TRANSFORMATION PATHS OF LOCAL DISTRICT HEATING WITH ELECTRICITY AND HEAT SECTOR COUPLING IN GERMANY

[Pedro Girón, Fraunhofer IEE, +49 561 7294-481, pedro.giron@iee.fraunhofer.de]
[Britta Zimmermann, Fraunhofer IEE, britta.zimmermann@iee.fraunhofer.de]
[Elias Dörre, Fraunhofer IEE, elias.doerre@iee.fraunhofer.de]
[Alexander Dreher, Fraunhofer IEE, alexander.dreher@iee.fraunhofer.de]

Overview

The scope of the paper is to combine a techno-economic approach to transformation processes in energy systems with a focus on district heating. This approach represents a knowledge base for the modelling of different district heating systems and is therefore an important basis for future research in the energy economics field.

In the simulation of energy scenarios related with climate protection, sectoral partial models are mostly used (e.g. in long-term planning). Those determine economically optimal transformation paths based on CO2 reduction costs and its impact on revenues, for example.

In the area of fundamental model-based overall system investment and deployment planning, the mathematical models have been improving. These consider economically optimal scenarios, but also new developments of energy supply technologies. In these sense, the models need to establish additional connections. First, to relate the investment decision-making process with regard to a predominant CO_2 target reduction. Secondly, to connect the heat demand coverage and the influence of electricity market prices. This paper presents a simulation of the dynamics of the renewable energy supply incentives.

Methods

To define a cost-optimal transformation path, the model presented in this paper implements a district heating system from a region of Germany. In principle, it would be presented the possible combinations of technologies, as a result of the hourly operation of sector coupling between electricity and heat. This means that individual investment projects are evaluated as a district heating supply technologies portfolio with regard to their economic efficiency. The simulation environment will optimize the operational decision making of combined heat and power plants, heat pumps, solar thermal, district heating consumers and heat storage systems.

In the model used to support investment decisions, this paper emphasizes the transformation of the heating sector, considering new regulatory frameworks requirements. Thus, the optimization problem is significantly further developed compared to the traditional revenue simulation for power plant units available on the district heating grid. Investment decisions are then not only made on the basis of price expectations (i.e. electricity sold on the spot market), but also taking into account alternative operational economic incentives for producing electricity and heat. with renewable energies. The savings of CO_2 emissions can also be taken into account.

Results

A portfolio of different technologies conform the cost-optimal transformation path of the district heating, that also outline when the investment is needed. A planning horizon of 35 years, from 2020 to 2055 is used to calculate the Net Present Value and, for each year, the Heat Generation Cost that triggers the technological transformation path.

The heat generation and investment cost are presented for periods of 5 years, having 7 (cut-off) reference years to put in perspective the benchmark scenario, wich reflects the use of Natural Gas boilers (short-term) and decentral heat pumps (mid- and long-term), respectively. Also the outlook of scenarios relying stronlgy on the use of Heat Pumps will be discussed. In this sense, different sensitivities related to regulatory mechanisms and energy policy strategy are analysed.

Conclusions

Most of the transformation paths lead to generation cost that are competitive in relation to the benchmark supply, under consideration of the assumed incentives. An energy policy with a faster decrease of levies and taxes for electricity used by sector-coupling technologies and a faster increase of CO_2 prices leads to an earlier decarbonisation of the district heating systems.

Systems with no or low potential for using low-cost base load, such as industrial or municipal waste heat, are critical regarding Heat Generation Cost compared to a decentralized supply. Heat pumps are essential for the decarbonisation, however, the newly-built capacity depends on the assumed incentives, while solar thermal technologies are built in very limited capacities.

The fossil fuels used on existing Combined Heat and Power technologies decrease the Heat Generation Cost over the whole period under consideration, while the impact depends on their lifetime.

Network extensions can be economically feasible under certain conditions. However, the feasibility is important given the current energy policy in Germany, and investment decisions have to be considered and analysed as single study cases.