Impact assessment in energy transition scenarios

Technical file #8

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.

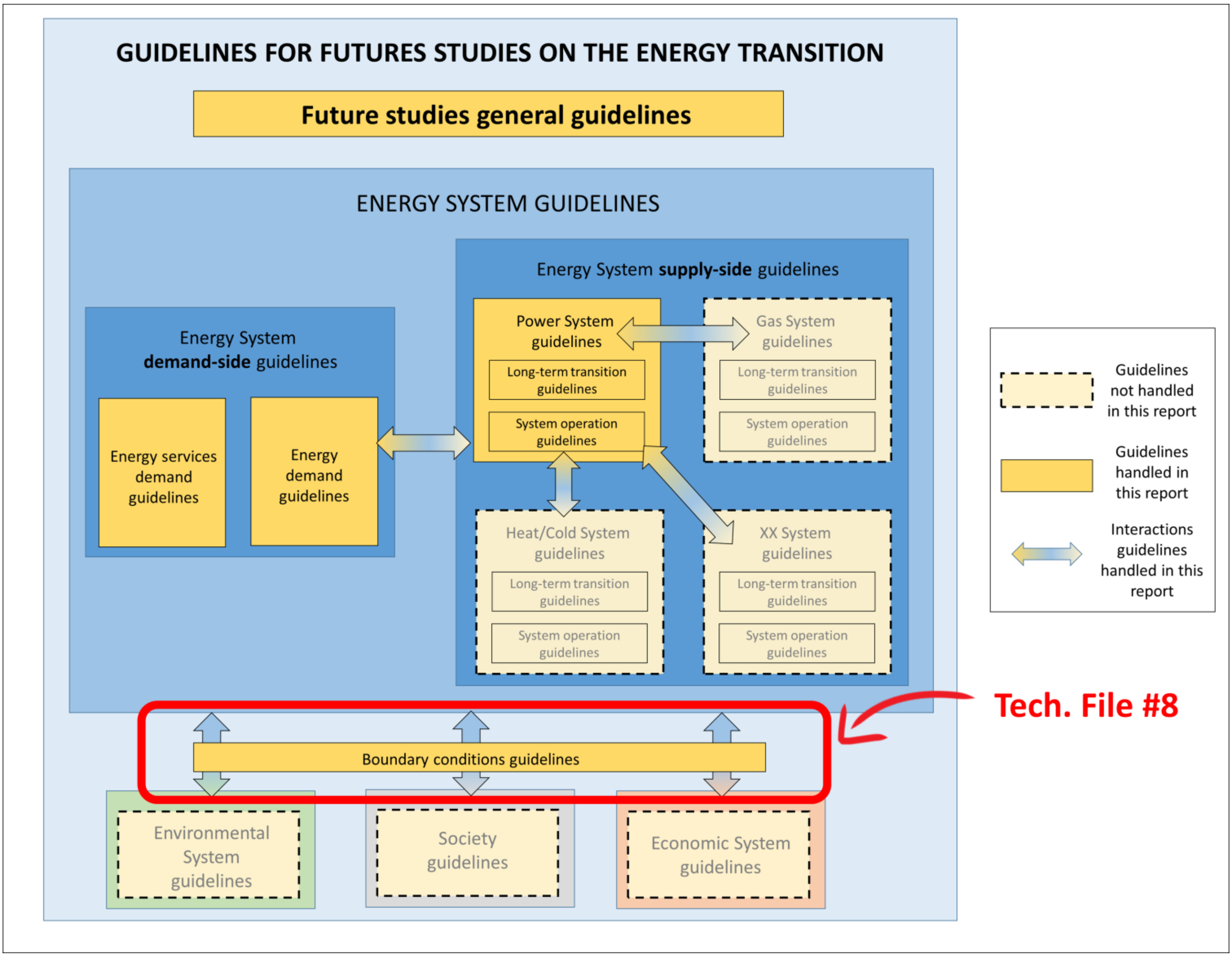
Our project, "Power Systems 2050 – Guidelines for future studies on energy and power transitions," started in January 2018, involved approximately 60 experts through interviews and workshops, reviewed more than 300 works, including about 20 future studies. The objectives and approach of this project 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 to 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 relate to 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. Key concepts for performing impact assessments

As described in section about Future studies, impact assessment fundamentally is about telling the story of how systems surrounding the core system[1] (such as the environment, society, or the economy) evolve during the proposed energy transition, due to the activities taking place within a given geographical and/or sectoral perimeter.

Here are a few examples of impact assessments which could be performed by a future study for some or all of its energy transition scenarios:

- providing the yearly CO_2 emissions to the atmosphere due to all the activities taking place within the territory over the scenario timeframe
- providing a qualitative narrative of the evolution of the natural habitats due to the activities linked to the consumption of the people living in a territory, including activities not taking place on the territory (that is, activities to produce imported goods), over the scenario timeframe
- estimating the evolution of the number, and nature, of jobs in the energy sector due to the evolution of the energy-related activities taking place within the territory over the scenario timeframe
- providing a qualitative narrative of the evolution of the lifestyles of different types of households living on the territory over the scenario timeframe

In this section we cover the general aspects of impact assessment: transparency about which impacts are assessed in the study, and possible consequences and risks of not taking into account the other impacts; transparency about the activities considered as generating impacts in the evaluation, consistency between this choice of activities and the driving questions and transparency about the methodology to compute/describe the impacts.

This section is an introduction to the more specific sections about the desirability of transition, economic assessment, employment assessment and environmental assessment of the transition. In these sections, the various aspects handled here are applied to the corresponding surrounding systems and detailed in that respect.

A. Considering different interactions with surrounding systems may lead to different study results, hence the list of considered interactions should be transparent

For each surrounding system (environment, society and economy), a great number of variables can be looked at to provide information about its interactions with the core system transition. The difference in results between a study which takes into account an interaction (by endogenizing it in the model) and another study which does not may be significant. Consider for instance the interaction between the energy transition and water use, scenario A taking into account water needs for the proper running of the power system and scenario B not taking it into account, all else being equal. Obtaining a significant result difference between scenario A and B would reveal that the considered interaction actually limits the possibilities to achieve some pathways. For example, one may imagine that in a +3°C climate change scenario, water use constraints in Southern Europe may affect the capacity of thermal power plants and of hydropower plants to operate, significantly altering the possible power mixes. Thus, a study which takes into account constraints on water use would get significantly different results than a study which does not take it into account, revealing that water use was actually a significant constraint under those hypotheses.

Defining the interactions which will be studied may leave room for the choice of specific indicators which inform about these interactions. The choice of specific indicator(s) may itself strongly affect the study's outcomes. For example, CO_2 emissions can be monitored as a yearly flow to the atmosphere or as a stock within the atmosphere, accumulating over the years. For a scenario in which the CO_2 emissions are backcasted[2], a flow approach (e.g.

[1] The core system is the system which undergoes the described transition in the scenario (often, the energy system, or the power system). This system is considered to be interacting with surrounding systems (the economy, society, the environment). See section on Future studies.

[2] For a definition of backcasted components, see section on Future studies: they are those variables whose value is fixed before the modeling as they are deemed desirable by the scenario producer, such as maximum levels of GHG emissions.

"80% emission reduction by 2050") may drive investments toward lowest abatement costs solutions. It can lead to lock-in effects, and non-optimal emission trajectories from a stock point of view. On the contrary, with a stock approach, the first abatement solutions can be the most expensive ones, the goal being to reduce the cumulated emissions.

Recommendations to scenario producers

The choice of which interactions are considered in the study should be clearly stated, and this list should be substantiated with regards to the driving questions.

For each interaction, chosen indicators should be clearly defined, and these choices should be substantiated with regards to the driving questions (see each section about surrounding systems).

For example, are greenhouse gases emitted to the atmosphere considered? If yes, which ones are considered? Is biodiversity considered, and which specific indicators have been selected? What are the reasons of these choices?

B. Precisely and transparently defining the assessment perimeter of each impact

1. Territory approach *vs* footprint approach

Studies regularly perform impact assessments. Typically, they assess costs, GHG emissions, and sometimes employment patterns. In all those cases, they **perform an inventory of the energy system components (or, more precisely, the associated processes and activities, such as building and operation of energy system components)** that they consider as impacting.

The first aspect of the inventory is the assessment perimeter which is selected.

The descriptive perimeter has to be differentiated from the assessment perimeter. The assessment perimeter corresponds to the activity perimeter containing the end-consumer's activities (driving one's car, heating one's house) and the activities for the production of goods and services (industrial, or tertiary activities) which are considered for impact assessment (see Figure 1). Two main options exist for assessment perimeter definition:

- Only activities happening within the descriptive perimeter could be considered. This is what most scenarios do. We call this approach the *territory approach*.
- Or, external production activities can be taken into account through imports, and internal production activities be withdrawn through exports. In this case, the geographical assessment perimeter corresponds to a consumption perimeter: *the footprint* of agents consuming in the descriptive perimeter is counted, even if the corresponding impacts originate from outside. We call this approach the *footprint approach*. In this case, another question arises: what agents are part of the assessment perimeter? For example, for individual consumers, are they the nationals of the area (even if they do not live here)? Or, are they people who permanently live in the area (independently of their nationalities)?

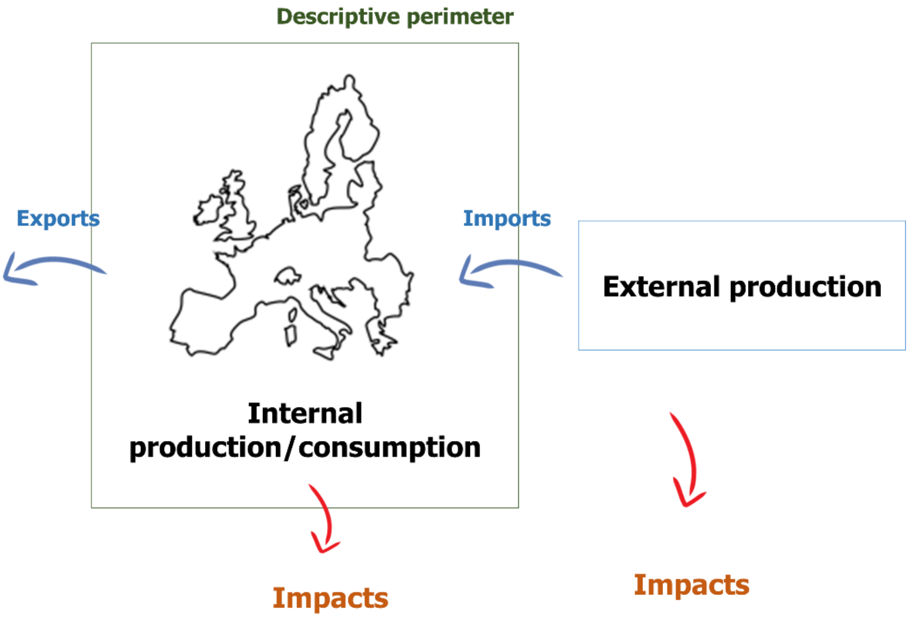

Figure 1: Illustration of the difference between the descriptive perimeter and the assessment perimeter. Here the descriptive perimeter is the European Union (EU) + United Kingdom. Economically speaking, the agents in this perimeter import and export goods and services. Activities taking place within the descriptive perimeter lead to impacts on the surrounding systems. Also, production activities to produce goods and services which are imported within the descriptive perimeter lead to impacts. The footprint approach corresponds to adding to internal production and consumption impacts, the impacts of external production, and withdrawing the impacts of the production of exports.

Mobility and freight are special activities for which some impacts (such as noise, CO_2 emissions, air pollution, accidents…) happen locally while moving and potentially crossing several territories. Such activities may remain inside the descriptive perimeter, such as a truck transporting goods within EU; or, they can entirely happen outside the descriptive perimeter (but still be counted in the assessment perimeter in the footprint case), such as a truck in China transporting intermediary production between two plants for producing a mobile phone which will ultimately be imported and bought in EU. In those two cases, impact allocation is clear: totally within the descriptive perimeter, or totally outside of it.

But some freight/mobility activity may happen both inside and outside the area (such as a truck importing goods from China to EU, or a plane going from Paris to New York City). In this case, a rule has to be arbitrarily defined: for example, half of the impacts might be allocated to internal production and half to the external production (such a practice is adopted in (Association négaWatt, 2014; Association négaWatt, 2017)).

Assessment perimeter depends on the considered core system (power system supply-side, whole power system, whole energy system…), as the activities included in the assessment perimeter are linked to the evolution of the core system. For example, a study about the power system supply-side which has a territory approach would include all the activities related to the power system supply-side over the considered territory (such as what is performed in (ADEME, 2015; ADEME / Artelys, 2018; Agora Energiewende, IDDRI, 2018)). A study about the power system supply-side which takes a footprint approach would include the imports for the capital and operation of the power plants and other components of the power system supply-side[3]. This approach is used in (Hammond, Howard, & Jones, 2013).

Assessment perimeter can be tuned for each considered interaction. For example, a study might choose a footprint approach for CO_2 emissions but a territory approach for economic matter[4].

[3] Such an approach may be called a Life Cycle Analysis (LCA) approach. Indeed, the LCA approach is used to assess the impacts of a product, or service, and it turns out the power system supply-side can be seen as a service (providing electricity). Hence for this perimeter, the footprint approach as described previously, is equivalent to an LCA approach.

[4] For example, the energy transition in EU interacts with the EU economy, but also with the economy of the rest of the world, through imports and exports. It might be too complex to assess the interactions between the EU transition and the economy of other regions of the world. Generally speaking, in this case, the economy of other world regions is fixed by the storyline of the scenario, and only the economic impacts within the EU are assessed.

2. Defining the *inventory* (what impacting activities are included in the assessment perimeter)

Once the assessment perimeter is defined, a more precise list of the activities which are included as impacting may be provided. We call this list the *inventory*. The inventory can contain activities related to the power system supply-side only, or to activities related to the whole power system (including demand-side), or to the whole energy system.

For example, (ADEME / Artelys, 2018) provides a list of all the power system's components which are included in the cost assessment This list actually contains activities that have to be financed (building of power system components, and operating them), rather than the power system components themselves.

Here is a summary of the activities involved in the power system building, transition, maintenance and operation, which can be included in an inventory:

- Power production : building of assets (power plants), financing these activities; operating and maintaining the power plants; respecting the legislations in place (can add extra activities such as pollution management or dismantlement)
- Power transmission, distribution and storage: building of assets (high voltage lines, pumped storage hydroelectric dams…), financing these activities; operating and maintaining the grid and related infrastructure; respecting the legislations in place including security of supply and electric wave quality requirements (see section on power system operation)
- Power services and power system change management: real time load management, electricity markets operation, commercial activities around electricity, change management in case of a transition
- Power consumption: production of electric appliances (ovens, light bulbs, electric cars, electric industrial processes…); financing of this production; use of these appliances
- Transition activities: activities which modify the power system, such as campaigns for sobriety, house insulation…

Some of these activities (such as physical capital production) require that a whole industrial value chain work on them. Hence these activities may be located all around the world as opposed to where the asset is built, or where the appliance is finally assembled. This consideration is important for environmental assessments and for employment assessment of the transition. A choice has to be made about whether only the activities directly linked to the core system are included (this is the *technical assessment*), or if all the sectors of the economy are included (this is the *macroeconomic assessment*). More details are available in the section about economic evaluation.

3. Taking a *system point of view* to better inform society on the energy transition debate

In our framework, the energy system, the power system, or the supply-side of the power system are defined along the services they bring to society. The energy system fulfills *energy services demand* (under the form of useful energy such as mobility, warmth, laundry washing, see section on consumption) whereas the power system fulfills *energy services demand specifically requiring the electricity carrier* (still under the form of useful energy such as light, electric mobility, warmth from electricity…). The power system supply-side fulfills *electricity demand* (under the form of electricity, such as powering a light bulb, an electric car, an electric heater…), which is not a service.

Services provided by the energy system or the (whole) power system are macro-services: they are defined for a whole population, as opposed to for a low number of energy "sampling points" (energy service for a given TV set or a given household, or at a given point in the grid; oil at a given pipeline, and so on). These services are… services, meaning that they directly fulfill human needs. For example, the electricity at the output of a PV power plant, or at a socket, is not a service as humans do not consume electricity directly. Hence the PS supply-side does not provide a service in that sense. Electricity is consumed by appliances, industrial processes and so on. Note that the PS demand-side alone (without being plugged to the supply-side) cannot provide any service neither. This is why the whole PS provides a service whereas both of its subparts (supply-side and demand-side) do not.

When such a macro-service can be precisely defined, an associated *system point of view* can be defined[5]. This point of view is taken when the **inventory includes all the activities necessary to provide the corresponding macro-service and only these activities**. These activities include activities for modifying the system providing the macro-service, in case the system undergoes a transition.

However, the activities required to provide the macro-service are potentially infinite given their macro-economic nature: does the activity of the canteen workers of the German factory in which a specific part of a tool machine required to produce solar panels in China is produced, count in the inventory for the Spanish power system (supply-side) in which these solar panels are installed? The inventory should be selected depending on the impact which is considered so as to properly assess the bulk of the considered impact in the simplest way.

As described in section about economic evaluation, taking a precisely defined system point of view prevents from:

- Comparing indicators which do not cover the same points of view
- Using indicators which do not cover a global service, for influencing society-wide decision-making: e.g. using indicators on specific technologies to influence decisions on the whole power system

On the contrary, it leads to better practices such as:

- Comparing indicators covering the same services
- Properly informing decision-making about society-wide services and their evolution by comparing the implications of choosing evolution A to evolution B about the system providing this service.

4. Aligning the assessment perimeter and inventory with the driving questions

The choice of assessment perimeter, and inventory, is driven by the driving questions and the storyline. The conclusions that can be derived from an impact assessment depends on the chosen inventory. Here is an example illustrating how the driving questions, the inventory and the conclusions of a study are linked:

Study X is a fictitious study which seeks to investigate the effects of reducing overall power demand on costs.

The study compares two scenarios: scenario A with a reduced demand compared to scenario B. In scenario A, demand is lower because houses have been insulated, requiring less space heating and water heating. The supply-side system in scenario A is smaller (lower installed capacity, less fuel consumed…) because it fulfills a lower demand level.

Two different inventories may be chosen: the first one includes the power system supply-side (from power generating units to the end of the distribution grid) only, whereas the second one further includes the power system's demand-side (all the devices consuming the electricity as well as their technical and organizational environments). With the first inventory, costs are lower for scenario A because demand is lower hence the supply-side is smaller, hence cheaper. With the second inventory though, the assessment is not so clear between scenarios A and B, because in scenario A the transition of the demand side includes the costs of insulating the houses.

In this example, the first inventory enables to answer the question: is a power system fulfilling a lower demand cheaper, or more expensive, than a power system fulfilling a larger demand? This question is of little interest for society (because the cost of houses insulation should be included in the assessment), but it can be interesting for power systems actors having to size their financing needs in the situation where a law about house insulations have been passed.

The second inventory is necessary to answer the question: are overall costs minimized by insulating houses with regard to the associated impact on the power system? This question investigates the overall effect of the house insulation lever on costs, which is much more useful from a system perspective.

The same line of reasoning can be performed for other impacts: the previous example can be applied to CO_2 emissions, with the following questions:

[5] Reciprocally, no system point of view can be defined if a service is not defined beforehand. No system point of view can be defined if the service is not applicable to a whole population.

- Inventory 1: does a power system fulfilling a lower demand emit more CO_2, or less CO_2, than a power system fulfilling a larger demand?
- Inventory 2: does insulating houses (which is an activity generating CO_2 emissions per say) leads to decrease overall CO_2 emissions with regard to the associated impact on the power system?

These examples illustrate the limits of "supply-side optimization studies" using a supply-side only inventory[6], that is, studies assuming a given level of demand as an input and seeking to compare different power system supply-sides to meet this demand. These studies can bring only partial conclusions about levers acting on demand. Hence they cannot investigate the overall effects of energy efficiency levers, or the overall effects of sobriety levers.

Similarly, studies performing a technical assessment (that is, including only the sectors directly linked to the core system as opposed to all the economic sectors) cannot answer questions about macroeconomic effects such as growth, or de-growth effects.

Still in the same line of reasoning, the territory approach and the footprint approach do not answer the same questions:

- The territory approach is centered on production place. It is the oldest approach and is the one used in international agreements for climate impacts. This approach corresponds to the legal responsibility of States (they are responsible for how production is organized on their territories). Hence such an approach provide decision elements about States levers (Ministère de l'écologie, du développement durable et de l'énergie, 2015), or more generally about the levers the considered territory has.
- The footprint approach is centered on consumption place. It informs about what different consumers (households, organizations, companies…) can do about the considered impacts by changing their consumption patterns (Ministère de l'écologie, du développement durable et de l'énergie, 2015). For example, for a power system supply-side study, the consumers are the companies operating power system's components, as they decide what components to buy and install. The footprint approach includes information about imports and exports, hence about the dependence of a territory to other territories. In a way, this approach provides decision elements about the levers on internal consumption as well as those on trade with other territories (for the territories willing to use such levers).

Recommendations to scenario producers

A study strategy about assessment perimeter(s) definition(s) should be defined and justified with regards to the driving questions. The inventory for each impact should be the same across all scenarios of the study. The following aspects should be reported about:

- Territory approach or footprint approach. If the footprint approach is preferred, then the group of individuals which are included in the scope should be precisely defined.
- Technical assessment or macroeconomic assessment.
- Complete inventory: the list of all the activities included in the assessment should be provided.
- Specific considerations for measuring the impacts of mobility and freight.
- Differences (if any) in the assessment perimeters for different impacts.
- When assessing the effects of specific levers, considerations on how the assessment perimeter contains the activities impacted by these levers. As a rule, if the driving questions are about investigating the effects of a lever, then the assessment perimeter should include all the activities significantly impacted by that lever.

Scenario producers should precisely and transparently define what they call a "society point of view," or a "system point of view," if they seek to inform a public debate on the evolution of systems providing macro-services such as the energy system or the power system. They should justify their choice effectively represents society's interests.

[6] (ADEME, 2015; ADEME / Artelys, 2018; Agora Energiewende, IDDRI, 2018) are such studies; (RTE, 2017) has the same approach and acknowledges its limitation.

In this effort, they may follow this approach:

- Precisely define the macro-service which is under consideration in the study
- For each impact assessment, precisely define the inventory so that the inventory covers all the activities necessary and sufficient to provide the macro-service and to make the providing system evolve. In doing so, some activities may be rejected because their impacts are negligible.

C. Making the assessment methodology transparent

The interaction assessment can be performed through a model for quantitative assessment, or through a narrative qualitatively linking the obtained energy transition to the considered surrounding system.

The assessment technique depends on each specific impact and indicator. However, the usual methodology consists in listing the different activities happening within the core system during the scenario timeframe (for example, describing all the activities and processes related to the energy sector taking place each year of the scenario) and linking these activities to the considered surrounding system (e.g., GHG emissions in the atmosphere). The link can be straightforward (such as the link between fossil fuel consumption processes and CO_2 emissions, which is a quantitatively linear link) or more complex (such as the link between energy consumption processes and local air pollution).

Recommendations to scenario producers

For each impact indicator, the assessment methodology should be clearly stated and at least qualitatively described. *For example, which model has been used and what are its main mechanisms?*

D. Tackling horizon effects to prevent lock-in effects after time horizon and impact assessment biases

As described in section about future studies (II.A.1), the fact that scenarios have an end-date (a horizon) may lead to some results distortions, both in terms of obtained energy transition[7] and in terms of scenario assessment. A few techniques exist to correct, or reduce these horizon effects.

In order to reduce the risks of lock-in effects a first, computational technique is to run the model up to a horizon well beyond the described time horizon. With this technique, the obtained energy transition takes into account the constraints which may happen after the described time horizon, so that the risks of generating lock-in effects after time horizon are reduced. Of course, the hypotheses about what happens after time horizon are key drivers of what will be considered as lock-in effects and what will not. For example, (SFEN, 2018) analyzes scenarios whose time horizon is 2070 and compares them with similar scenarios (E3MLab & IIASA, 2016), ran with the same model (E3Modelling, 2018), whose time horizon is 2050.

A second, qualitative technique, would be to perform the same kind of work through a narrative explaining how the proposed energy transition would not entail adverse consequences for people living during the decades after time horizon.

A third, quantitative technique, is to correct impact assessments by incorporating in the scenario timeframe impacts happening after the time horizon. Such a technique is described in section about economic evaluation.

[7] Taking into account the so-called lock-in effects may change the scenario results.

Recommendations to scenario producers

Scenario producers should describe and justify their strategy to tackle horizon effects. The following aspects should be considered:

- Lock-in effects (happening after time horizon) generated by each proposed transition scenario and/or strategy to avoid these lock-in effects
- Biases on impact assessments generated by time horizon effect: qualitative description, or quantification of these biases, methods to avoid them…

Bibliography

ADEME. (2015). *Un mix électrique 100% renouvelable ? Analyses et optimisations*.

ADEME / Artelys. (2018). *Trajectoires d'évolution du mix électrique 2020-2060—Synthèse*.

Agora Energiewende, IDDRI. (2018). *L'Energiewende et la transition énergétique à l'horizon 2030*.

Association négaWatt. (2014). *Scénario négaWatt 2011-2050—Hypothèses et méthode*.

Association négaWatt. (2017). *Scénario négaWatt 2017-2050 | Dossier de synthèse* (p. 48).

E3MLab & IIASA. (2016). *Technical report on Member State results of the EUCO policy scenarios* (p. 381).

E3Modelling. (2018). *PRIMES MODEL VERSION 2018—Detailed model description* (p. 221).

Hammond, G. P., Howard, H. R., & Jones, C. I. (2013). The energy and environmental implications of UK more electric transition pathways : A whole systems perspective. *Energy Policy*, *52*, 103-116. https://doi.org/10.1016/j.enpol.2012.08.071

Ministère de l'écologie, du développement durable et de l'énergie. (2015). *Stratégie nationale bas-carbone* (p. 208).

RTE. (2017). *Bilan prévisionnel de l'équilibre offre-demande d'électricité en France*.

SFEN. (2018). *Le nucléaire français dans le système énergétique européen*.

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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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