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.
Bridging the gap using energy services: Demonstrating a novel framework for soft linking top-down and bottom-up models

Giving policy advice related to climate mitigation requires insights that take both sectoral and technology effects (and their interactions) into account. This paper develops a novel soft-linking method for bridging the gap between sectoral top-down and technology rich bottom-up models. A unique feature of the approach is the explicit modelling of energy service demand in the top-down model, which creates a direct correspondence to the energy service production in the bottom-up model. This correspondence allows us, unlike previous work, to capture the macroeconomic impact of energy system investment flows. The paper illustrates the full-scale application of the method in the Danish IntERACT model, considering the unilateral introduction of coal carbon capture and storage in the Danish concrete sector. The policy leads to a reduction in the Danish concrete production, and in turn, a carbon leakage effect of 88%. Results also underscores the importance of accounting for the macroeconomic impact of energy system investment flows, as this is the source of approximately half of the policy-induced reduction in macroeconomic activity.

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