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Energy Systems Modelling Research and Analysis

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ABSTRACT

This editorial introduces the seventh volume of the International Journal of Sustainable Energy Planning and Management. The volume presents part of the outcome of the project Energy Systems Modelling Research and Analysis (ENSYMORA) funded by the Danish Innovation Fund. The project carried out by 11 university and industry partners has improved the basis for decision-making within energy planning and energy scenario making by providing new and improved tools and methods for energy systems analyses.

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Systems analyses and policy
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1. Editorial

This volume of the International Journal of Sustainable Energy Planning and Management presents part of the outcome of the project Energy Systems Modelling Research and Analysis (ENSYMORA) funded by the Danish Innovation Fond.

Liberalization of the electricity marked, increased deployment of volatile only partly predictable renewable energy sources and internationalization imply that market players and regulators face increased uncertainty, investment risks and requirements for flexibility. In addition, ambitious environmental targets increasing the share of renewables points to further challenges in the future energy system. With focus on the Danish/Nordic energy system the aim of the ENSYMORA project has been to improve methods and models used for energy system analysis and energy planning and to use the models to analyse technical options, economic incentives and policies related to the demand and supply of electricity. Major research topics in ENSYMORA have been:

1. Analysis of electricity demand with an hourly resolution.
2. Description of uncertainties and how individual agents may operate in a volatile and uncertain market, and
3. Analysis of the entire energy system and national policy.

These topics and more have been targeted by the partners in the ENSYMORA project; four Danish university partners, universities in England, Norway and Germany and industry partners in Denmark. A total of 11 partners contributed, as listed below:

- DTU Management Engineering, Technical University of Denmark
- DTU Informatics, Technical University of Denmark
- Department of Development and Planning, Aalborg University
- Department of Mathematical Sciences, University of Copenhagen
- RAM-løse edb

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- Chair for Management Science and Energy Economics, University of Duisburg-Essen
- Department of Industrial Economics and Technology Management, Norwegian University of Technology and Science
- College of Life and Environmental Sciences, University of Exeter
- Energinet.dk
- Danish Energy Association

2. Electricity demand analyses

Looking at electricity demand with an hourly resolution, in this volume Møller & Andersen [1] analyse if industrial customers in Denmark react to variations in the hourly price of electricity. Looking both at the aggregate industry and at a specific industrial customer, the general conclusion is that at present Danish customers do not react to hourly prices. To get customers to react to hourly prices either hourly price variations have to increase considerable or demand response technologies should be installed. Other research within the project shows that hourly consumption profiles vary considerably between both individual and categories of customers, and although this is the case incentives for reacting to hourly electricity prices are quite limited [2 and 3].

3. Agents in volatile and uncertain markets

Related to uncertainties and the operation of individual agents this volume contains four papers.

In the first paper Zugno *et al*. [4] present a general mathematical framework for optimization under uncertainty that is directly applicable to problems of decision-making under uncertainty in the energy market. In addition, the paper reviews a few applications where trading-/decision-strategies are evaluated taking into account uncertainties in the energy market. Compared to deterministic solutions, in the cases analysed, the inclusion of uncertainties in decision strategies improves the financial performance of the agents.

The second paper on uncertainty and the operation of individual agents, Alnæs *et al*. [5], analyse actual bidding behaviour of three Norwegian hydro power producers in the Nord Pool day-ahead market and compares the actual bidding to a calculated optimal bidding. The optimal bidding is modelled by a two-stage mixed-integer linear programme model presented in Fleten & Kristoffersen [6]. The overall conclusion of the paper is that quite often hydro power producers come close to the optimal bid calculated from the model. However, their performance correlates with the variation in prices meaning that optimal bidding becomes more difficult when price variations are high. There is room for improved bidding e.g. through optimization approaches, however the potential gains are evaluated to be quite modest.

The third and fourth papers on uncertainties and individual agents focus on demand flexibility and how different technologies may contribute to balance the varying supply from renewable technologies. Thavlov & Madsen [7] model heat in an office building with air infiltration and Juul *et al*. [8] analyse different charging strategies for electrical vehicles, both technologies showing a potential for demand flexibility. Juul *et al*. [8] compare the costs of uncontrolled charging of electrical vehicles with charging at night and alternatives where vehicle owners or an aggregator are engaged in the regulating market. The main conclusion is that all vehicle owners gain from acting intelligently in the market. The simplest strategy of just delaying the charging to night hours considerably decreases the charging costs and engaging in the regulating market further increases the benefit of acting intelligently.

4. Holistic energy systems analyses and policy

Looking at the entire energy system and national policy this volume includes three papers: Henningsen *et al*. [9] look at the environmental productivity of Danish power plants, Østergaard *et al*. [10] analyse how changes in the profile of hourly electricity consumption affect alternative scenarios for the future Danish energy system, and Kitzing & Weber [11] analyse how different support schemes for investments in renewable technologies have different risk implications affecting the incentive to invest.

Henningsen *et al*. [9] analyse a panel of virtually all fuel-fired power generation units in Denmark over the years 1998 to 2011 and show that the environmental productivity for this group of power producers has been fairly unchanged over the fourteen years. That is, the main increase in the environmental productivity of the Danish power sector comes from the introduction of renewable technologies, while efficiency improvements for conventional producers have been limited.

Østergaard *et al*. [10] look at hourly electricity consumption profiles for categories of customers, forecast the aggregate profile to 2030 and 2050 and analyse how changes in the aggregate profile affect the energy system using methodology from [11]. In the medium term (year 2030), comparing fixed and flexible profiles for individual heat pumps and electrical vehicles, although the number of heat pumps and electrical vehicles is assumed to be moderate, their flexibility has significant effects improving the integration of wind power. In the long term (year 2050), where all private vehicles and most heating is electric and flexible, a main conclusion is that additional flexibility from conventional consumption by households and sectors will have a limited effect on the energy system.

Kitzing and Weber [12] compare how the different risk exposure in a feed-in-tariff and a feed-in-premium support system affects the investment incentive for a private investor. Looking at a wind power project, under a feed-in-tariff the private investor face uncertainty related to the production from the wind turbine, while under a feed-in-premium the investor face an additional uncertainty related to the market price of electricity. Looking at a specific German offshore wind park the analysis concludes that under a feed-in-premium, the required support level has to be 4-10% higher than under a feed-in-tariff, implying that the difference in risk has a significant effect on the required support level and should be included when policy makers decide support systems and levels.

Finally, further information on the ENSYMORA project and a complete list of publications from the project is found in the final report from the project – see *http://www.ensymora.dk/Deliverables/Final%20report.pdf*

References

[1] Møller NF, Andersen FM. An econometric model for analyzing electricity demand response to price changes at the intra-day horizon. Int J Sustain Energy Plan Manage (2015) pages 4–16. *URL:dx.doi.org/10.5278/ijsepm.2015.7.2*

[2] Andersen FM, Larsen HV, Boomsma TK. Long-term forecasting of hourly electricity load: Identification of consumption profiles and segmentation of customers. *Energy Conversion and Management 68(2013) pages 244-252.* URL: *dx.doi.org/10.1016/j.enconman.2013.01.018*

[3] Andersen FM, Larsen H V, Kitzing L, Morthorst PE. Who gains from hourly time-of-use retail prices on electricity? Analysis of consumption profiles for categories of Danish electricity customers. *WIREs Energy Environ.* 3 (2014) pages 582–593.URL: *doi:10.1002/wene.120*

[4] Zugno M, Morales JM, Madsen H. Decision Support Tools for Electricity Retailers, Wind Power and CHP Plants Using Probabilistic Forecasts. Int J Sustain Energy Plan Manage *7*(2015) pages 17–33. *URL: dx.doi.org/10.5278/ijsepm. 2015.7.3*

[5] Alnæs EN, Grøndahl RB, Fleten SE Boomsma TK. Insights from Actual Day-Ahead Bidding of Hydropower. Int J Sustain Energy Plan Manage 7(2015) pages 34–54. *URL: dx.doi.org/10.5278/ijsepm.2015.7.4*

[6] Fleten SE, Kristoffersen T. Stochastic programming for optimizing bidding strategies of a Nordic hydropowet producer. Eur. J. Oper. Res., 181(2) (2007) pages 916-928. *URL: dx.doi.org/10.1016/j.ejor.2006.08.023*

[7] Thavlov A, Madsen H. A Nonlinear Stochastic Model for an Office Building with Air Infiltration. Int J Sustain Energy Plan Manage *7*(2015) pages 55–66. *URL: dx.doi.org /10.5278/ijsepm.2015.7.5*

[8] Juul N, Pantuso G, Iversen JEB , Boomsma TK. Strategies for Charging Electric Vehicles in the Electricity Market. Int J Sustain Energy Plan Manage *7*(2015) pages 67–74. *URL: dx.doi.org/10.5278/ijsepm.2015.7.6*

[9] Henningsen G, Henningsen A, Schröder ST, Bolwig S. The Development of Environmental Productivity: the Case of Danish Energy Plants. Int J Sustain Energy Plan Manage *7*(2015) pages75–93.URL*:dx.doi.org/10.5278/ijsepm. 2015 .7.7*

[10] Østergaard PA, Andersen FM, Kwon PS. Energy systems scenario modelling and long term forecasting of hourly electricity demand. System effects of electrical vehicles and individual heat pumps being flexible or not. Int J Sustain Energy Plan Manage 7(2015) pages 95–112. *URL: dx.doi.org/10.5278/ijsepm.2015.7.8*

[11] Østergaard PA. Reviewing optimisation criteria for energy systems analyses of renewable energy integration. Energy 34(9)(2009) pages 1236–45. *URL: dx.doi.org/10.1016/j.energy.2009.05.004*

[12] Kitzing L, Weber C. Support mechanisms for renewables: How risk exposure influences investment incentives. Int J Sustain Energy Plan Manage *7*(2015) pages 113–130. *URL: dx.doi.org/10.5278/ijsepm.2015.7.9*