to go further than the raw classifications "gross or net assessment", "technical or macroeconomic assessment", an activity inventory should be provided, clearly defining the perimeter of the assessment (see section on impact assessment): *what professional activities are included in the employment assessment?* Discussion about the inclusion of the demand-side sectors in the inventory should be provided. Choice to restrain the assessment to job creations only or job destructions only should be discussed.
- Consistency between the selected inventory, the selected perspective (system or specific actors) and the drawn conclusions and recommendations. E.g., conclusions cannot be drawn on the mining sector if this sector is not in the inventory (unless extra analysis is performed).
- Methodology to assess employment evolutions, and justification of the choice of methodology with regards to its transparency and the concreteness of description it enables. *Is the method used a manual one or a full-model one?*

The strategy on regional assessment should be made explicit and justified with regards to the study strategy. If such an assessment is performed, the type of method used should be described.

Further details on the methods used are provided in the next section.

IV. Uses and limitations of methodologies used in future studies

This section provides in-depth description and discussion about the different methods to quantitatively assess employment we observed in future studies. It provides recommendations for each of them.

These methods all rely on estimates of how many jobs are required to produce physical flows, or monetary added-value, in different sectors of the economy, called employment content (per unit of physical flow, or per unit of monetary added-value). We first discuss the dynamics of employment content.

A. The dynamics of employment content

Employment content can vary greatly from one sector to another. This can have a strong overall impact on the employment need of a pathway. Typically, economic activities that come with transition pathways (energy efficiency, RES, etc.) are usually more job intensive than current energy activities (oil, gas and coal, etc.)

In addition, the **employment content of each sector also changes over time**. As shown through the description of several employment assessment methods in this section, the job content of the different sectors vary over time according to many parameters: evolution of productivity, changes in energy and raw material prices, locality of employment, etc.

Recommendations for scenario producers

The job content of each sector is different, and evolves during the scenario timeframe. Thus, the dynamics of the employment content of the several sectors considered should be explained, with a clear narrative to illustrate evolutions of these values, and their influence on the main results of the employment assessment.

What are the most employment-intensive sectors? How do some changes observed within the scenario timeframe impact the job content values over time? To what extent do these trends influence total employment need?

B. Transparently describing technical methods to assess employment

This part provides a description and discussion about the two technical types of employment assessment methods. The first one takes only direct jobs into account while the second one considers both direct and indirect jobs.

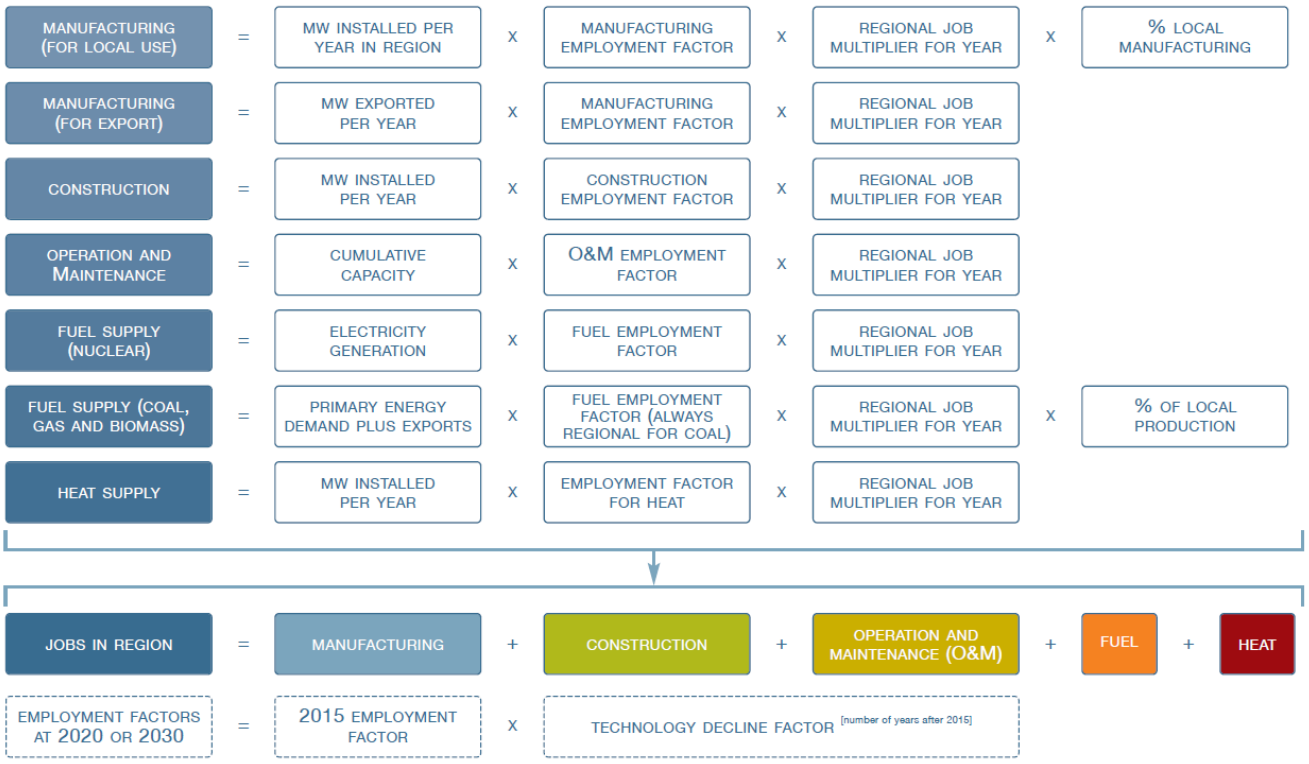
1. Assessing branches directly involved in the transition: net direct employment needs

The first method is a technical and manual one, focusing on direct employment only. The related equation would be:

Net employment need = Δ direct jobs

a. A method based on 'physical' employment factors

This is an approach used in studies such as (Greenpeace, 2015) and (Lappeenranta University of Technology / Energy Watch Group, 2017). They both explain the several steps of their employment assessment. The method behind these two assessments is described in details in (Rutovitz et al., 2015), and summed up by (Greenpeace, 2015) with the following figure:



Source: (Greenpeace, 2015)

Figure 2: Overview of the net direct employment assessment method from (Rutovitz et al., 2015)

Jobs are divided into **seven branches**: manufacturing for local use, manufacturing for exports, construction, operation and maintenance, nuclear fuel supply, coal, gas, and biomass fuel supply, and heat supply.

For each branch there is a **physical need derived from the scenario**: MW installed each year for manufacturing, energy demand each year expressed in PJ for fuel supply, etc.

Each physical quantity is multiplied by a **job factor**, expressed as jobs/MW or jobs/PJ. In order to distinguish this type of employment factors from those expressed in jobs/€ (see next method), we will call them **'physical' employment factors**.

Since these physical job factors are calculated for OECD countries, a regional adjustment is applied where a local factor is not available thanks to a "regional job multiplier". Furthermore, each physical job factor is also time-adjusted thanks to a "technology decline factor" that reflects the increase in productivity over time. Indeed, as technologies and companies become more efficient and production processes are scaled up, the employment content of an activity progressively decreases.

Finally, the results for the seven branches are added together to obtain the final result.

As explained in (Rutovitz et al., 2015), there are still some significant areas of employment which are not included in the evaluation such as jobs in periodic replacements of the plants, jobs in energy efficiency, and a portion of the jobs related to heat supply. This is a transparent limitation specific to this study.

More generally, most of the work of such methodology lies in **estimating the physical employment factors**. As explained in the Limitations section, this can be a complicated task.

Note: this method can also be used for gross assessments such as the estimation of direct job creation need only. (Breitschopf et al., 2012) describes how to perform a gross assessment with this method. This is what they call "Employment factor approach". Further information can be found in (Breitschopf et al., 2012).

b. Limitations of the methodology: indirect jobs are not included and the inventory is not defined transparently

The first obvious limitation of this type of method is that **it doesn't take into account indirect effects**. These are not negligible: as mentioned in (Rutovitz et al., 2015), "The inclusion of indirect jobs would typically increase job numbers by 50 – 100%." It can be noted that the study is transparent on this limitation, which is a good practice.

The second limitation of this approach lies in the way physical employment factors are determined. As (Breitschopf et al., 2012) explains it [bold added]: "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 of the system boundaries of technologies are not always transparent." Results could be very different between two studies using different databases.

(Rutovitz et al., 2015) confirms that a large number of assumptions are required to make the calculations. Indeed, "Quantitative data on present employment based on actual surveys is **difficult to obtain**, so it is not possible to calibrate the methodology against time series data, or even against current data in many regions".

This is related to the fact that there is **no clear separation between direct and indirect jobs**. In other words, the inventory of which activity is included in the assessment is not precisely defined. This blurred lines result in an uncertainty range for the physical employment factors values **for each sector**. Therefore, final results could be strongly biased upwards or downwards.

NB: we could also mention as a third limitation the static nature of physical employment factors, which evolve only under the influence of productivity. This limitation is developed for the next type of method but partly applies to this one too.

Recommendations for scenario producers

When evaluating net direct employment needs, the following aspects should be considered:

- The activity branches included in the job assessment should be listed in an activity inventory.
- Conclusions and recommendations on employment should be consistent with the inventory
- In addition, scenario producers should provide discussion about the uncertainty around the physical employment factors values, especially about the fact that for each sector the distinction between direct and indirect jobs is often unclear. The static nature of physical employment factors should also be discussed.

2. Assessing branches directly involved in the transition and the related supply chain branches: net direct & indirect employment needs

As the previously presented method, this type of approach is also both technical and manual. It enables to consider both direct and indirect effects. The related equation would be:

Net employment need = Δ direct employment + Δ indirect employment

a. A method based on 'monetary' employment factors determined through an Input-Output analysis

The following steps are described in line with explanations presented in (Quirion, 2013).

As with the previous method, different branches are defined and a physical need is derived from the scenario for each branch (let's take the example of MW of installed wind turbines).

Then, a **unit cost** is calculated for each branch (these would be the €/MW value of installed wind turbines). This unit cost can vary over the time to reflect changes in costs in each branch during the scenario timeframe. Compared to previously presented method, **additional information** is required to evaluate these unit costs.

The multiplication of physical need and the corresponding unit cost gives a monetary demand associated with each activity (total amount of € for wind turbine installation).

Each monetary demand is then multiplied by a **job factor**, expressed as **jobs/€**, which will be called here **'monetary' employment factors** in order to distinguish it from physical employment factors (see previous method). The monetary employment factor of each branch is estimated by an **input-output analysis**, which enables to count the jobs related to all intermediate consumption. Indeed, cost implicitly integrates the entire value chain and therefore **both branches directly involved and the related supply branches**. This is the advantage of using monetary employment factors: they enable to take both direct and indirect jobs into account.

This results in the net job needs associated with each branch. All the branches can be added together to obtain the total net result.

This calculation is carried out twice: once for a reference scenario and once for the assessed scenario. Employment need is therefore expressed as the difference between the outcomes for the two scenarios.

This is the method used in (« Outil TETE - Transition Ecologique Territoires Emplois », 2018) for example.

An advantage of this type of method is the possibility of taking into account **a large number of sectors**. This enables a wide range of choices in the way results are presented. Indeed, the results for these numerous sectors can be merged in many ways to provide useful information. This sectoral disaggregation thus enables to **build very specific narratives** so as to better enlighten public debate and the discussion with stakeholders.

Note: as for the previous method, this method can probably also be used for a gross assessment. (Breitschopf et al., 2012) presents a similar method (with a few differences) they call 'Gross Input-Output modelling', for gross assessment. They describe the several assessment steps in detail, with concrete examples. Further information can be found in (Breitschopf et al., 2012).

b. Limitation: the static nature of this method implies additional work and assumptions to make it more dynamic

The main limitation of this approach when applied to future studies is its **static nature due to the use of an input-output matrix**[5] (Cambridge Econometrics, 2019).

Indeed, this matrix reflects the **current functioning** of the economy. Thus, keeping the values contained in the input-output matrix fixed would consist in assuming everything goes as if the economy didn't change during the scenario. This remains true as long as the studied system remains relatively similar to today's system; however it is not necessarily the case.

Simulating an evolution of the functioning of the economy in accordance with the changes happening within the studied scenarios requires the integration of **several phenomena**. However integrating all these elements would represent a **considerable amount of work**, which naturally leads to simplification assumptions.

[5] The previously presented method is also of a static nature, except when it includes the variation of productivity.

Here are three of the main elements that can be made dynamic so as to make the structure of the economy of an input-output matrix evolve[6]:

- **Changes in productivity**. Indeed, as previously explained, employment content of an activity progressively decreases when productivity increases. This parameter should logically be distinguished for each branch and its evolution should depend on changes occurring in each scenario. However, productivity is a complicated parameter to measure. Therefore, there is often a single value for all branches, which is also not distinguished between reference scenario and assessed scenario. In that case, it means productivity is considered exogenous (indeed no matter the changes occurring within the pathways, productivity would evolve in the same way, which means that "something else" outside the scenarios is responsible for the productivity evolution).

- **Intermediary goods prices such as energy and raw material prices**. E.g. if oil price increases, monetary employment factors (jobs/€) of branches related to oil activity decreases. Similarly, if the price of certain raw materials increases, then the employment content related to certain renewable energy branches would decrease for the same reason.

- **Imports-exports situation evolution within single branches**. If part of a branch is offshored, then its monetary employment factor evolves. This is another type of change within the scenarios timeframes that requires additional work to be integrated into the input-output matrix. Changes in monetary employment factors values typically depend on assumptions about the locality of employment. Indeed, job content varies differently depending on whether the job is created locally or not (as explained in the subsection about Regional evaluation).

Recommendations for scenario producers:

When using input-output analysis for employment assessment, transparency on the following aspects should be provided:

- Inventory of the considered activities included in the employment assessment should be provided.
- the static nature of the simulated economy should be discussed. *Is the input-output matrix modified according to changes in productivity along the scenario? Or changes in imports-exports situation? Or changes in intermediary goods prices?*
- In any case, a narrative on the economy should be provided to justify these choices with regards to the driving questions and to the conclusions drawn on employment needs. *Why would productivity increase faster in the assessed scenario compared to the reference scenario? Why value would differ from one branch to another? How is job content affected in my scenario after a change in oil prices depending on the country where job destructions or creations happened?*
- Assumptions about the locality of employment are also important to that extent since it can impact job content greatly.

3. Discussions about technical methods

As previously explained, the two types of methods presented here are both **technical** (since no macroeconomic effect is taken into account) and **manual** (since they do not require the use of a macroeconomic model).

Both types of methods first start the calculation with the physical flows of each considered branch and then uses employment factors.

[6] The first and the third elements (change in productivity and imports-exports situation evolution) can also make physical employment factors more dynamic.

The first approach uses physical employment factors and can be summarized by "jobs = MW(h) * jobs/MW(h)". The second approach uses monetary employment factors and can be summarized by "jobs = MW(h) * €/MW(h) * jobs/€".

Because these are **manual methods**, they are more transparent by nature, which enables better discussion with stakeholders. However, each method has its own limitations, particularly on the values of employment factors.

Because they are **technical methods**, only the branches directly involved in the transition (first approach) and the supply-related branches (second approach) are taken into account.

Hence several branches of the economy are not included within their scopes. These methods **do not enable discussion on the total net job need of a scenario for the whole economy**. Several sources (Breitschopf et al., 2012; Criqui, 2013; Quirion, 2013) seem to share this vision. Technical methods have for example a **cost bias favoring expensive solutions** since they do not assess expenses-induced jobs. Indeed, as explained in (Quirion, 2013): "as Huntington (2009) points out, the most costly technical and organizational options typically create more jobs per unit of energy than the others, but their extra cost will necessarily be paid by economic agents who will consequently reduce other expenses, leading to a drop in activity and to a negative "induced" effect on employment." Similarly, focusing only on jobs in the energy sector does not allow to take into account the employment impact of a change in energy prices or costs. As this is a key parameter for the industry, many jobs creation or destruction are concerned.

C. Transparently describing macroeconomic methods to assess employment

Technical methods provide useful insights about job transition for the professional branches included in the inventory. As technical methods are also manual methods, transparency is more easily achieved. Technical methods are not truly adapted for estimating the total (macroeconomic) net job need. Macroeconomic methods should be preferred for that purpose.

This part provides a description and discussion about the two macroeconomic types of employment assessment methods. The first approach is a manual one and takes direct, indirect and some induced jobs into account while the second one is a full-model approach and considers all effects.

1. Assessing 'technical' branches and some other branches of the economy: a manual method to evaluate net direct, indirect and some induced employment needs

This type of approach is macroeconomic and manual: it enables to manually take some macroeconomic effects into account. These are called induced effects. The related equation would be:

Net employment need = Δ direct employment + Δ indirect employment + Δ some induced employment

Recommendations for scenario producers:

Since the meaning of "induced effect" varies from one study to another, a clear explanation of what is actually assessed should be provided whenever an "induced effect" is calculated.

a. Two methods based on input-output analysis

The two methods that will be presented here **calculate separately direct and indirect effects on the one hand and one or more types of induced effects on the other hand** before adding them together. They also both use input-output analysis.

(Quirion, 2013) method

This first method is described and applied to (NégaWatt, 2011) study in (Quirion, 2013).

Firstly, **direct and indirect effects are calculated thanks to the previously presented approach**, using monetary employment factors determined with an input-output matrix.

Secondly, **an expenses-induced effect is calculated**. As explained in Box 1, expenses-induced jobs are the jobs created or destroyed by the change in expenses of all economic agents: if they benefit from cost reductions, money that is not saved is reused, which **increases consumption in other sectors of the economy**. This leads to job creation. If they have to pay for additional costs it is opposite and it leads to job destruction. Expenses-induced effect can be significant.

Calculating this effect requires **further hypothesis**: *which economic actors will support the extra costs, how will they change their savings and consumption in response to these extra costs?* (Quirion, 2013) assumes that cost variation goes to households and that they consequently change their consumption by the same amount and with a distribution similar to their initial consumption.

In this case, calculating expenses-induced effect consists in estimating the **variation in the amount of household expenditure** on the one hand and the **average employment content created by household consumption** on the other hand, before multiplying the two values. See (Quirion, 2013) for more insights and for the application of this method to a future study.

(Breitschopf et al., 2012) "Net Input-Output modelling" method

This corresponds to one of the four methods presented in the (Breitschopf et al., 2012) methodological guidelines. It requires the use of two types of input-output matrix: a *quantity* IO model and a *price* IO model.

After estimating direct and indirect effects with the quantity input-output model, this method estimates two types of induced effects:

- The first one corresponds to the **changes in household income due to employment in concerned industries**. It is estimated with the same quantity input-output model. This type of induced effect is not taken into account by (Quirion, 2013) method.
- The second one corresponds to the **changes in electricity prices caused by the switch to a new electricity mix**. The price changes are borne by electricity consumers and affect consumption and other production industries. It is estimated with the price input-output model. This induced effect is a portion of the previously presented expenses-induced effect.

Many more insights (detailed calculation steps, data requirements, discussions, etc.) can be found in (Breitschopf et al., 2012).

As they are based on input-output analysis, an advantage of this type of method is the possibility of taking into account **a large number of sectors.** As explained previously, this enables to **build very specific narratives** so as to better enlighten public debate and the discussion with stakeholders.

b. Limitations: some missing effects and a static nature

A first limitation of such approaches is intrinsic to every non 100% technical method: **additional assumptions of a macroeconomic nature has to be added.** For example, in (Quirion, 2013): *Which economic actors will support the extra costs, how will they change their savings and consumption in response to these extra costs?*

A second obvious limitation is that **other macroeconomic effects are not taken into account**, such as feedback loops and interactions between actors, prices, quantities and markets (Breitschopf et al., 2012). Adding them one by one 'manually' would probably be a far too complex exercise. This is why the only way to take all these effects into account is to use a full model-based approach.

Therefore (Quirion, 2013) provides qualitative evaluation and discussion about the magnitude of some neglected macroeconomic effects. It concludes that some of these main missing effects ('full employment' effect and 'elastic' effect on balance of trade balance) should be small given the context of the study (high unemployment and European context), and that the main drivers of the results would remain the same.

Further considerations on the magnitude of these neglected effects are presented in the 'Discussions about macroeconomic' section.

Recommendations for scenario producers:

When using a macroeconomic manual approach, both macroeconomic assumption and magnitude of neglected macroeconomic effects should be discussed.

The third limitation comes from the method used to determine direct and indirect effects. As previously explained methods using input-output matrix are of a static nature and imply additional work and assumptions to make it more dynamic.

Therefore (Breitschopf et al., 2012) study explains Net Input-Output modelling method loses part of its accuracy when applied to depict future effects, compared to a present effects analysis.

2. Assessing all branches of the economy: full model approaches

This type of approach enables to take all macroeconomic effects into account. The related equation would be:

Net employment need = Δ direct jobs + Δ indirect jobs + Δ some induced jobs + Δ jobs due to other macroeconomic effects

a. Three types of model

This kind of assessment is used to evaluate the employment need of future studies such as (ADEME, 2012) though the use of ThreeME model, or (European Commission, 2011) that relies on (Cambridge Econometrics, 2011) to evaluate the net employment effects of the EU's 20-20-20 targets, based on Cambridge Econometrics' E3ME model.

Note: we have not studied this type of method in depth. Other sources such as (Breitschopf et al., 2012) already provide many useful insights. What is presented below is directly based on this source.

There are **three main types** of model-based methods: macro-econometric models, general equilibrium models, and system dynamics based models. Each type has its own characteristics:

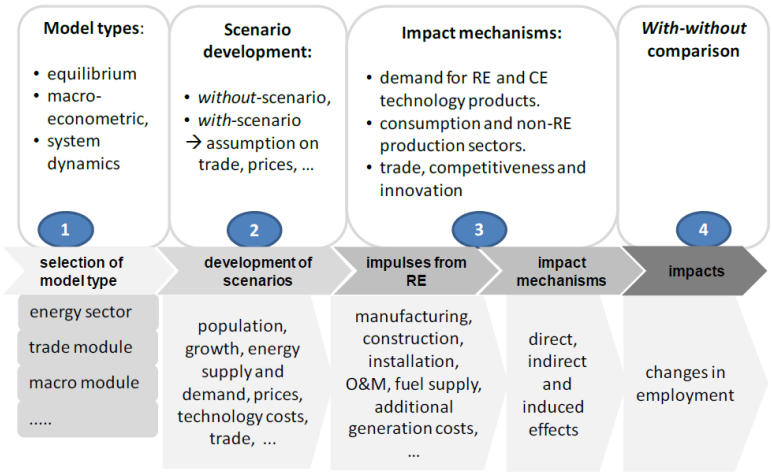
Table 5-4: Overview of model types and their general characteristics

	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)

Source: (Breitschopf et al., 2012)

(Breitschopf et al., 2012) explores in detail this kind of model-based methods. General procedure of such approach is explained and summed up in this sketch (further insights can be found in (Breitschopf et al., 2012)):

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



Source: (Breitschopf et al., 2012)

Data requirement is also explored, as a large amount of data is necessary and assumptions need to be made:

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	GJ/capita % €/GJ GJ/# €/GJ €/GJ km/GJ	National statistics; European Statistics: Eurostat, ...
Transportation per FEC		
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, ...

Source: (Breitschopf et al., 2012)

b. Some examples of macroeconomic effects

Here are some of the main macroeconomic feedback loops that model-based methods enable to take into account (Breitschopf et al., 2012; Quirion, 2013):

- *Full employment* effect. If the economy is close to full employment, a policy that increases the demand for labor will push up wages. If firms consequently lose market shares and / or substitute capital for work this may reduce the initial positive effect on employment by reducing employment elsewhere in the economy.
- *Elastic* effect on balance of trade. After a policy improving trade balance, some mechanisms - especially though exchange rates - can bring the balance back to equilibrium. This also reduces the initial positive effect on employment.
- *Merit order* effect. If electricity price on wholesale markets is set with a merit order mechanism, a policy increasing the share of renewable energy sources would cause a decrease in the power price due to a higher supply of electricity from sources with low marginal costs (shift of the supply curve to the right). And as any price variation would affect household expenses and industry competitiveness, this would have an impact on employment need.

CO_2 price effect, crowding-out effect and multiplier effect are other feedback loops that could be named.

c. Limitations : complexity, less detailed sectoral desaggregation and biases of the chosen economic theory

The first limitation of model-based methods is their **complexity**.

Using such methods implies a greater need for data and know-how, and therefore a higher budget. This complexity also results in a **higher difficulty to identify the main drivers of the results**. Indeed, even if a transparent explanation of the model is provided, too many mechanisms are involved to enable a quick comprehension of the overall dynamic. This complicates the debate with the stakeholders.

The second limitation is that these models do not offer the possibility of taking into account a large number of sectors.

In these models, the productive sector is represented by **a maximum of about fifteen sectors**, compared to 118 in the analysis presented in (Quirion, 2013). Key information can be lost with to aggregated sectors: for example, if jobs in gas and electricity are gathered in the same sector, job evolutions in the case of an evolving share between gas and electricity cannot be properly performed and disclosed. This makes the construction of specific narratives more complicated or impossible and complicates the debate with the stakeholders.

Recommendations for scenario producers:

Due to their complexity and low sectoral disaggregation, full model methods are not naturally adapted to create transparency and clear narratives that stakeholders can grasp so as to create a debate.

Thus, when a full model method is used, scenario producer should put a special effort into building a comprehensive narrative to illustrate the results provided.

What are the main drivers of the results? What do the provided results mean for the different stakeholders?

The third limitation is that the chosen model is subject to the **biases of the chosen economic theory**. Indeed, there are fundamental differences from one economic theory to another, and these difference are still discussed among economists. Results on employment can therefore potentially be significantly impacted by the choice of model.

Recommendations to scenario producers

When a full model method is used, scenario producer should discuss the extent to which the choice of economic theory can impact the results of the employment assessment.

3. Discussion about macroeconomic methods

The two types of methods presented in this section enable to inform **a macroeconomic perspective**.

The first type of method is manual, and uses an input-output analysis to calculate direct and indirect effects on the one hand, and then one or more induced effects on the other hand. This type of method offers the possibility of a large sectoral disaggregation, and is naturally transparent. However its static nature implies additional work and assumptions to make it more dynamic and it does not take into account all macroeconomic effects.

The second type of method is composed of full model approaches that make it possible to take into account all the effects dynamically. However it is a complex, prone to ideological biases, approach (difficulties to identify the main drivers of the results) with a relatively low sectoral disaggregation.

There is therefore a **trade-off between clarity and completeness.**

As already recommended, if the first type of approach is chosen, an effort should be made to explain the assumptions and limitations related to the static nature of input-out matrix and the magnitude of the neglected macroeconomic effects. If it is rather the second type of approach, then the effort should be put into making the results clear, transparent and accessible for stakeholders.

(Perrier & Quirion, 2017a) provides to that extent useful insights by comparing **input-output approach and full model approach**. Three effects are tested both with an IO model and a computable general equilibrium model (full model approach): labour share, wages and trade. A quantitative employment assessment analysis is then performed with the same data using the two types of model. Some discrepancies do appear even if there is **no major inconsistency in the results**. Reasons for divergence between the two models are then discussed.

(Breitschopf et al., 2012) provides a table comparing the main characteristics of **net Input-Output modelling and full economic model approaches:**

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 and 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-
	payment sector (linear - limitational)	cal, climate, energy sector, household consumption, policies, etc.

Source: (Breitschopf et al., 2012)

They also propose to choose between the two types of methods according to budget availability, human resource, know-how and data availability. They recommend the net IO modelling if these are "limited", and the full economic model approach if these are "sufficient".

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The Shift Project

The Shift Project, a non-profit organization, is a French think-tank dedicated to informing and influencing the debate on energy transition in Europe. The Shift Project is supported by European companies that want to make the energy transition their strategic priority & by French public funding.

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