TIMES-DK: Technology-rich multi-sectoral optimisation model of the Danish energy system

As Denmark progresses towards a carbon neutral future, energy system models are required to address the challenges of the energy transition. This article describes design, input data and current usage of TIMES-DK, the first Danish energy system model that includes the complete national energy system, covering long-term technology investments. The article aims at explaining the modelling approach; highlighting strengths and reflecting upon limitations of the model; illustrating possible applications of TIMES-DK and inspiring new model developments. Some of the key strengths of the model include simultaneous optimisation of operation and investments across the complete energy system over the whole modelling horizon, explicit representation of the most important sectors of the economy, modular structure and the possibility of linking to a computable general equilibrium model for an additional insight on, e.g. public finance or CO2-leakage. TIMES-DK is being developed in close collaboration between an energy agency, a university and a consulting firm, to improve its robustness, relevance and impact on policy making. It allows for a wide range of applications including exploratory energy scenarios and policy analysis. To meet challenges of the future, further development of the model is needed and consequently the article provides references to ongoing projects addressing current development needs, such as improved representation of transport and flexible handling of the temporal dimension. To support a democratic and transparent process around decisions for the future Danish energy system, TIMES-DK should become available to interested parties.
Improvements in the representation of behavior in integrated energy and transport models

The inclusion of sociological aspects, as human behavior related to transportation, in energy–economy–environment (E3) models may enable an inclusive representation of the system under analysis, thus providing a more likely representation of reality. This article presents a review of integrated energy and transport models characterized by a detailed description of the passenger transport sector and by the presence of transport behavioral features. First, we propose a working taxonomy based on the level of integration of the energy and transport sectors. As the study underlines, a high level of integration is a precondition for incorporating the consumer behavior related to purchase decisions and use of transport technologies in energy and transport models. Second, we identify and review the recurring behavioral features related to transport included in current integrated energy and transport models: technology choice, modal choice, driving pattern, and new mobility trends. The main contribution of the paper resides in analyzing the modeling methodologies adopted in the literature to incorporate behavioral features in transport and in examining opportunities and challenges of each of them. We draw recommendations on model structure and relevant attributes to consider in relation to consumers’ choices in transportation.

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A Long-Term Strategy to Decarbonise the Danish Inland Passenger Transport Sector

This study applies a novel modelling framework to assess how alternative policies may contribute to a fossil-free transport sector for Denmark and the potential contribution they may have to a well-below 2°C world. The approach adopted consists of linking an energy system optimisation model, TIMES-DKMS, with a private car simulation model, the Danish Car Stock Model. The results of this study include the magnitude of CO2 abatement presented alongside the corresponding change in tax revenue generated through combinations of policies focusing on the derogation of motor taxes for low emission vehicles and banning the sale of the internal combustion engines. The resulting cumulative emissions from the Danish energy system are also compared to a range of national carbon budgets, calculated to adhere to various levels of global temperature rise at different levels of confidence. The results indicate that a ban on the sale of the internal combustion engines enforced in 2025 would enable the largest cut in cumulative greenhouse gas emissions of all the policies considered. However, none of the policies analysed comply with Denmark’s carbon budget capable of maintaining the increase of global temperature limited to 1.5°C.

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The multi-port berth allocation problem with speed optimization and emission considerations

The container shipping industry faces many interrelated challenges and opportunities, as its role in the global trading system has become increasingly important over the last decades. On the one side, collaboration between port terminals and shipping liners can lead to costs savings and help achieve a sustainable supply chain, and on the other side, the optimization of operations and sailing times leads to reductions in bunker consumption and, thus, to fuel cost and air emissions reductions. To that effect, there is an increasing need to address the integration opportunities and environmental issues related to container shipping through optimization. This paper focuses on the well known Berth Allocation Problem (BAP), an optimization problem assigning berthing times and positions to vessels in container terminals. We introduce a novel mathematical formulation that extends the classical BAP to cover multiple ports in a shipping network under the assumption of strong cooperation between shipping lines and terminals. Speed is optimized on all sailing legs between ports, demonstrating the effect of speed optimization in reducing the total time of the operation, as well as total fuel consumption and emissions. Furthermore, the model implementation shows that an accurate speed discretization can result in far better economic and environmental results.

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Modelling alternative fuel production technologies for the future Danish energy and transport system

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Modelling Behaviour in Integrated Energy and Transport Models - A review

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Venturini, G., PhD Student, Department of Management Engineering
Münster, M., Main Supervisor, Department of Management Engineering
Gallachóir, B. P. Ó., Supervisor
Karlsøn, K. B., Supervisor, Department of Management Engineering
Jørgensen, B. H., Examiner, Department of Management Engineering
Bolkesjø, T. F., Examiner
Krook-Riekkola, A., Examiner
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Giada Venturini (Participant)
Department of Management Engineering

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Giada Venturini (Participant)
Department of Management Engineering
Abstract: The challenging task of adequately including sociological aspects as human behaviours related to transport in economy-energy-environment models, may enable an inclusive representation of the system under analysis, thus providing results which are closer to reality. This work represents a preliminary review of energy systems models where a sufficiently detailed representation of the transport sector is present. This in particular allows to study which transport-related behaviours are modelled in energy system models and which methods are adopted, with the aim of comprehensively understand the opportunities and challenges of such implementation in TIMES-DK. The analysis firstly provides a classification of economy-energy-environment models, according to the level of integration of the transport system, here emphasizing the need for clarifying the aggregation level required in the representation of the transport system in order to include human behaviours. The study subsequently reviews above 25 models where different transport-related behaviours were accounted for, highlighting on the one side the focus and direction of the current research and on the other side the overlooked aspects. The work thus offers a contribution in this research area, providing an updated overview of selected transport-related behaviours and the different possibilities for representing them in integrated energy and transport models.

Presentation: Modelling Behaviour in Integrated Energy and Transport Models - A review