Workshop Proceedings

Hybrid Modelling: Linking and Integrating Top-Down and Bottom-Up Models

Proceedings of the Modelling Workshop “Top-Down Bottom-Up Hybrid Modelling”
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1 Introduction

Two contrasting concepts of modelling techniques for analysing energy systems have been present: a bottom-up, sectoral, or engineering approach, and a top-down, macroeconomic approach. While the first approach uses descriptions of technologic aspects of the energy system for building the model, the top-down approach models the economy as a whole and emphasizes the possibilities to substitute different production factors. The considerable differences between both approaches may lead to results differing significantly from each other, such that policy advice can become ambiguous. A potential remedy is the linking of models of both types. Hybrid modelling is used to indicate a mix of both modelling perspectives with the expectation that “the whole” should exceed the sum of its parts. Integrating aspects and functionality from top-down and bottom-up modelling approaches results in “hybrid” models, which may provide more insight than the individual models could do on their own.

This note presents the synopsis of a modelling workshop in Trondheim, 24-25 November 2016, on this topic. It aims to deliver an overview of the lessons learnt. The remainder of this note summarises briefly each of the presentations, followed by a summary of the discussion panel, and – finally – some concluding remarks on the workshop.

2 Presentation sessions

Professor Christoph Böhringer from University of Oldenburg gave the opening session about hybrid modelling in the integrated mixed complementarity (MCP) framework. This framework generally allows for a large degree of flexibility, which can be necessary for combining models. However, complexity and dimensionality quickly restrict practical applications, such that a decomposition method should be used. The top-down, MCP problem is separated from the bottom-up framework. An iteration algorithm is used that solves the top-down model and passes variables to the bottom-up model, which solves subsequently, before the algorithm checks for convergence and starts the next iteration step. This unified but decomposed approach allows both models to be specified and run in their own respective programming interfaces but to be solved in an iterative, computationally feasible way.

A practical implementation of this method was presented by Dr. Jan Abrell from ETH Zürich in his session on the application of hybrid modelling. Among other points, he raised the issue of robustness in generation decisions with respect to changes in costs and how this can be overcome with the usage of varying elasticities of substitutions along the branches of the nested utility function.

In a hands-on session following Dr. Abrell’s presentation, the workshop participants have explored and applied a classroom version of Jan Abrell’s model for simulating the effect of different climate policies on the energy mix.

Strengthening the ties between the consortia funded through the Horizon2020-LCE21-call, the SET-Nav modellers were glad to welcome Professor Ulrich Fahl from University of Stuttgart as a representative of the REEEM project. In his session, he presented several hybrid models: NEWAGE (which integrates hybrid features into a computable general equilibrium model), TIAM-MACRO and TIAM-LOPEX (energy systems models with macroeconomic extensions and an oil market extension respectively) as well as linkages of TIMES-PanEU with E2M2 and NEWAGE for analysing the European energy sector.

Another input session, given by Per Ivar Helgesen and Dr. Gerardo Perez-Valdes from NTNU, dealt with applied issues in the hard-linking of TIMES-Norway and REMES as a regionalized energy system model.
and a regionalized computable general equilibrium model for Norway respectively. Besides explaining the system of linkage, the session emphasised the different practical obstacles one faces in model linkages that arise from differences in granularity, i.e., a different (dis-) aggregation patterns regarding time, geographical regions, and demand or other sectors. To overcome this issue, appropriate mappings have to be specified for implementation of hard-linked model interface.

Phillip Härtel from Fraunhofer IWS presented some results of the North Sea Offshore Network (NSON-DE) project. In particular, he described a novel approach of *regional decomposition with a subsequent unit decomposition* to solve an – otherwise infeasible – convex linearly-constrained non-smooth problem of European transmission expansion planning. Although yielding initial success, up-scaling and determining appropriate termination criteria, in addition to practical implementation challenges, still leave ample scope for future research.

3 Panel discussion - Future research directions in hybrid modelling

Following the presentations, a concluding session sought to summarize lessons learned and identify future developments and issues in hybrid modelling. Dr. Franziska Holz from DIW Berlin was joined on the panel by Dr. Jan Abrell, Professor Ulrich Fahl, and Per Ivar Helgesen. The following subsections briefly reflect some discussed items and suggestions by category.

3.1 Drivers of model development

- Research questions (should) drive the developments. These originate from policy analysis and decision support.
- Where can hybrid modelling be located, compared to integrated assessment modelling? Emphasis was given to the fields climate, emissions, footprints, maritime ecosystems.
- How important is a further decomposition of the household? This raises the point of distributional impacts and their reflectance in computable equilibrium models: To which extent can the absence of distributional impacts in models lead to solutions that are then found to be not implementable for political reasons and, hence, not applicable?
- Instead of focussing on climate policy, other issues should be included. Among them, most importantly, the emerging idea of NEXUS issues, i.e. interdependencies between different dimensions such as energy, food and land use, and water. In that way, hybrid modelling could become an important tool in assisting the UN Sustainable Development Goals (SDG). A functioning and reliable energy system, in general, is a prerequisite for human well-being and economic development, but it is not an objective in itself, in a narrow sense. Therefore, it has to be seen in the context of broader societal questions.
- Often, researchers face only low incentives to develop novel models, due to the lack of funding, missing long-term resources, and because development time often amounts to multiple years.
- Integrated assessment models, as a potential rivalling concept to the hybrid models dealt with in this workshop, often assume GDP and/or population data. Hence, there is no feedback between the energy systems and the economy. The framework might broadly profit from including ideas of bottom-up modelling.
3.2 Improving hybrid modelling

- Hybrid models need more detail and a better representation. However, often, this often results in higher computation time. Hence, detailed models should only be used when needed.
- When aggregating a model to perform the integration, one needs to be careful to not lose the strengths of the different original models.
- A future issue might be multi-sector bottom-up models.
- The time horizon in modelling has been named an important issue. As SET-Nav project’s workshop 3 will cover, mappings in temporal resolution are non-trivial. However, they are central for the model’s outcome. As always, when determining a model’s resolution, the right balance between computational or data effort and the degree of detail needs to be found. This does not necessarily invoke an hourly resolution, especially for policy support.

3.3 Expanding modelling scope and size

- Linking dynamic recursive computational equilibrium modelling with bottom-up modelling was named as a potential way forward. Problematically, dynamic recursion implies myopic foresight, with is inconsistent with perfect foresight from bottom-up modelling.
- Sector coupling has been named an important buzz word in the field. Current energy system models could benefit from a better sector coupling, and top-down models often lack a heating sector.
- The question was raised, if it is possible to link more than two models. The panel has found that it is possible, as long as the direction of causality is clear, such as performed by an IIASA model that combines three bottom-up models or the SET-Nav three layers of models. However, it may prove difficult if models have fairly different strengths.
- Solving larger models requires decomposition. In general, such decompositions need tuning, fine-adjusting, and a lot of testing. Alternatively, some aspects can be integrated by functional linkages, such as flexible and self-adjusting boundary conditions and functional forms. For instance, supply or demand curves that mimic the stronger model in these regards can be implemented.

3.4 Communication

- When input data with higher detail is required, it might be necessary to lobby with statistics bureaus for a future collection of data with the necessary degree of detail.
- Cross-disciplinary communication towards the broader public is necessary to create awareness and teach the contributions, strengths and weaknesses of models. Problematically, public dissemination does typically not involve scientific reward. Large numbers of graduating master students in “energy system modelling” is certainly a step in the right direction, but still more interdisciplinary study programs that work cross-disciplinary and cross-regional are necessary.
- Initiatives pushing for data sources and models to be published under open-source/open-access licenses are an interesting development that might influence future modelling.

4 Conclusions for future research directions

Relevant policy questions should drive our research. The latter should by no means be limited to questions of energy and climate policy but include other relevant fields such as the food-water-land nexus or distributional aspects in economics. Still, in modelling, a better representation of problems does
not always imply more detail, a larger scope, or better temporal and regional resolutions. Dependent on the needs, not all aspects of a problem need the same level of detail or precision and can easily lead to a numerical over specification that requires more data but might actually restrict the results wrongly to those permitted by the input assumptions. Obviously, oversizing models can also affect computation time adversely: While top-down models may solve in minutes, bottom-up models can take hours for doing so.

All these factors need to be considered when linking or integrating models, and maintaining the relative strengths of each approach is a central task. Hybrid models can be soft- and hard-linked or integrated, but sometimes it may be enough to have functional expressions for boundary conditions. Decomposition approaches will continue to be needed for solving large problems. Besides modelling work, communication and creating awareness about capabilities of our models to a broader audience as well as lobbying to statistics bureaus to adjust data provision to modellers’ requirements are future tasks.
About the project

SET-Nav aims for supporting strategic decision making in Europe’s energy sector, enhancing innovation towards a clean, secure and efficient energy system. Our research will enable the European Commission, national governments and regulators to facilitate the development of optimal technology portfolios by market actors. We will comprehensively address critical uncertainties facing technology developers and investors, and derive appropriate policy and market responses. Our findings will support the further development of the SET-Plan and its implementation by continuous stakeholder engagement.

These contributions of the SET-Nav project rest on three pillars: modelling, policy and pathway analysis, and dissemination. The call for proposals sets out a wide range of objectives and analytical challenges that can only be met by developing a broad and technically-advanced modelling portfolio. Advancing this portfolio is our first pillar. The EU’s energy, innovation and climate challenges define the direction of a future EU energy system, but the specific technology pathways are policy sensitive and need careful comparative evaluation. This is our second pillar. Ensuring our research is policy-relevant while meeting the needs of diverse actors with their particular perspectives requires continuous engagement with stakeholder community. This is our third pillar.

Who we are?

The project is coordinated by Technische Universität Wien (TU Wien) and being implemented by a multinational consortium of European organisations, with partners from Austria, Germany, Norway, Greece, France, Switzerland, the United Kingdom, France, Hungary, Spain and Belgium.

The project partners come from both the research and the industrial sectors. They represent the wide range of expertise necessary for the implementation of the project: policy research, energy technology, systems modelling, and simulation.

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