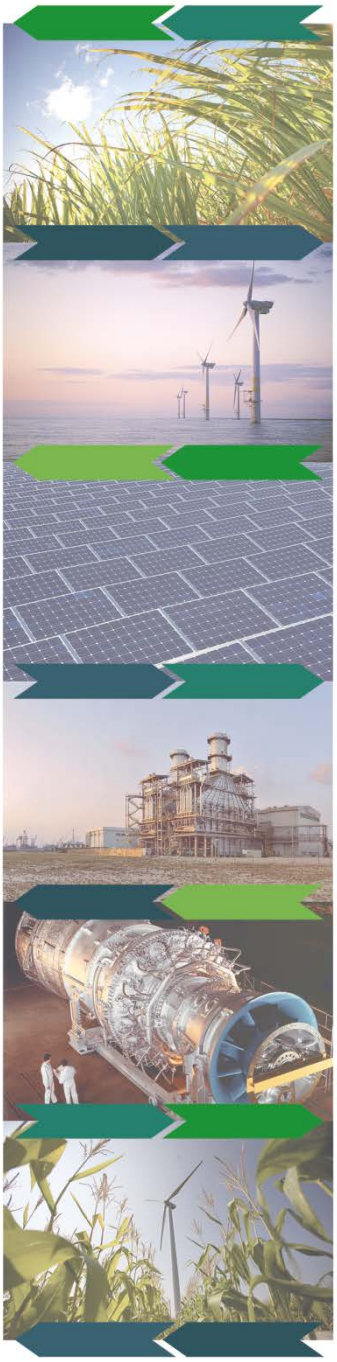
NAVIGATING THE ROADMAP FOR CLEAN, SECURE AND EFFICIENT ENERGY INNOVATION



Workshop proceedings on

Two-stage decision making and modelling for energy markets

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October 2018

A report compiled within the H2020 project SET-Nav
(work package 10, deliverable D10.5)

www.set-nav.eu

Project Coordinator: Technische Universität Wien (TU Wien)

Work Package Coordinator: DIW Berlin

SET-Nav
Strategic Energy Roadmap

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 691843 (SET-Nav).

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1 Overview

On October 11, 2018, DIW Berlin held a high-level workshop on the subject of "Two-Stage Modelling of Energy Markets". Two- and multi-level numerical models allow for the study of complex sequential decision processes in markets. Such a situation exists, for example, when power markets first decide on expansions of the power grid and then, in a subsequent step, market decisions are made regarding power generation and grid usage. Even non-cooperative dynamic games can be modelled in this format.

Well-known experts in mathematical methods and energy applications presented the current state of research to a diverse audience of users and modelers. After an introduction to the modelling methods by Prof. Sauleh Siddiqui (Johns Hopkins University Baltimore, USA), exemplary applications from the research on electricity and natural gas markets were presented by DIW Berlin scientists, the European University Institute Florence, the HU Berlin and the Comillas University of Madrid presented. A lecture by Dr. Ibrahim Abada (Engie) showed that this modelling method is also used in the research departments of large energy companies. Prof. Olivier Massol (ifp School Paris) and Prof. Ruud Egging (NTNU Trondheim) discussed methodological extensions and simplifications of the methods currently used. Prof. Franz Hubert (HU Berlin) raised the question of whether energy markets are better studied through the lens of cooperative game theory.

The workshop was part the series of modelling workshops in the SET-Nav project organized by DIW Berlin over the past two years, including workshops in Trondheim ("top-down bottom-up modeling"), Zurich ("modeling of risk and uncertainty") and Vienna ("linking models with different spatial and temporal resolutions") and contributions to the EMP-E conference the workshop in Berlin the last event of the series. Therefore, a final panel discussed how advanced modelling methods are needed or perhaps too complex for scientific policy advice. There was a consensus among the panellists that even complex methods should be used but must be communicated in a user-oriented way. In addition, it has been found that users of model results seem currently more interested in discussing the data than the methods.

2 Content

An introduction to (multilevel) equilibrium modelling
Sauleh Siddiqui (Johns Hopkins University)

Special emphasis needs to be given to a group of mathematical problems that are summarised under the umbrella term multilevel equilibrium problems. These problems represent multiple interdependent optimisation problems that are constrained by other optimisation problems. In a general context of decision-making, such a problem represents sequential decisions by actors who anticipate each other's actions and behave strategically. Hence, multilevel equilibrium problems can often be connected to issues of (dynamic) game theory, which aims to predict the outcome of strategic interactions. This talk outlined main characteristics of mixed complementarity problems (MCPs), mathematical problems under equilibrium constraints (MPECs), and equilibrium problems under equilibrium constraints (EPECs).

Modeling coordination between renewables and grid: Policies to mitigate distribution grid requirements using residential PV-battery systems
Paul Neetzow (Humboldt University Berlin)

This talk focussed on the interaction of prosumage with the distribution and transmission grid and investigated how efficient regulation can be used to overcome countervailing objectives of different entities. The researchers evaluated different incentive schemes and regulations introduced by the distribution system operator (DSO) with respect to their efficiency and distributional effects. These policies allow the DSO to influence storage dispatch and hence decrease required grid expansion. However, the resulting storage operation and distribution grid capacities are not cost efficient from a systems perspective and lead to non-optimal deployment of transmission lines and use of dispatchable generation.

Network Expansion to Mitigate Market Power
Alexander Zerrahn (DIW Berlin)

The researchers proposed a three-stage model to describe how network investment can reduce market power exertion: a benevolent planner decides on network upgrades for existing lines anticipating the gaming opportunities by strategic generators. These firms, in turn, anticipate their impact on market-clearing prices and grid congestion. In this respect, we provide the first model endogenizing the trade-off between the costs of grid investment and benefits from reduced market power potential in short-run market clearing. In a numerical example using a three-node network, the researchers illustrated three distinct effects: firstly, by reducing market power exertion, network expansion can yield welfare gains beyond pure efficiency increases. Anticipating gaming possibilities when planning network expansion can push welfare close to a first-best competitive benchmark. Secondly, network upgrades entail a relative shift of rents from producers to consumers when congestion rents were excessive. Thirdly, investment may yield suboptimal or even disequilibrium outcomes when strategic behaviour of certain market participants is neglected in network planning.

Least-cost distribution network tariff design in theory and practice
Tim Schittekatte (Florence School of Regulation / Paris-Sud University)

In this talk, a game-theoretical model with self-interest pursuing consumers is introduced to assess how to design a least-cost distribution tariff under two constraints that regulators typically face. The first constraint is related to difficulties regarding the implementation of cost-reflective tariffs. In practice, so-called cost-reflective tariffs are only a proxy for the actual cost driver(s) in distribution grids. The second constraint has to do with fairness. There is a fear that active consumers investing in distributed energy resources (DER) might benefit at the expense of passive consumers. We find that both constraints have a significant impact on the least-cost network tariff design, and the results depend on the state of the grid. If most of the grid investments still have to be made, passive and active consumers can both benefit from cost-reflective tariffs, while this is not the case for passive consumers if the costs are mostly sunk.

Inconsistent policies in an MPEC framework
Olivier Massol (ifp School)

Mathematical problems under equilibrium constraints (MPECs) are a special form of optimisation problems constrained by optimisation problems (OPcOP). An important field of application is a public authority that sets a policy in anticipation of a market equilibrium. This talk elaborated the idea, that an optimal policy should not depend on the point in time at which the optimisation problem is solved. Otherwise, the policy may be regarded as time inconsistent and cannot be optimal in a dynamic framework. Therefore, this talk advocated for the use of feedback approaches, which nest multiple MPECs for different time periods in each other in order to achieve time consistent optimal policies.

A new game theoretical approach for modeling export energy markets equilibria
Ibrahim Abada (Engie, Center of Expertise in Economic Modeling and Studies)

For resource-based economies, regulating exports is crucial. Nevertheless, we observe different countries deploying different export policies. The researchers explained this difference via strategic interactions by giving two competing countries the possibility to design their export markets and select the level of competition they exert. In a first step, the researchers tested standard models and find that they fail to explain the multitude of observed behaviours: under the closed loop Nash equilibrium paradigm, the equilibrium is reached when countries completely open their export market. The Stackelberg game on the other hand concentrates the market in a plausible way but is not symmetric since it appoints a leader and follower. In a second step, the researchers let countries choose between being strategic or passive in their interaction and demonstrate that the competitive outcome that they find in the closed loop Nash game rarely occurs. Only this last setup complies with the commonly observed situations.

Multi-objective bi-level optimization problem for the investment in new gas infrastructures
Aurora del Valle Díez (Comillas Pontifical University)

This talk presented the GASMOPEC model, which is a multi-objective bi-level optimisation model for representing the investment decision process in the European natural gas market. The upper level is the investment decision process in pipelines and regasification units, while the lower level problem is a downstream equilibrium for the natural gas market. The model recognises that for the decision towards to so-called projects of common interests, several criteria need to be taken into account. For this example, the researchers identified investment costs, supply security, market integration, and competition as the different main objectives, which is why these criteria are inserted into the multi-objective modelling framework. The case study shows that Western Europe is well interconnected, that the investment in two new European regasification terminals will enhance consumer utility, and that the pipeline capacity with incumbent major gas suppliers should increase.

Bargaining power in networks: a cooperative game theory approach
Franz Hubert (Humboldt University Berlin)

This talk introduced a novel methodology for analysing bargaining games on network markets, which are markets where transactions occur by means of distribution networks (e.g., gas, electric energy, water, etc.). The overall economic surplus obtained in the market is distributed among all network agents the on the basis of their bargaining power, which in turn depends on a variety of factors: position of each agent (e.g., a country) in the network, reliability in the cooperation scheme (e.g., geo-political stability), existence of market distortions and availability of outside options (e.g., alternative energy sources). The method the researchers proposed, which is illustrated here through an application to a fictitious network structure, is based on a two-stage process: first, a network optimization model is used to generate payoff values under different coalitions and network structures; second, cooperative game solutions are identified. Any change in the network structure entails both a variation in the overall welfare level and in the distribution of surplus among agents, as it affects their relative bargaining power. Therefore, expected costs and benefits, at the aggregate as well as at the individual level, can be compared to assess the economic viability of any investment in network infrastructure. A number of model variants and extensions are also considered: changing demand, exogenous instability factors, market distortions, externalities and outside options.

Convex formulations for equilibrium & bi-level problems
Ruud Egging (NTNU)

This talk elaborated on the issue that (bilevel) equilibrium problems suffer from a strong curse of dimensionality, which is why the computation of solutions to large-scale problems may not be feasible. Therefore, this talk advocated for the reformulation of (bilevel) equilibrium problems as convex non-linear optimisation problems, which can be solved much quicker due to more developed computational solvers and the omission of non-convex complementarity terms present in equilibrium models. The method was shown to lead changes in the order of magnitude regarding computation time for selected problems, but future research will still need to establish generalisations.

Panel discussion:
Which road for applied modelling - scientific excellence or policy communication?
Moderation: Franziska Holz (DIW Berlin)
Discussants: Rudolf Egging (NTNU), Oliver Massol (ifp School), Sauleh Siddiqui (Johns Hopkins University), Marijke Welisch (TU Wien)

The panel discussion concluded the workshop and also the workshop series of SET-Nav Work Package 10. The panellists and the audience therefore discussed the broader topic of how advanced modelling methods are needed or perhaps too complex for scientific policy advice. There was a consensus among the panellists that – depending on the research questions – there is also need for complex methods, in particular multi-stage modelling and model linking. However, for policy advice, there must be a substantial – and improved – effort to be communicated in a user-oriented way. The panellists confirmed that the users of model results are currently more interested in discussing the data than the methods.

SET-Nav
Strategic Energy Roadmap

Project duration:	April 2016 – March 2019
Funding programme:	European Commission, Innovation and Networks Executive Agency (INEA), Horizon 2020 research and innovation programme, grant agreement no. 691843 (SET-Nav).
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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.