Electrification of space and water heating: A model-based scenario analysis to reach a climate-neutral EU in 2050

Themenbereich (3) Sektorkopplung und Flexibilität or (2) Energieerzeugung

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Motivation and key question

The heating and cooling sector accounts for half of European energy consumption and is still largely based on fossil fuels [1,2]. Thus, a fundamental transition is needed to archive climate neutrality in 2050 in the EU. Given the current crisis, the transition becomes even more vital to reduce import dependencies. For space and water heating, electrification is seen as the main solution [3,4]. However, some analyses favour heat pumps [5], while others foresee a higher deployment of hydrogen [6]. To contribute to this discussion, the paper analyses different pathways for heating buildings, considering interactions with the upstream supply sector.

Methodology

An explorative scenario-based modelling approach, combining two highly detailed models, is used. A set of 12 scenarios is defined that explores different levels and means of electrification of space and water heating. The 12 scenarios are divided into three different scenario groups: (1) direct electrification, (2) indirect electrification with hydrogen, and (3) indirect electrification with synthetic e-fuels, which are hydrocarbon-based gaseous or liquid fuels. Within each scenario group, four different scenarios with different minimum shares of the specific energy carrier are defined, varying from 20% to 80%.

The scenarios are processed in a model chain, combining the two models Invert/Opt[1] and Enertile[2]. A detailed description for Invert/Opt can be found in [7] and for Enertile in [8]. Invert/Opt generates the demand datasets and Enertile produces the upstream supply datasets. For all 27 MS of the EU, the pathway until 2050 is modelled. All of the scenarios achieve climate neutrality in 2050, not only in space heating but in the overall energy system. Assumptions in all sectors except space and water heating are kept constant. In that way, technology-specific effects caused by changes in space and water heating can be identified, quantified and interpreted.

Results and conclusions

Based on the detailed modelling approach, the following results and conclusions are developed:

- It can be concluded that there is a clear merit order of heating technologies. Decentral heat pumps and district heating (where heat densities are sufficiently high) are economically most viable, while hydrogen and e-fuels are relatively more expensive.
- All scenarios show a significant decrease in the energy demand until 2050, whereby renovation rates are somewhat higher in the *H2* and *E-Fuel* scenarios.

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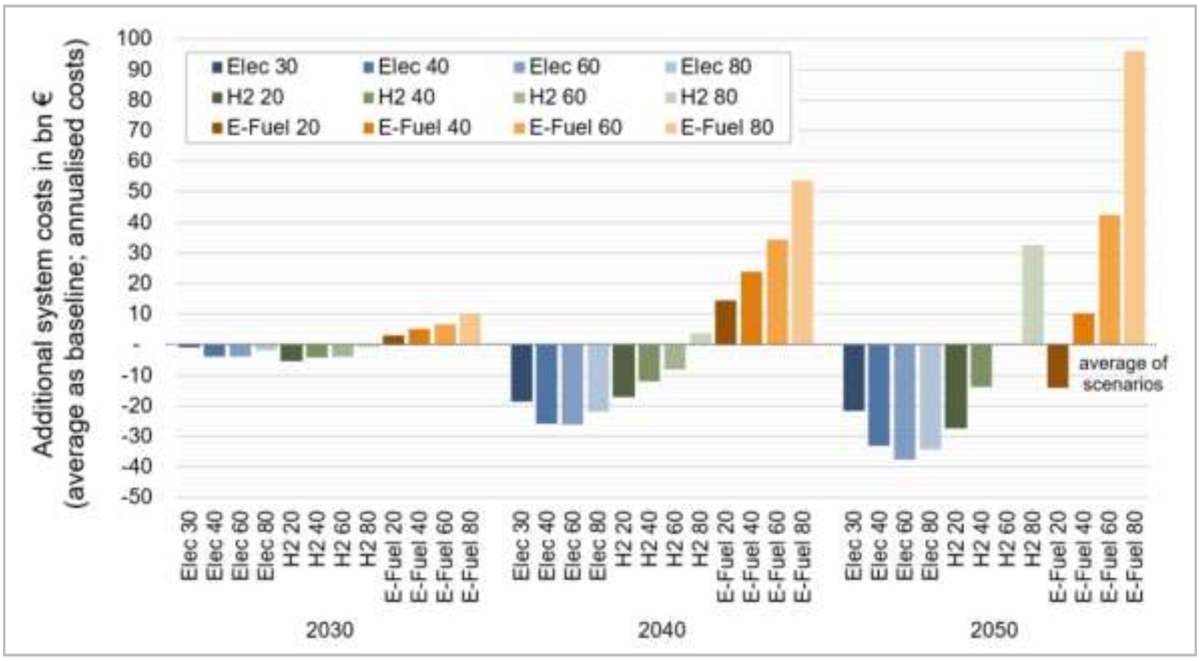
[1] Invert/Opt is developed based on the model Invert/EE-Lab. https://www.invert.at/

[2] https://www.enertile.eu

- In district heating, heat pumps provide the majority of heat in 2050 in all scenarios. Hydrogen is only used to cover peak loads.
- A significant increase in electricity generation, dominated by wind and solar, can be observed in all scenarios. Thereby, the *H2* and *E-Fuel* scenarios show higher electricity needs in 2050.
- The direct electrification scenarios (*Elec*) are the most cost-efficient pathways. The lowest costs are reached in the *Elec 60* scenario (compare figure 1).

Concluding, scenarios with high shares of heat pumps show lower system costs, slightly lower renovation activities and lower electricity generation compared to scenarios with high shares of hydrogen or e-fuels.



Note: The visualised system costs include capital costs and operation and maintenance costs from both models. The average of the system costs per decade in the scenarios serves as a baseline for the comparison. Hence, only the additional costs are visualised to make the differences between the scenarios more obvious. For example, in 2030 the cost in the E-Fuel 80 scenarios is 10 bn € higher than the average costs of all scenarios.

Figure 1: System costs in EU-27 with average of scenarios as a baseline

Literature

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