Fraunhofer-Institut für System- und Innovationsforschung ISI

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

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In cooperation with Consentec, TU Vienna, e-think, REKK

# Electrification of space heating

## Relevance of topic and objective

- The feasibility of reaching a climate-neutral energy system in 2050 has been discussed extensively in the literature, which builds on modelling of different scenarios or transformation pathways.[1]
- There seems to be agreement on the pathway for the power sector with a phase-out of fossil fuels and a rapid expansion of renewable electricity.[2]
- Regarding heating and cooling of buildings, electrification (sector coupling) is one of the main solutions in several studies.
- However, the results are strongly debated and different decarbonisation pathways and their impact are still under discussion. Some publications favour an uptake of heat pumps, while others foresee a higher deployment of secondary energy carriers, such as green hydrogen.[3]

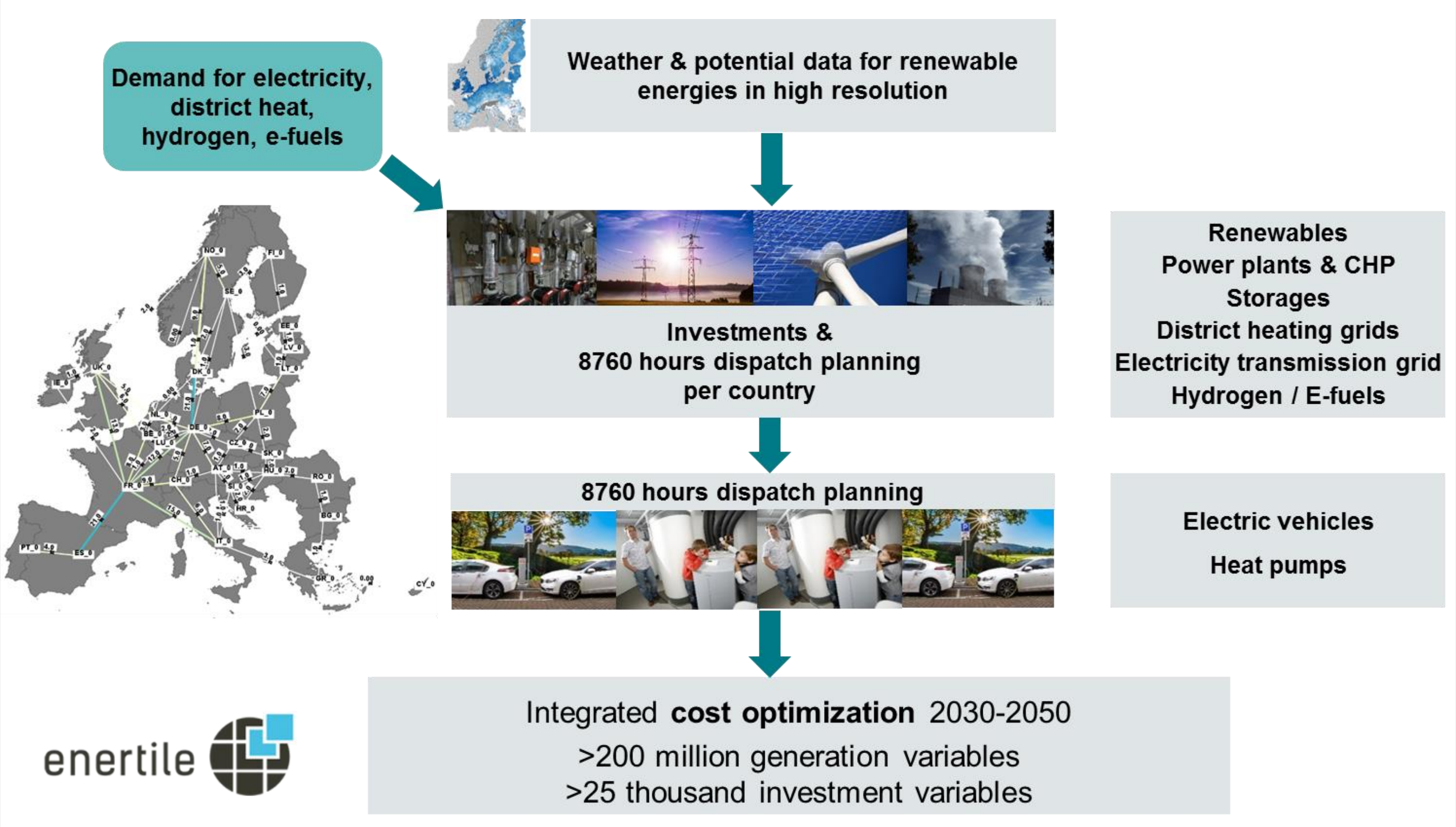
➢ Objective: Analysing the effects of different levels and means of electrification of space heating in order to identify the most favourable pathway for heating buildings.

[1] e.g. Tsiropoulos et al. (2020) or IRENA, REN21, IEA (2022); [2] e.g. Kranzl (2022); [3] Kranzl et al. (2022) vs. Hoogervorst (2020)

# Electrification of space heating

## Methodology and models

- Explorative scenario-based modelling approach, combining two models.
- **Invert/Opt** optimises energy-related investment decisions in buildings focusing on space and water heating (TU Vienna).[1]
- **Enertile** is a techno-economic optimization model for energy systems (Fraunhofer ISI).[2]




[1] e.g. Müller (2015), Kranzl et al. (2013), Hummel et al. (2020); [2] e.g. Pfluger et al. (2013), Lux and Pfluger (2020)

# Electrification of space heating

## Scenarios

- In total, 12 different scenarios with decarbonisation pathways until 2050 are modelled, geographically covering all 27 member states of the EU.
- Three **scenario groups**:
  (1) direct electrification of space and hot water heating
  (2) indirect electrification with hydrogen produced with renewable electricity
  (3) indirect electrification with synthetic e-fuels, which are hydrocarbon-based gaseous or liquid fuels produced with renewable electricity
- All scenarios reach **climate-neutrality in all sectors**.

| Scenario name | Energy carrier | Share of heated floor area supplied by energy carrier in 2050 |
|---|---|---|
| Elec 30 | Electricity | 30% |
| Elec 40 | | 40% |
| Elec 60 | | 60% |
| Elec 80 | | 80% |
| H2 20 | Hydrogen | 20% |
| H2 40 | | 40% |
| H2 60 | | 60% |
| H2 80 | | 80% |
| E-Fuel 20 | E-fuels | 20% |
| E-Fuel 40 | | 40% |
| E-Fuel 60 | | 60% |
| E-Fuel 80 | | 80% |

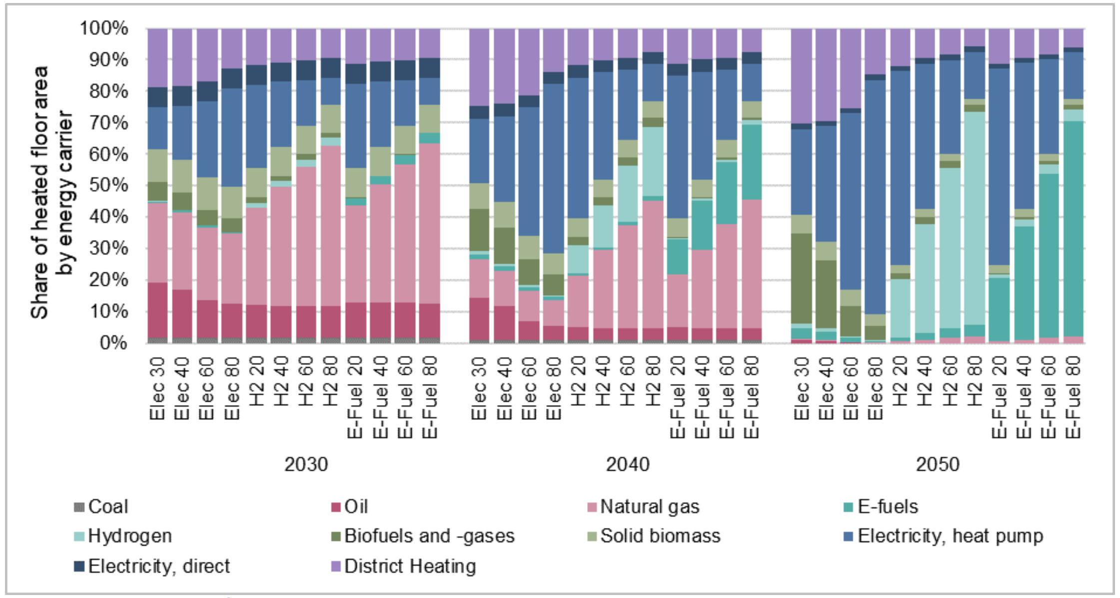



Figure: Share heated floor area

# Electrification of space heating

## Energy demand in buildings from Invert/Opt

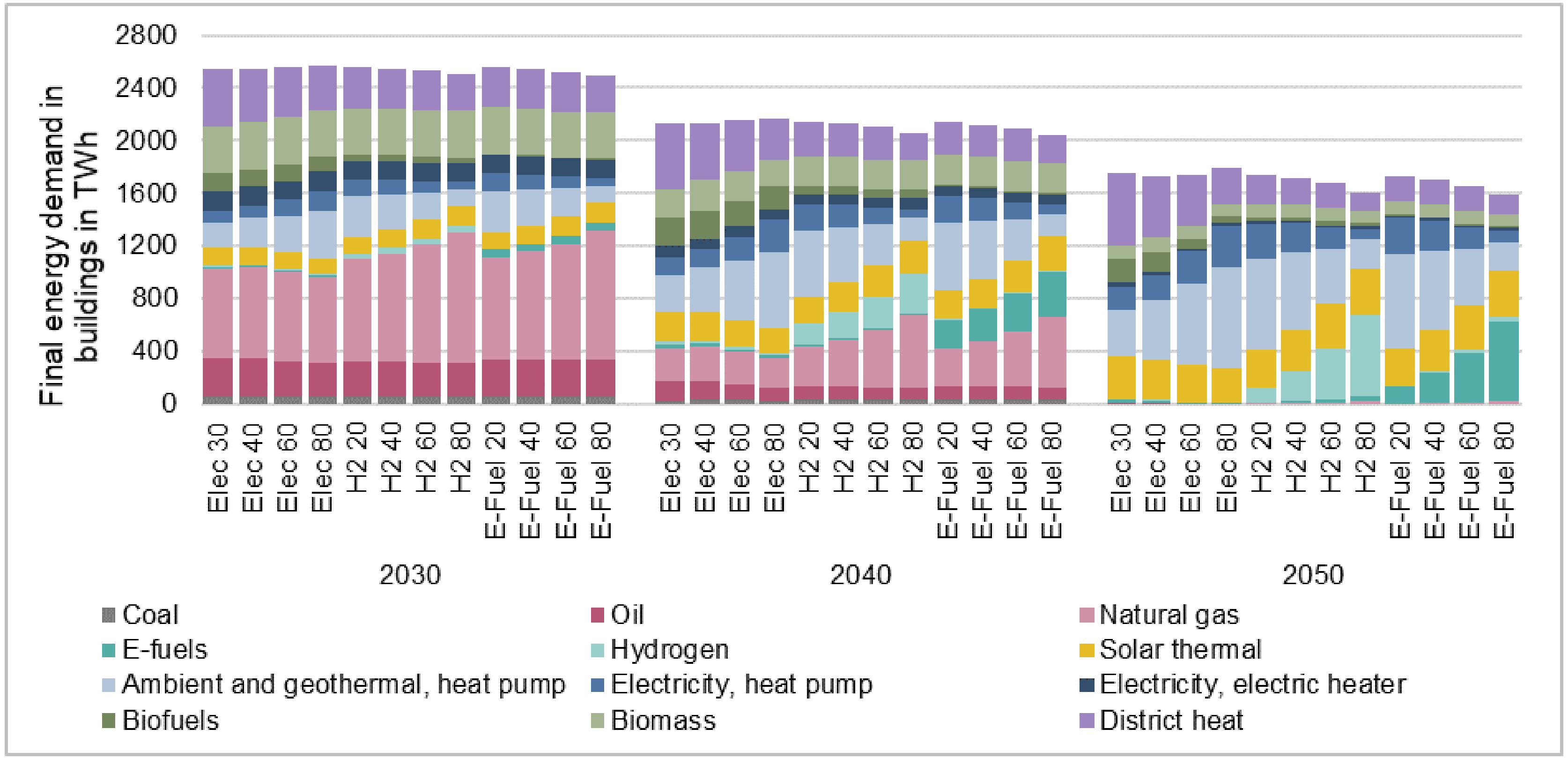



Figure: Final energy demand in buildings

- All scenarios show a significant decrease in the final energy demand until 2050, thus, an uptake of building renovation and subsequent energy savings.
- Renovation rates are somewhat higher in the H2 and E-Fuel scenarios, compared to the Elec scenarios. This difference is due to high variable costs of hydrogen and e-fuels.

# Electrification of space heating

## DH generation from Enertile

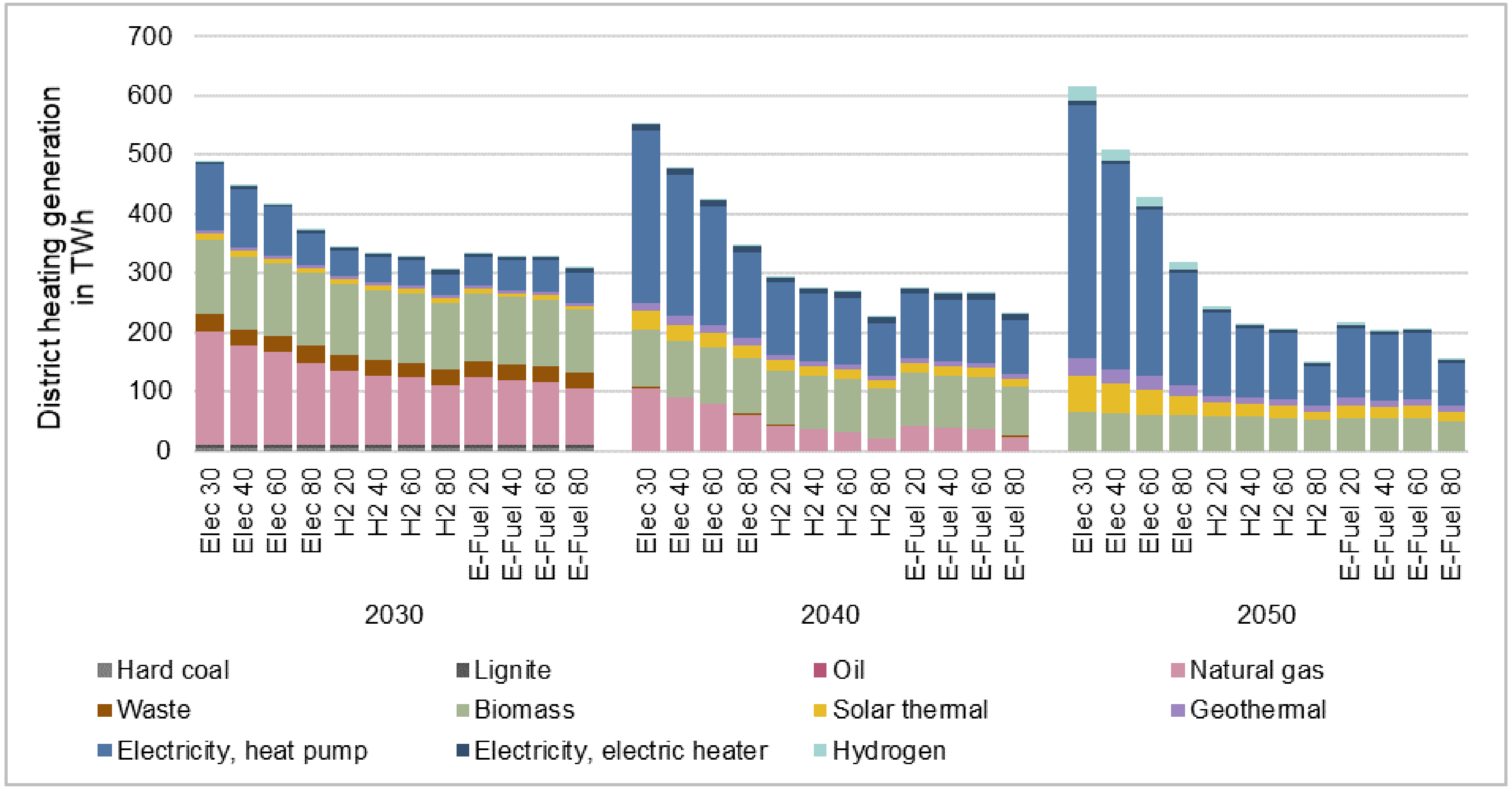



Figure: District heating generation mix

- There are significant variation in DH generation across scenarios.
- Highest share of DH and thus highest generation in Elec 30; lowest share in H2 80 and E-Fuel 80.
- High share of heat pumps in 2050 in all scenarios. Heat pumps cover most of the variation in overall generation.
- Hydrogen boilers are only used in times of electricity shortages (backup role).

# Electrification of space heating

## Electricity generation from Enertile

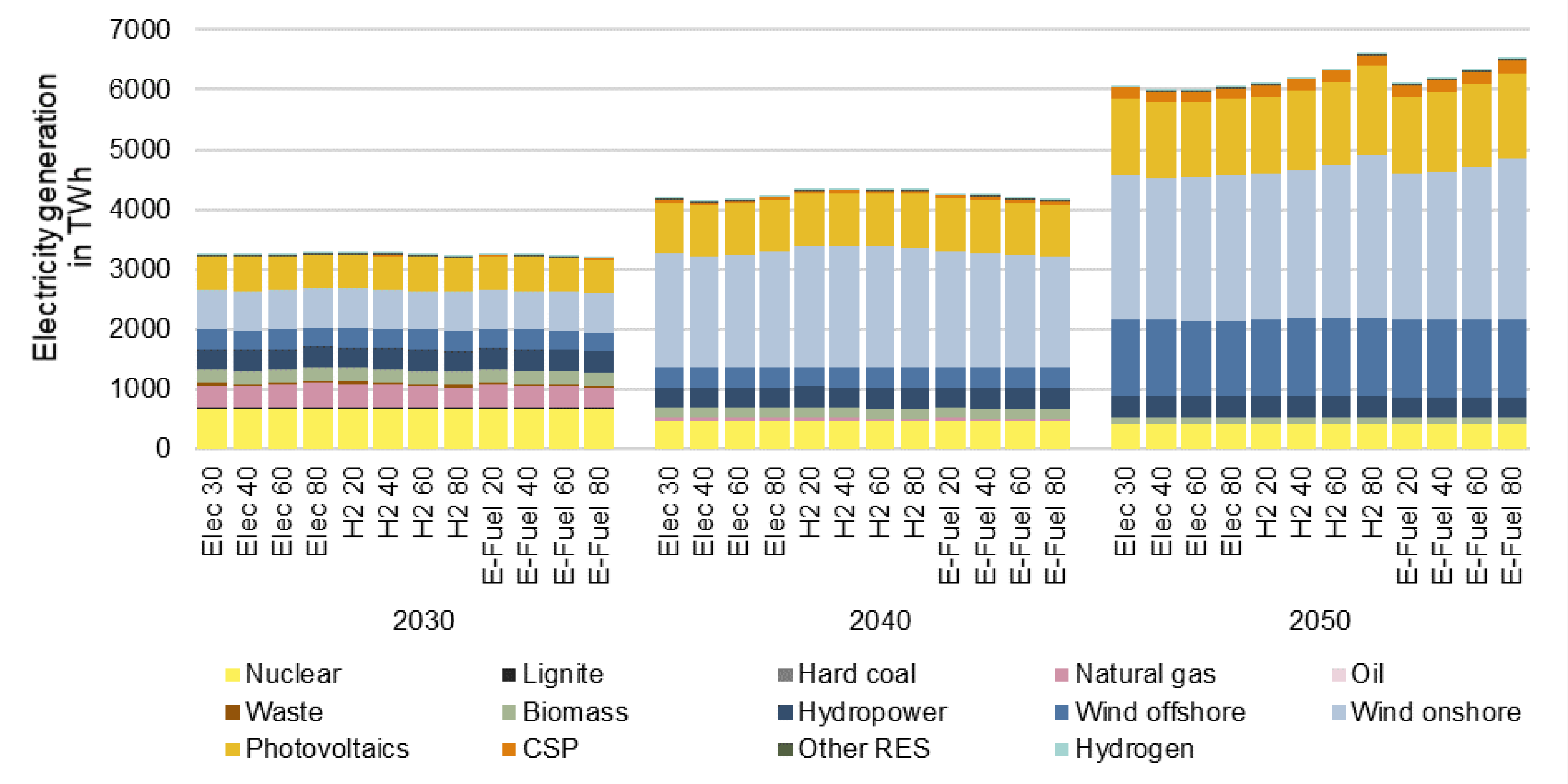



Figure: Electricity generation mix

- Increase in electricity generation and phase-out of fossil fuels in all scenarios.
- Elec scenarios require a lower generation than H2 and E-Fuel scenarios.
- No significant variation in the mix, changes are most pronounced in onshore wind and PV.

# Electrifiation of space heating

## System costs from Invert/Opt and Enertile

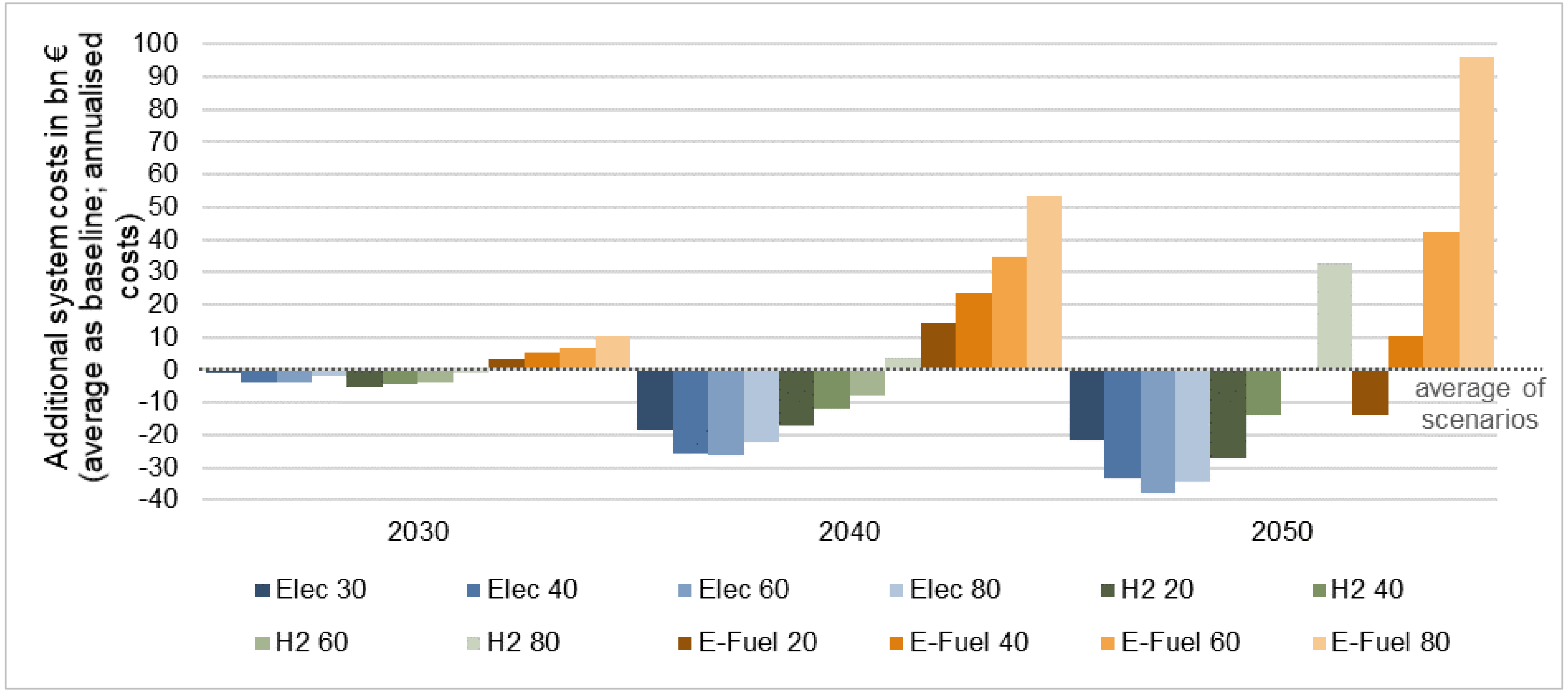



Figure: System costs

- Cost differences between the scenarios are rather low in the period up until 2030, but become much more substantial in 2040 and 2050.
- In 2050, Elec 60 scenario is the cheapest with a very small difference compared to Elec 40 and Elec 80.
- Overall, scenarios with a comparatively low usage of hydrogen or e-fuels have lower costs.

# Electrifying space heating

## Conclusion

➢ Directly electrifying a substantial amount of the heating demand of buildings is cost-efficient. The scenario with the lowest costs is the Elec 60 scenario.

**Developments across all scenarios → key elements for the transition**

- Uptake in building renovation, particularly comprising deep retrofitting, is costs-efficient in all scenarios
- Increase in renewable electricity generation is needed in all scenarios

**Characteristics of the scenario with the lowest costs (Elec 60)**

- High share of decentral direct electric heating systems, i.e. 60% in 2050
- High share of DH, i.e., around 25% in 2050
- DH generation is dominated by central large-scale heat pumps
- Hydrogen boilers are only used as a back-up technology in DH (less relevance for decentral heating)

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# Thank you for your attention!

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# Literature


Tsiropoulos I., Nijs W., Tarvydas D., Ruiz P., 2020. Towards net-zero emissions in the EU energy system by 2050: Insights from scenarios in line with the 2030 and 2050 ambitions of the Euro-pean Green Deal. https://publications.jrc.ec.europa.eu/repository/handle/JRC118592

IRENA, REN21, IEA, 2022. Renewable Energy Policies in a Time of Transition: Heating and Cool-ing. Available from: https://www.irena.org/publications/2020/Nov/Renewable-energy-policies-in-a-time-of-transition-Heating-and-cooling.

Kranzl L, Forthuber S, Fallahnejad M, Büchele R, Müller A, Hummel M et al., 2022. Renewable Space Heating under the Revised Renewable Energy Directive. https://op.europa.eu/en/publication-detail/-/publication/16710ac3-eac0-11ec-a534-01aa75ed71a1/language-en.

Hoogervorst N., 2022. Waterstof Voor De Gebouwde Omgeving; Operationalisering In De Startanalyse 2020. https://www.pbl.nl/sites/default/files/downloads/pbl-2020-waterstof-voor-de-gebouwde-omgeving-operationalisering-in-de-startanalyse-2020_4250.pdf.

Müller, A., 2015. Energy Demand Assessment for Space Conditioning and Domestic Hot Water: A Case Study for the Austrian Building Stock. Technische Universität Wien.

Kranzl, L., Hummel, M., Müller, A., Steinbach, J., 2013. Renewable heating: Perspectives and the impact of policy instruments. Energy Policy. https://doi.org/10.1016/j.enpol.2013.03.050.

Hummel, M et al., 2022. How cost efficient is energy efficiency in buildings? A comparison of building shell efficiency & heating system change in the European building stock. Submitted to the Journal “Energy Efficiency” in June 2022, under review.

Pfluger B., 2013. Assessment of least-cost pathways for decarbonising Europe's power supply. A model-based long-term scenario analysis accounting for the characteristics of renewable en-ergies: A model-based long-term scenario analysis accounting for the characteristics of renew-able energies.

Lux B, Pfluger B., 2020. A supply curve of electricity-based hydrogen in a decarbonized Europe-an energy system in 2050. Applied Energy 269:115011. https://doi.org/10.1016/j.apenergy.2020.115011.

# Annex: Electrification of space heating

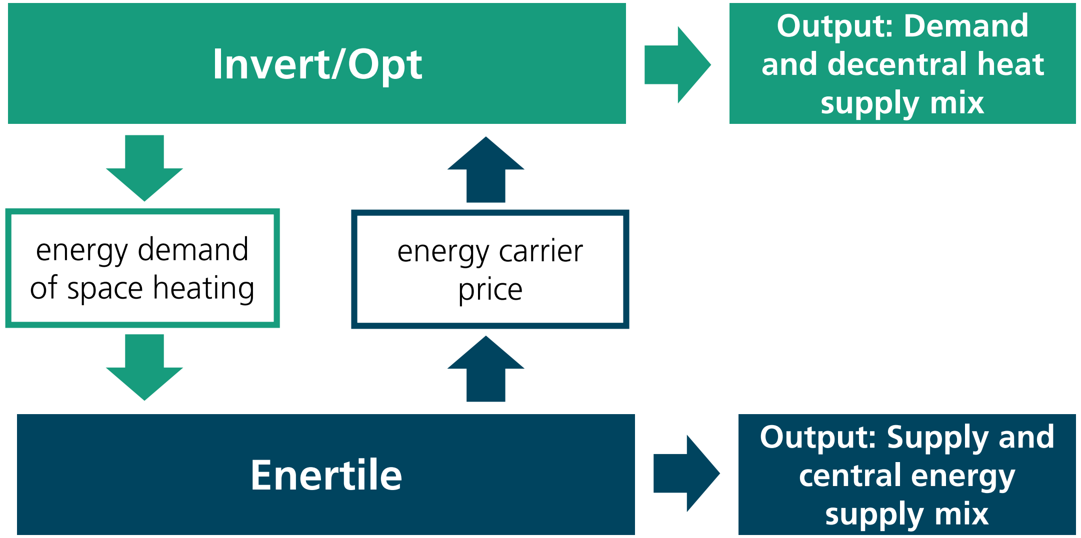
## Methodology

The two models are used in an iterative order:

(1) Invert generates the demand datasets and a preliminary decentral heat supply mix

(2) Enertile produces the central energy supply and energy system datasets

(3) The energy prices derived from Enertile are returned to Invert through impacting the final decentral heat supply mix





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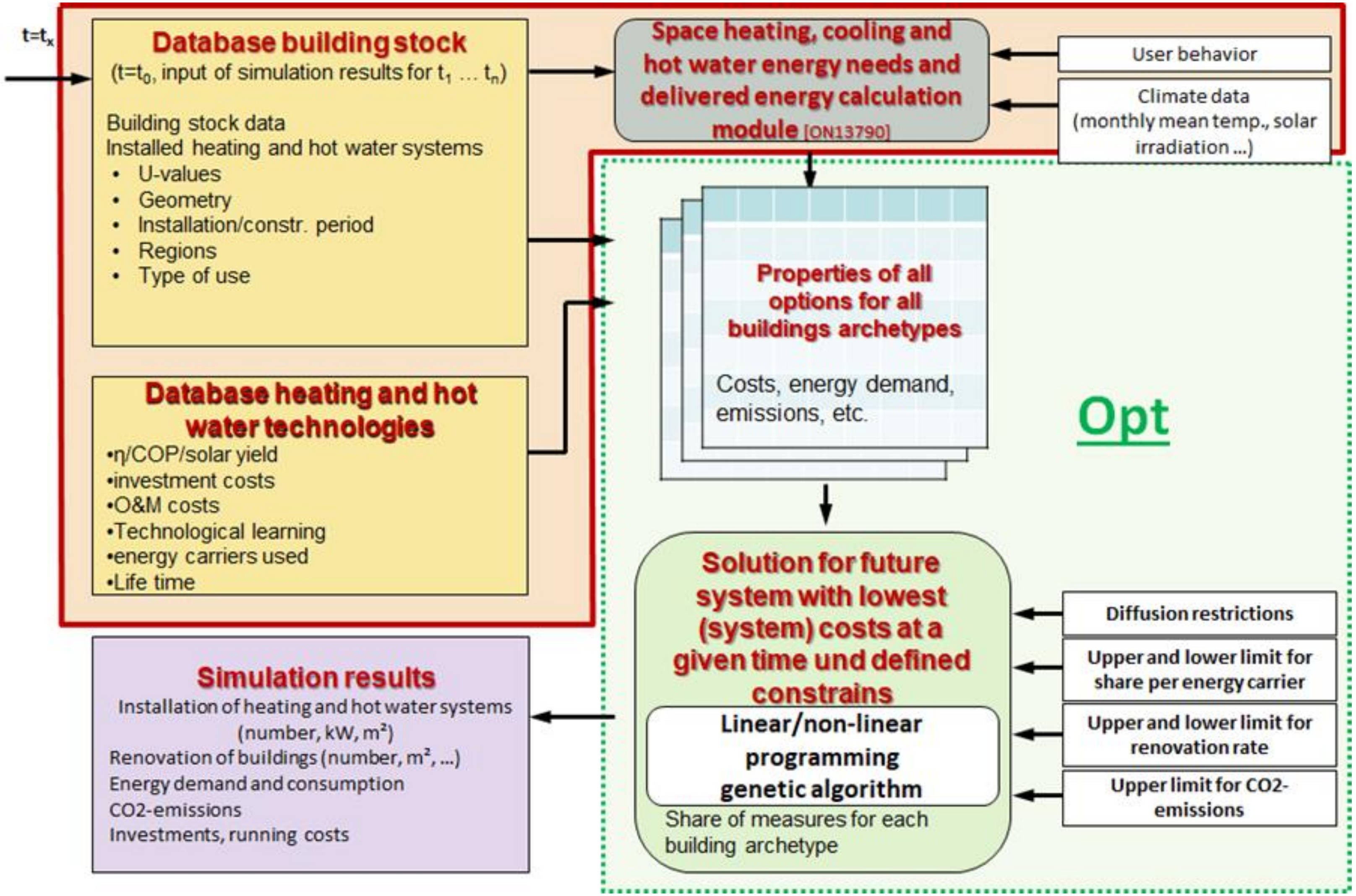
# Annex: Electrification of space heating

## Invert/Opt



# Annex: Electrification of space heating

## Invert/Opt

| Result | Indicator/unit |
|---|---|
| Installed space heating and hot water appliances (units) | Heated floor area ($m^2$), number of buildings (-) or capacity (GW) |
| Level of building refurbishment | Achieved savings ($kWh/(m^2*yr)$) or U-values in different parts of the building stock |
| Costs of building refurbishment | Euro |
| Costs heating and hot water system | Euro (invest), Euro/yr (O&M) |
| Energy demand by energy carrier (including district heating) | Energy demand (TWh) |
| Useful energy demand | Energy demand (TWh) |

# Annex: Electrification of space heating

## Enertile

| Result | Indicator/unit |
|---|---|
| **Electricity** generation and installed capacity (including renewables) per country | Energy / TWh<br>Capacity / GW |
| **District heat** generation and installed capacity per country | Energy / TWh<br>Capacity / GW |
| **Hydrogen and e-fuels** production and installed capacity per country | Energy / TWh<br>Capacity / GW |
| **Greenhouse gas emissions** from supply sector (electricity and district heat) and **emission factors** | Tons of CO2<br>Tons of CO2 / MWh |
| **Annual costs** for the supply of electricity, district heat, hydrogen and e-fuels | Euro/a |
| **Energy prices** for production of electricity, district heat, hydrogen and e-fuels | Euro/MWh |