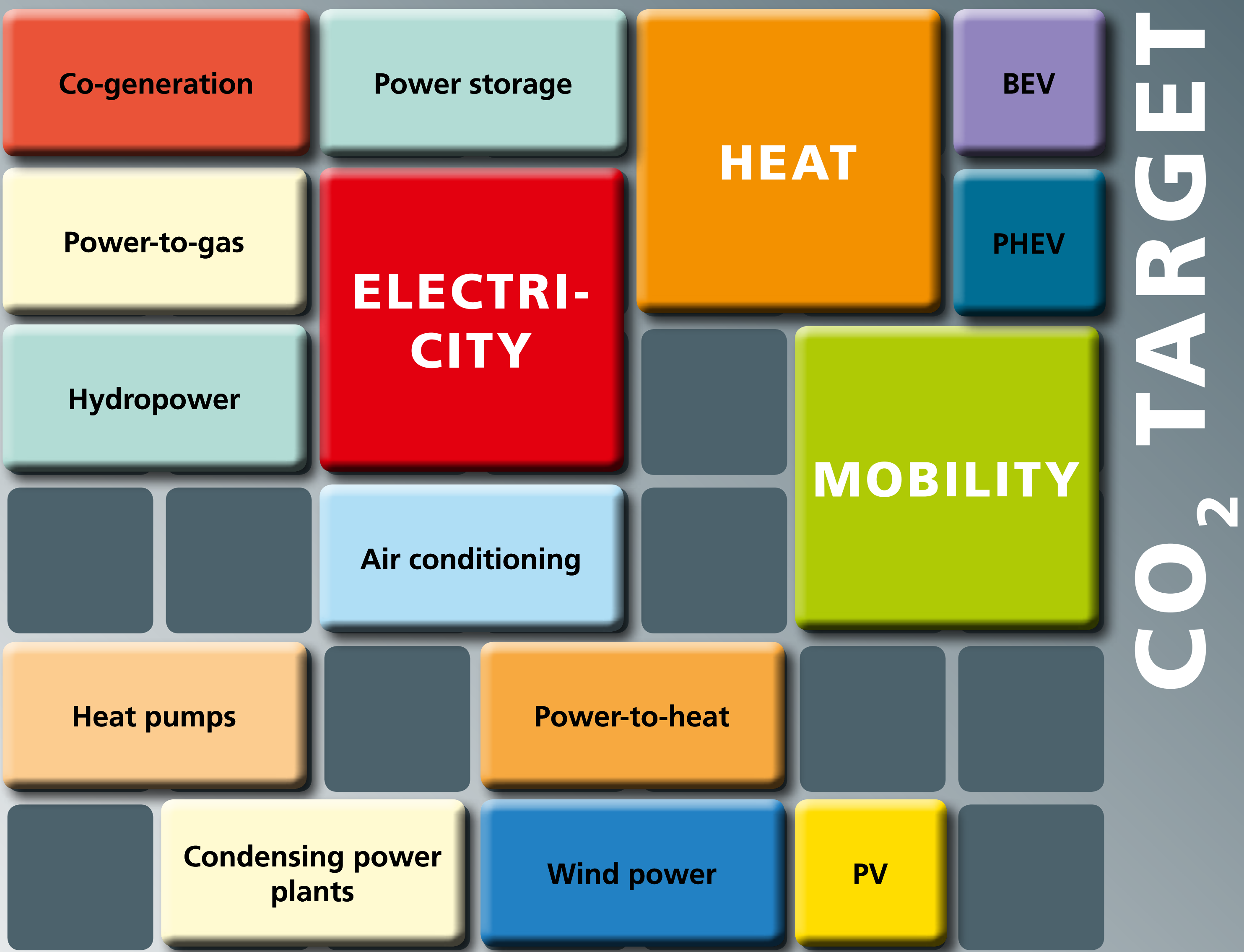
FRAUNHOFER INSTITUTE FOR ENERGY ECONOMICS AND ENERGY SYSTEM TECHNOLOGY IEE

SCOPE

CROSS-SECTOR OPTIMISATION OF DISPATCH AND INVESTMENT FOR ANALYSIS OF FUTURE ENERGY SUPPLY SYSTEMS



OPPORTUNITIES AND CHALLENGES IN THE FUTURE ENERGY SYSTEM

Future challenges in the energy system

The energy transition presents an enormous challenge for the energy system. Against the backdrop of constantly increasing power generation from decentralised and fluctuating renewable energy sources, established structures and business models must be reviewed in the context of changing boundary conditions and entire lines of business must be refined in accordance with the new requirements.

However, these changes also hold opportunities for new business areas and the establishment of efficient technologies. In order to be able to take advantage of the opportunities of the energy transition, early analysis of future development paths and targeted development of the regulatory framework are needed.

Model-based analysis as a guide

For a detailed analysis of possible developments depending on different assumptions, energy system models, combined with energy economic knowledge and experience, form an important methodological basis. The knowledge gained from this can then serve as the basis for short, medium, and long-term decisions.

At the Fraunhofer IEE, there is an extensive range of models available which, thanks to their modularity and variety, are able to address a wide range of energy economics questions. The SCOPE model is an important tool in this context as it optimizes cross-sector dispatch and investment decisions for future energy system scenarios. Its model framework is under constant development in various projects and can be adapted to specific problems and research questions.

The »SCOPE« energy system model

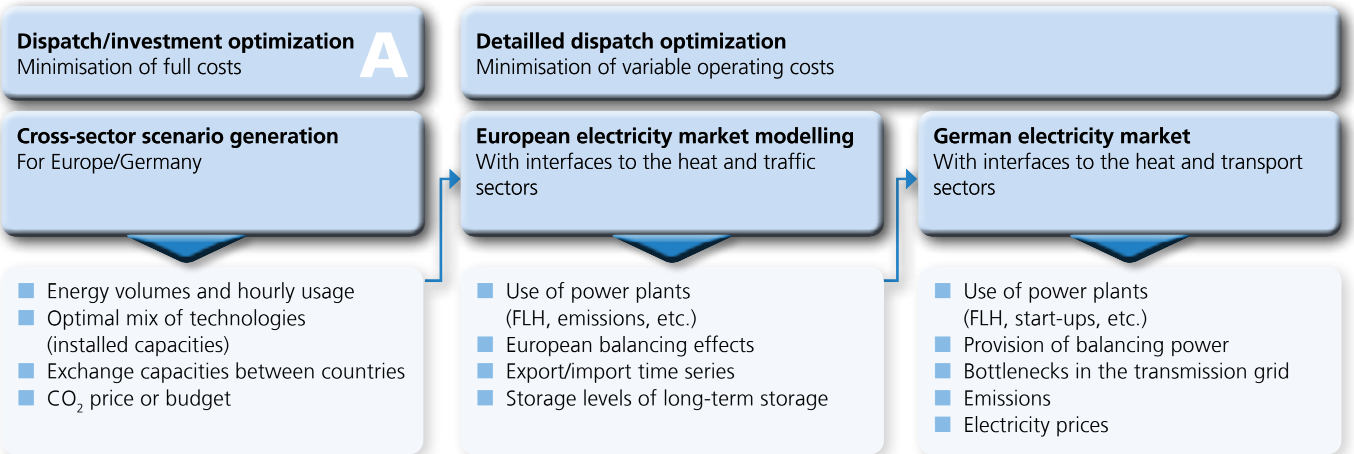
Modelling approach

The »SCOPE« model approach is a modularly constructed fundamental model for the generation and analysis of cross state and multi-area energy scenarios. The model determines the minimum cost of covering demand profiles from the electricity, heat and transport sectors by the various energy units from a macroeconomic perspective. In order to determine a cost-minimal technology mix for future scenarios, investment decisions based on annuitized technology costs can be taken into account in the objective function.

Scope of the content

Thanks to the hourly modelling of the supply and demand characteristics of a scenario year, it is possible to model both the renewable energy producers and conventional power plants, as well as the use of storage technologies and flexibility options, in detail. A wide variety of conventional and renewable generation technologies are available for power generation. The necessary flexibility for the integration of renewable power generation is modelled using various storage technologies, load management options, and European cross-border exchanges of energy. Depending on the research question, the heat and transport sector, with their interfaces with the power sector, can be modelled with a high degree of temporal and spatial detail.

In addition to hourly demand coverage in all sectors, other boundary conditions can be applied to the target system. For example, an upper budget limit for CO_2 emissions in specific countries or sectors for compliance with specific climate targets can be taken into account instead of a fixed CO_2 certificate price.



SCOPE – Model configuration and potential interactions

Input data

As a data basis for the model, the Fraunhofer IEE has a comprehensive techno-economic database for Germany and European which is continually expanded and updated.

This includes in particular:

- A comprehensive database of thermal power stations and renewable power plants
- High temporal and spatial resolution potentials and time series for electricity from renewable sources (historic and model-based for future scenarios)
- Detailed techno-economic data sheets on energy storage systems and flexibility options
- Comprehensive emission and energy demand data base

Technical implementation

The »SCOPE« modelling framework is implemented in MATLAB® and the commercial solver IBM® ILOG® CPLEX® is used to solve the optimisation problems. The Fraunhofer IEE also features a high-performance computing cluster for rapid solutions of even compelx optimsation problems..

Configuration options

Thanks to the modular implementation of »SCOPE«, the model can always be individually adapted to suit your questions and requirements. The level of detail and functionality of the model is thus adjusted in exactly the system areas which are relevant for you and the computing time is kept manageable through simplification in the peripheral areas if necessary.

Two typical model configurations are:

A The application of the model as a combined investment and dispatch optimization for the creation of cross-sectoral target scenarios of the future energy supply system as well as the determination of transformation paths based on upper and lower bounds of the necessary technological developments to achieve the target scenario.

B The use of the model for the analysis of the short- to medium-term development of the electricity market which is as realistic as possible in order to evaluate various technologies (e.g. with regard to efficiency and CO_2 reduction potential).

CONFIGURATION OPTIONS THE BIG PICTURE... OR ALL THE DETAILS

A Scenario development

The »SCOPE energy system« model configuration allows for the generation of cross-sector target scenarios for future energy systems. Here, the model environment can be configured such that both existing plants and investment decisions for a cost-optimised energy system are modelled.

Method

The determined target scenarios are based on optimal investment decisions for all technology types with an hourly, linear asset scheduling (8760 h). In addition to conventional and renewable generation, storage, and transmission technologies on the electricity market, the model also includes heat generation technologies, numerous drive concepts for motorised road transport, and other flexibility options.

Key input parameters here are the techno-economic parameters for all technology options, detailed emission and energy demand structures, and potentials and restrictions for the possible expansion of the various technologies. Key boundary conditions are the CO_2 reduction targets which can either have a cross-sector effect or separately cover the individual areas which are not subject to the the European emission trading (ETS). Investment decisions for storage and flexibility effects associated with demand technologies can be comprehensively modelled using the hourly modelling.

This results in additional electricity demand for CO_2 reduction in the heating and transport sector as well as cross-sector CO_2 abatement costs.

Typical result variables

- Optimal mix of technologies for the electricity, heat, and road traffic sectors
- Electricity and overall energy consumption for achieving CO_2 reduction targets

B Electricity market simulation

The »SCOPE electricity market« model configuration is characterised by a detailed model of the existing conventional power stations and inclusion of high temporal and spatial resolution time series for renewable power plants.

Method

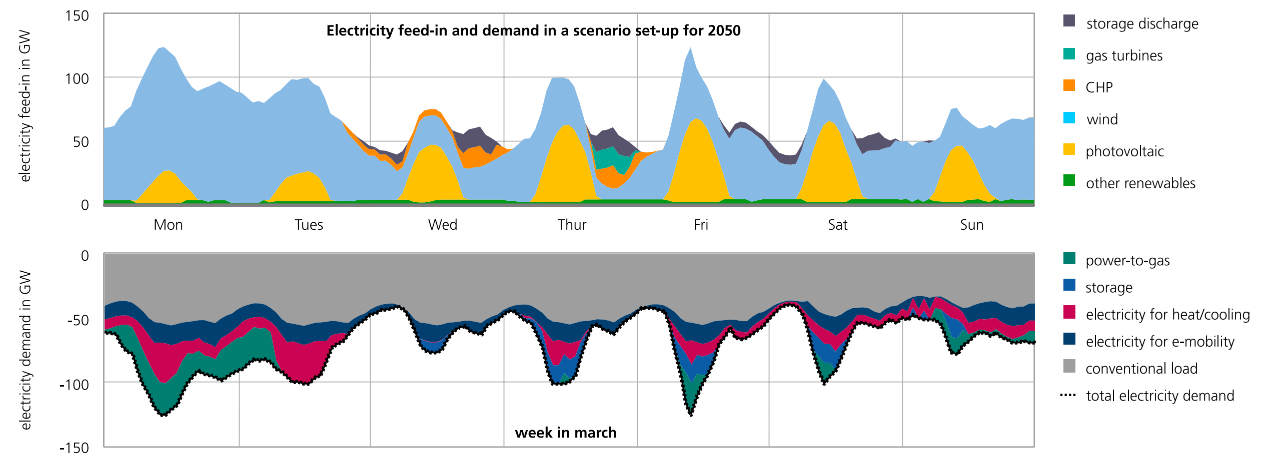
Market simulations are typically carried out in two steps. First, the plant utilisation is determined in a European context. A continuous, linear abstraction of the model is used for this, which makes it possible to conduct a closed optimization for the European study area for a year (8760 h). Cross-border imports and export time series between the European countries and filling level curves for long-term storage (particularly hydraulic storage power plants) are determined with the help of this upstream optimisation step.

Building on this, the plant utilisation for Germany or Europe is recalculated. The rolling planning horizon used here is adapted to suit the flows on the electricity markets and allows uncertainties to be taken into account through forecast data which is updated step by step. Thanks to the mixed-integer linear programming which is used in this variant, the technical minimum output and start-up costs for thermal power plants are also taken into account per plant. Furthermore, the provision of balancing power or limited domestic transmission capacities can be integrated into the detailed modelling.

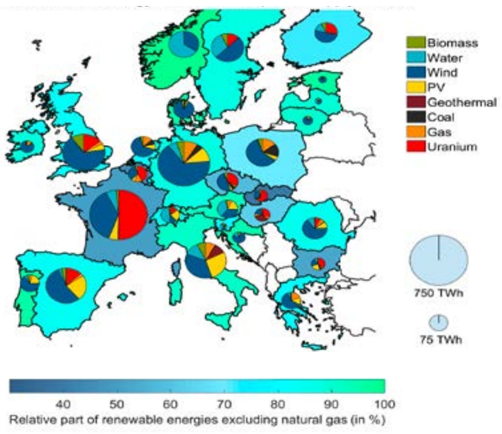
Typical result variables

- Change in the utilisation of existing and new thermal power plants due to increasing shares of renewable energy-sources
- Analysis of the demand and efficiency of energy storage systems and other flexibility options
- Hourly electricity price time series for further technology assessment

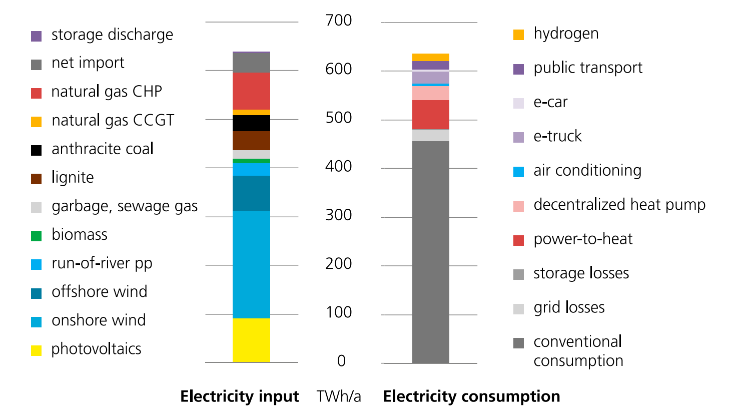
GRAPHICAL ANALYSES

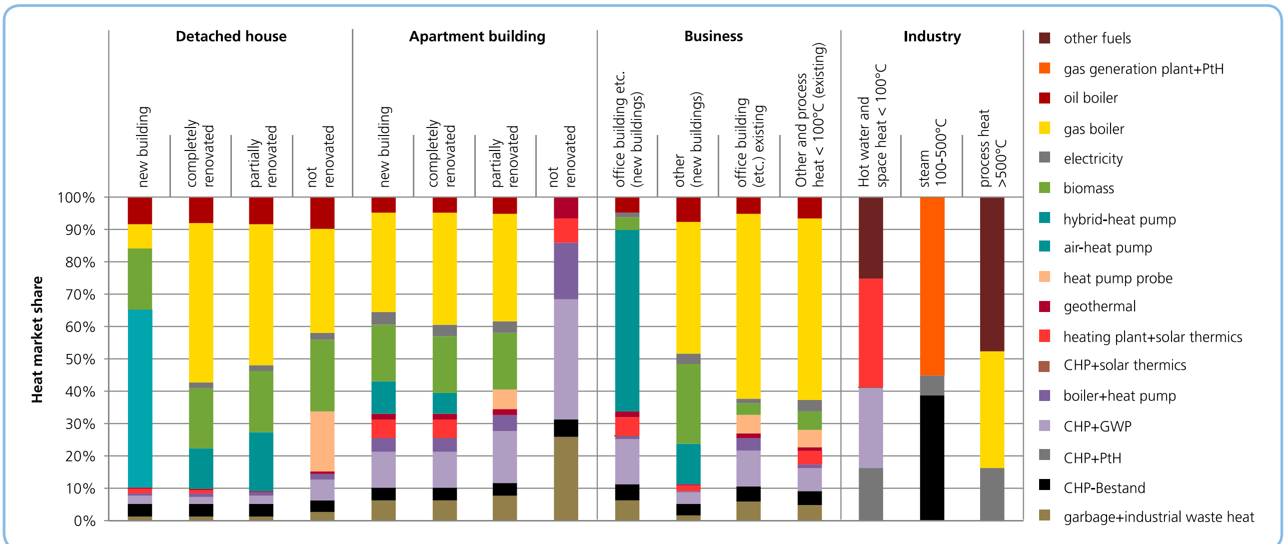


Distribution of energy sources in power supply in 2030



Electricity balance for Germany (2030 scenario)





CUSTOMISED SIMULATIONS AND ANALYSES

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We offer

- Together with you, we make assumptions and create energy scenarios that show possible developments and trends in the energy system (e.g. growth in renewable generation shares)
- We calculate hourly electricity price time series for future scenarios on the electricity market and analyse the efficiency of various technology on this basis
- We determine energy-related CO_2 emissions and CO_2 savings potential through the use of various decarbonisation measures in the energy system
- We analyse framework conditions and possible applications for new technology, in particular for energy storage systems and other flexibility options (e.g. power-to-heat, heat pumps, e-mobility)
- We analyse questions on future market design (e.g. analysis of various regulatory frameworks)

Selected reference projects and studies

- Development of road traffic and linking with the energy system (2016-2018; customer BMUB [German Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety]) www.energieversorgung-elektromobilitaet.de
- Heat transition 2030 (2016-2017; customer Agora) https://static.agora-energiewende.de/fileadmin2/Projekte/2017/Heat_System_Benefit/143_Heat_System_benefits_WEB.pdf
- North Seas Offshore Network: feasibility and implications of various offshore network concepts in the North Sea region (2014-2017; customer BMWi [German Federal Ministry for Economic Affairs and Energy]) https://iee.fraunhofer.de/de/projekte/suche/2017/nson.html
- How Germany can still achieve its climate target (2018; customer Greenpeace) https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/energieszenario_fuer_2020.pdf
- Shaping the path to a greenhouse gas-neutral Germany in a way which saves resources (2015-2019; customer German Federal Environment Agency) https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/rescue_studie_cc_36-2019_wege_in_eine_ressourcenschonende_treibhausgasneutralitaet.pdf
- Interaction between electricity from renewable sources, heating and transport (2012-2015: customer BMWi) What might a future energy system look like in view of the climate protection requirements? publica.fraunhofer.de/documents/N-356297.html