ENERGY SCENARIOS AND MODELS: IMPROVING METHODS TO ASSESS FUTURE ENERGY DEMAND

On 9-10 October 2014, IRGC co-organised a workshop on "Energy Scenarios and Models: Improving Methods to Assess Future Energy Demand."

This paper highlights some of the points presented and discussed at the workshop, focusing on non-technical considerations.

The workshop brought together 35 researchers and decision-makers from academia, policy institutions and private sectors to discuss how scenarios and energy-economy models could better inform our understanding of the evolution of energy demand. Indeed, the rules of the game are set to change considerably, with energy consumption increasing in some parts of the world and possibly decreasing in others. In spite of advances in energy efficiency measures and potential decrease in growth in some OECD countries, the global energy demand will continue to increase, due to sustained growth in demand in some countries like India and China. When planning for energy transitions, decision-makers are therefore interested in possibilities to influence energy demand. Models and scenarios should therefore move beyond reductionist approach to energy consumption and harness interdisciplinarity.

The workshop reviewed various approaches for developing scenarios for energy transitions, focusing on the demand side, in order to identify *gaps* in scenario development, and to, accordingly, provide *recommendations* for both researchers and policy makers.

Contributions were made by participants listed in appendix. Presentations and discussions highlighted some aspects that are particularly relevant for the use of scenarios (and their supporting models) in policy. They also helped determine areas where progress should be made.

Different scenarios and models are required for different end-uses

Considering that scenarios can be described as visions or explorations of the future, and thus help to deal with uncertainty[1], the workshop covered a broad array of scenarios, in particular (i) qualitative[2] vs. quantitative[3] scenarios; (ii) exploratory vs. normative scenarios[4]; and (iii) descriptive vs. prescriptive scenarios. Scenarios used in decision-making, however, are often variations of these different categories.

Scenario development is a complex exercise and should follow certain steps to be relevant. The discussion suggested several "best-practices" as follows:

- *Selecting an appropriate type of scenario*

  The choice of type of scenarios, by those who use and commission them and those who develop them will depend on:
  - The **end-use**, which includes for whom the scenarios are being developed (audience) and for which type of decision. Developing scenarios can be done for various purposes, including: understanding drivers of change and possible important events (to inform); determining strategic options and informing decision making (to improve decision making)[5], and influencing attitudes and behaviour (to trigger behaviour change). Other purposes include: communication, education, consensus-building, stakeholder

[1] See dealing with uncertainty in energy scenarios (Hughes)
[2] See systematic approaches for qualitative scenarios (Schweizer)
[3] See techniques for quantitative scenarios (Trutnevyte)
[4] For normative scenarios, see long-term scenarios for Germany (Pregger)
[5] See Greenpeace scenarios (Teske), to support strategic decision

participation or research. "Worst-case-scenarios" can be useful for the purpose of triggering changes in thinking or deciding, that otherwise would not be seen as necessary. In this sense, scenarios can also be used as management tools, especially when the underlying goal of a scenario is to contribute to building long-term sustainability.

- The **context and relevant spatial and temporal scales**,
- The **type of input available**: trends, expert advice, participatory approaches or literature reviews. There is often a scarcity of data, which must be taken into account before selecting a type of scenario.
- The level of details that is needed for various types of use in policy.

The choice must also reflect an appropriate trade-off between transparency and complexity.

- *Quantitative and qualitative scenarios*

Scenarios can be developed, either quantitatively or qualitatively or both. Quantitative scenarios are based on either simple forecasting models or more complex macro-economic models[6]. Some also include modelling of micro-economic behaviour (agent-based modelling[7]). The presentations and discussions highlighted some important considerations when developing these scenarios, as listed below:

- It is important to carefully pair qualitative scenarios with models.
- For qualitative scenarios, the "internal consistency" of the scenarios needs to be verified for robust decisions.
- Sociotechnical scenarios (STScs) ought to be further developed to inform current transitions, considering the embeddedness of technical systems in social systems. A constituent part of STScs is the combination of qualitative context scenarios with quantitative energy models in order to assess the scenario implications and inform policy-making. [8]
- There is growing interest to integrate approaches, based on different perspectives, scales and disciplines, for example that:
  - Combine bottom-up and top-down modelling[9].
  - Combine normative and explorative scenarios (backcasting and forecasting). Some explorative scenarios are in fact based on strong normative framework assumptions[10].
- Combine qualitative scenarios (storylines) and numerical modelling. Combining approaches increases the complexity, which increases the methodological and communication challenge.

Communication Imperative

Communication gaps between scenario developers and decision-makers are frequent and must be avoided. Decision-makers recurrently expect "accurate" predictions, although they should know that energy scenarios are not meant to provide predictions, but rather a set of plausible future alternatives. Instead of single trend extrapolations (simple predictions/forecasts), it is recommended to communicate about sets of alternative future developments and their underlying drivers.

Scenario developers are advised to carefully select those modelling outcomes that they want to communicate, and to do so in simple terms to avoid misunderstandings. Translating complex quantitative outcomes into narratives can be a way to inform decision-makers of the complexity of energy systems. Whenever sophisticated tools are needed there is a risk of loss of transparency about the models and data, leading to lack of clarity and difficulty to link the scenarios to decisions.

[6] See energy demand modelling in Statoil 2014 (Waerness)
[7] See for example contribution on Agent-based modelling and simulation for energy scenarios (Lukszo)
[8] See for example contribution about socio-technical scenarios (Kopfmüller, Poganietz, Schippl) and sustainability, and the E-Trans 2050 (Ornetzeder) project in Austria
[9] See: combining top-down scenario approaches with bottom-up assessment of policy measures (Mangalagiu)
[10] It is interesting to compare approaches developed in Germany (Lorenz), France (Meunier) and Switzerland (Faust), as presented at the workshop

A better understanding of the factors that shape the demand is necessary

Anticipating future energy demand in view of current transitions is not easy, especially that the drivers of energy demand are poorly understood and usually include primarily such factors, such as GDP, growth and population, while a broader set of factors social, economic, environmental, technological and political (STEEP) factors should be included. Feedback mechanisms of changes in e.g. energy prices are also rarely taken into consideration. The workshop presented some of the promising approaches that are being developed in France[11], Austria[12] and Germany, among other countries. Acknowledging that political, social, cultural and institutional elements can have a significant impact on energy demand, but are not always included in models, the workshop highlighted potential improvements from several approaches, including:

- *Exploring demand-side uncertainties*

  Energy demand is most often entered as an exogenous variable in energy-economy models or are derived from reductionist utility models. More accurate estimates of energy demand uncertainties are needed[13], for example to account for the rebound effect from energy efficiency policy instruments, or behavioural and lifestyle changes. Several insights can be gained from:

  - Investigating how and the extent to which energy demand is and can be decoupled from economic growth through energy efficiency measures and through reduction of energy demand services.
  - Disaggregating energy demand. Aggregate demand measures are deemed insufficient for understanding drivers of energy demand and for influencing energy consumption. Energy intensity is sector specific. Thus sectoral scenarios are needed to help uncover improvement potentials in energy consumption over different time scales.
  - Focusing on energy-services. Modellers need to analyse changes in structure of energy demand services such as heating and transportation due to individual and collective lifestyles changes. Linking energy sources to the energy services they provide can help structure discussion on energy demand around the fundamentals of consumption choice and inform policy.
  - Using Cross-Impact Balance analysis (CIB) to systematically include the uncertainty of social factors[14].

- *Understanding lifestyle and preference changes*

  People's preferences are not static, but are influenced by social, technological, economic, environmental and political changes that often trigger lifestyle changes. Some of these changes can emerge from grassroots innovations for sustainable consumption. Several (descriptive) scenarios have been developed based on assumptions about lifestyle changes. This is an emerging area based on empirical evidence that actual behaviour deviates from the rationalistic-economic theory from which energy demand projections are usually derived. Several approaches are being explored such as improved stratification of consumers e.g. based on their attitude towards technology adoption and vehicle usage intensity, and taking into account behavioural influences in decision-making.

- *Adding behavioural realism to energy-economy models*

  Further work is needed to better incorporate assumptions about people's behaviours in energy-economy models in order to be relevant for policy-making. For instance, the method of explorative context scenarios can also help to improve the awareness about the uncertainties of the energy demand expectations associated with lifestyle and preference changes.

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[11] See for example work of IDDRI (Colombier, Waisman)
[12] See for example work at IIASA (Krey)
[13] See accounting for societal uncertainties in energy scenarios: work of the Energy Trans project (Weimer-Jehle et al.)
[14] See for example use of a multi-level cross-impact approach in household energy consumption in Germany (Vögele et al.)

- *Backcasting energy demand*

  Backcasting here alludes to normative visions about the future level of energy demand, and the use of forecasting, exploratory and agent-based tools, singly or jointly, to inform short-term policies to influence demand in view of the energy demand vision. The process takes into account such challenges as social and political acceptability of certain policies and lifestyle changes. The energy targets set by the European Commission and some national governments reflect the interest for backcasting approaches in Europe, and potentially trigger work about how to achieve the necessary transformation of energy systems to reach the goals.

These approaches are either not widespread or only currently being developed. But policy makers concerned about secure, reliable and affordable access to (sustainable) energy as well as other decision-makers are interested in how behavioural and lifestyle changes will influence the pattern of energy demand locally, regionally and globally.

Inconsistencies and surprises in energy demand

Although it is important to ensure internal consistency for scenario quality, it may also be relevant to analyse the reasons for some inconsistencies, as they may be observed in particular in qualitative scenarios. Inconsistencies may reveal the existence of potential transitions and fundamental transformations that are not captured in quantitative modes.

Similarly, low-probability high-impact events do happen and render predictions based on most models inaccurate[15]. A brainstorming session about possible extreme events, surprises or game changers was organised during the workshop by Max Henrion (Lumina Decision Systems). A short report is available separately.

Cooperation between energy modellers and social scientists

The necessary improvements and promising approaches described in the workshop would require that the community of energy scenarios developers and modellers organises itself to share more about their experimentations and experiences. Including social scientists is necessary to better include the social factors.

Appendix

List of participants

Prof. Ines Azevedo, Carnegie Mellon University, USA; **Prof. Gregor Betz**, Karlsruhe Institute of Technology, Germany; **Dr Michel Colombier**, IDDRI, France; **Dr Jerome Dangerman**, PIK-Potsdam, Germany; **Dr Anne-Kathrin Faust**, Swiss Federal Office of Energy, Switzerland; **Ms Marie-Valentine Florin**, IRGC; **Prof. Dr. Armin Grunwald**, Karlsruhe Institute of Technology, German; **Dr Max Henrion**, Lumina Decision Systems, USA; **Mr Nick Hughes**, Imperial College, London, UK; **Dr Jurgen Kopfmuller**, Karlsruhe Institute of Technology, Germany; **Ms Hannah Kosow**, Stuttgart University, Germany; **Dr Volker Krey**, Energy Program, IIASA, Austria; **Mr Ullrich Lorenz**, Federal Environment Agency, Germany; **Dr Zofia Lukszo**, TU Delft, NL ; **Prof. Diana Mangalagiu**, Reims Management School, France; **Mr Laurent Meunier**, Economic and Prospective Department, ADEME, France; **Dr Anjali Nursimulu**, IRGC; **Dr Michael Ornetzeder**, Austrian Academy of Sciences, Austria; **Dr W-.R. Poganietz**, Karlsruhe Institute of Technology, Germany; **Dr Thomas Pregger**, German Aerospace Center, Germany; **Ms Sigrid Prehofer**, Stuttgart University, Germany; **Prof Dr Ortwin Renn**, Stuttgart University, Helmholtz-Alliance Energy Trans, Germany; **Ms Ricarda Scheele**, Stuttgart University, Germany; **Dr Dirk Scheer**, Stuttgart University, Germany; **Dr Jens Schippl**, Karlsruhe Institute of Technology, Germany; **Dr Vanessa Schweizer**, University of Waterloo, Canada; **Mr Sven Teske**, Greenpeace International, Netherlands; **Dr Evelina Trutnevyte**, Swiss Federal School of Technology (ETH) Zurich, Switzerland; **Dr Stefan Vögele**, Jülich, Germany; **Mr Eirik Waerness**, Statoil ASA, Norway; **Henri Waisman**, IDDRI, France; **Dr Wolfgang Weimer-Jehle**, Zirius University of Stuttgart, Germany.

[15] See "Can review of past surprises help reduce future surprises" (Henrion)