IntERACT
MODEL

WORKING PAPER NO. 01

14. January 2019

Lars B. Termansen
Steffen Dockweiler
Asbjørn Z. Hegelund
Birgitte Gersfelt
Rikke Næraa
Kristoffer S. Andersen

What is IntERACT – Introduction

Abstract:

The IntERACT model setup integrates a general equilibrium model with a technical energy system model. IntERACT is designed to evaluate long term consequences of climate and energy related policy initiatives. The purpose of this paper is to give a short overview of the model setup as well as shed light on the strengths and weaknesses of the chosen methodology

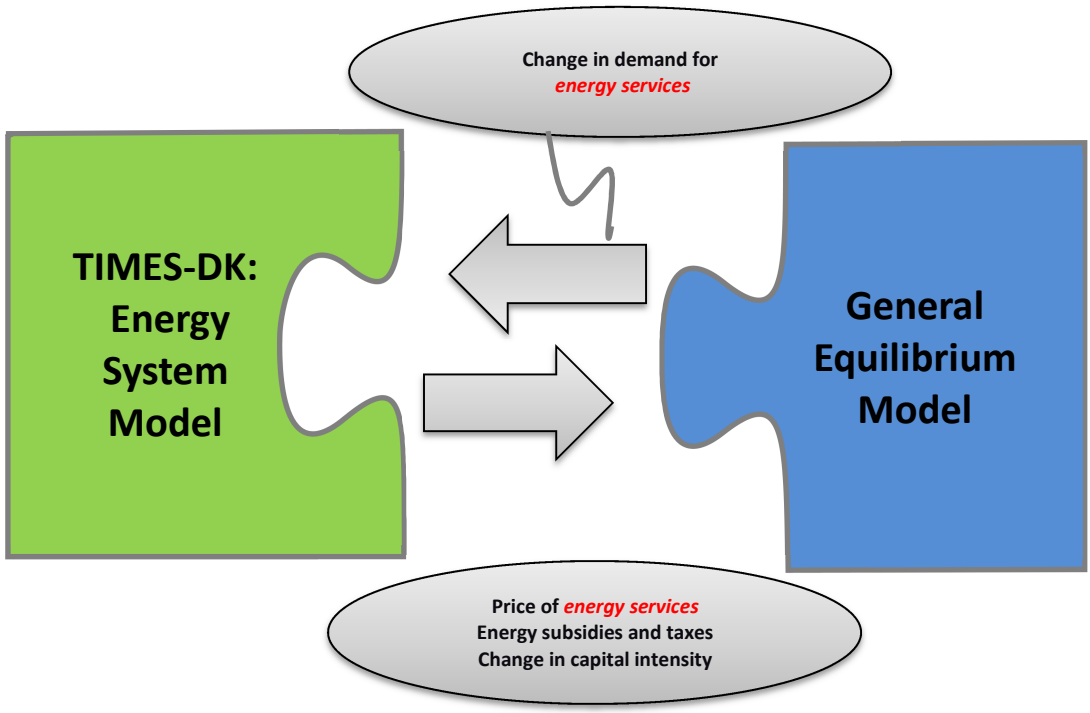
Initiated by The Energy Agreement and embedded in the Danish Energy Agency
The Energy Agreement of 22. March 2012 establishes the framework for developing a general equilibrium model of Denmark . The wording of the energy agreement is:

> *Development of a general equilibrium model for modeling the energy system and economic system to identify effective policies and future regulatory initiatives.*

Use of IntERACT and the development of the model is embedded in the Danish Energy Agency in order to tap into the established expertise, data and modeling tools available at the Agency.[1]

IntERACT links a general equilibrium model with a technical model
IntERACT is developed to have a satisfactory description of both the Danish economy and the Danish energy system, and especially the link between the two. The model setup consists of a top-down macroeconomic model and a bottom-up energy system model (TIMES-DK). The top-down model describes the macroeconomic relationships, i.e. economic flows between firms, households, the public sector and international trade. TIMES-DK describes the Danish energy system using a detailed technical modelling of the both production and use of energy.

The top-down model is a single country general equilibrium model covering Denmark. The bottom-up model is based on the international TIMES modeling framework. The modeling setup is shown in Figure 1.



Figur 1: The IntERACT-model

[1] The acronym relates to "INTegrated Economic eneRgy Applied Computational Tool."

The general equilibrium model yields a consistent description of the overall economy based on optimizing agents operating under rational behavior. The economic model evaluates welfare effects and sectorial changes from energy and climate policies.

The TIMES-DK accounts for the physical characteristics and technical constraints related to the production and use of energy. TIMES-DK further accounts for the impact of future technological improvements while also modelling rigidities in uptake of new technologies.

Linking the general equilibrium model with TIMES-DK allows us to tap into the strength of the each modeling types.

Energy services are the crux of the link

It is the concept of energy services that binds the two models together in IntERACT. An energy service is a representation of the function of the service that energy actually delivers – not the actual fuel itself. Examples of energy services for households could be lighting and space heating. For firms energy services could be melting, casting or pumping.

The premise in IntERACT is that agents make economic decisions based on the (relative) prices of energy services, while the specific fuel use and the specific technology applied in order to obtain the energy service is of secondary importance for the agent.

It is TIMES-DK – the technical model – that optimizes how the energy system is set up. At a given demand for an energy service, TIMES-DK finds the most cost efficient way of delivering that service. The composition of the energy system is basically optimized from three types of information: prices of fuels, data for technology and a range of other restrictions, e.g. rigidity in the uptake of a new technology and regulatory and policy constraints. The output from TIMES-DK consists of a range of prices for energy services, but also includes forecasts on investment requirements of the energy system. The investment costs are based on available technology catalogues from national and international sources.

Information on prices and quantities of energy services, fuel mix and investment demand are fed to the general equilibrium model, where they enter in the economic optimization decisions for agents. The equilibrium model also keeps track on any public revenue.

In turn, the general equilibrium model sends information back to the TIMES-DK model on demands for energy services, given the new energy service prices. TIMES-DK then recalculates the energy system for the new set of energy service demands. This iterative procedure is repeated until absolute convergence in fuel cost is achieved, typically 3-5 iterations.

The choice of the TIMES framework ensures longevity

The TIMES-DK model is built on the TIMES modelling framework, which is an internationally recognized tool for modeling energy systems. The framework is developed and maintained under the auspices of the IEA Energy Technology Systems Analysis Program (ETSAP)[2] and is a standardized framework for energy systems modellers to adopt data and

[2] See http://www.iea-etsap.org or for a longer introduction see: http://www.iea-etsap.org/web/Docs/TIMESDoc-Intro.pdf

knowledge for specific energy systems (i.e. local, regional, national or international). The TIMES framework is used by individual national teams in nearly 70 countries.

TIMES-DK is based on linear optimization that determines the most cost effective energy system pathway, as measured by total system cost. TIMES-DK allows for holistic modelling of production, supply and use of energy. It further captures future resource demand from the energy system, e.g. in the form of investments in new capital. In addition, the TIMES-DK allows for tracking of environmental flows, such as green-house-gas emission.

Finally, TIMES-DK is a versatile model that has a high degree of modularity and customization capabilities, as well as possibilities to include rigidities or constraints, that are deemed important for the description of the Danish energy system. This allows for a very flexible approach for the IntERACT model be customized to the analyses at hand. TIMES-DK is developed and maintained in a corporation between the Danish Energy Agency and the Technical University of Denmark.

Model development is incremental

IntERACT is developed gradually and incrementally in order to shed light and understand specific issues when linking the two types of models. For example how investment decisions in energy production is affected or linking issues with respect to capturing second order effects in the general equilibrium model. Relying on an incremental approach enables a closer cooperation with stakeholders to discuss and tap into the best available expertise. The incremental approach also strengthens knowledge building, error finding and generally reduces the overall risk of the project.

Conclusion

IntERACT has the special strength that it combines consistent macroeconomic modeling with a detailed and technical description of the energy system. This foundation allows IntERACT to provide insights on both economy and energy system wide effects of Danish climate and energy policy.

The following two peer-reviewed papers provide additional information on the IntERACT modelling approach and the TIMES-DK model respectively.

Andersen, K. S., Termansen, L. B., Gargiulo, M., & Gallachóirc, B. P. Ó. (2018). Bridging the gap using energy services: Demonstrating a novel framework for soft linking top-down and bottom-up models. Energy. https://doi.org/10.1016/j.energy.2018.11.153

Balyk, O., Andersen, K. S., Dockweiler, S., Gargiulo, M., Karlsson, K., Næraa, R., ... & Venturini, G. (2019). TIMES-DK: technology-rich multi-sectoral optimisation model of the Danish energy system. Energy Strategy Reviews, 23, 13-22. https://doi.org/10.1016/j.esr.2018.11.003