Electricity, gas, heat integration via residential hybrid heating technologies

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Introduction

- Space and water heating demand represent roughly 80% in Europe and 60% in the United States of final energy use in residential buildings.
- Residential heat electrification is promoted to reduce fossil fuel usage and increase use of efficient heat pumps, while power sector is decarbonised.

Hybrid Heating technology

- Hybrid heaters combine different heating appliances and can switch between those appliances during operation
- Advantageous from building perspective
  - Lower upfront cost compared to HP
  - No efficiency penalty at lower ambient temperatures compared to air-source HP

Objective:

Quantify system-wide planning and operational costs of deploying hybrid heating technologies in the residential sector

Methodology

A least-cost linear investment model

- Optimises power and residential heat sector, including thermal storage, jointly
- Internally determines capital investment and operational expenditure for both sectors
- for hybrid heaters, model optimises dispatch between the gas-fuelled appliance (B) and the electricity-fuelled appliance (HP or R) based on an also optimised hourly marginal electricity price
- Full hourly representation of supply and demand, in chronological order

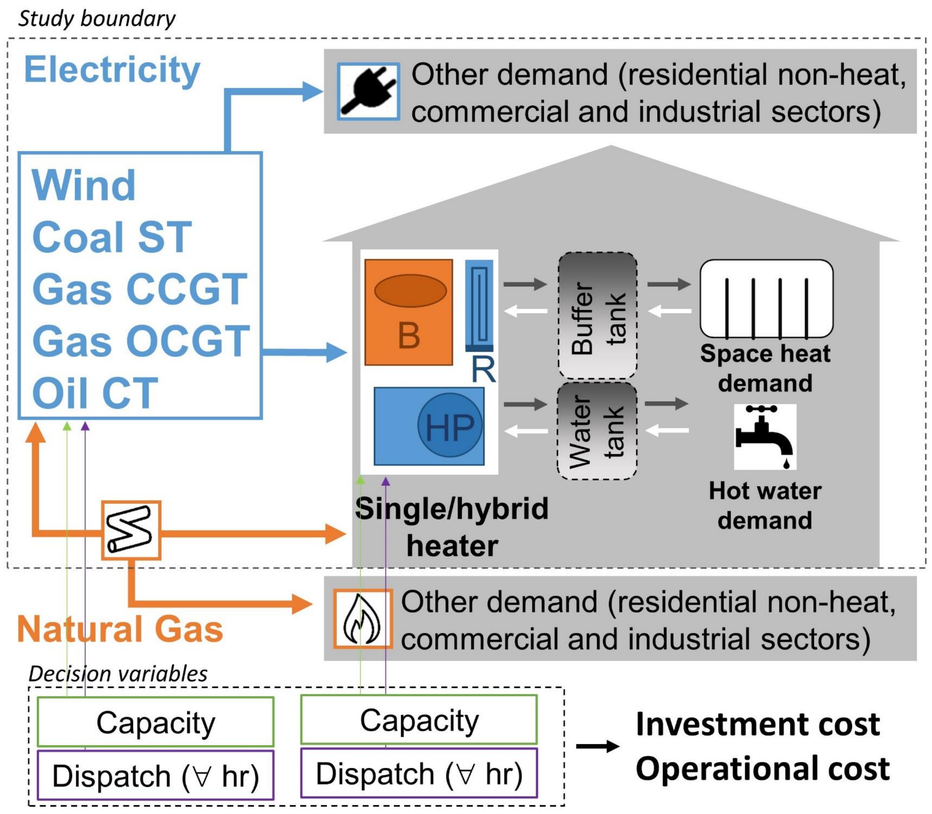


Figure 1: Schematic of the integrated power-residential heat system studied

Test System

- Irish all-island system, Target year 2030
- Wind capacity 6000 MW and other generation capacities from TSO capacity statement 2014-2023
- Share of households with new heating technology for all scenarios is 40%

Results:

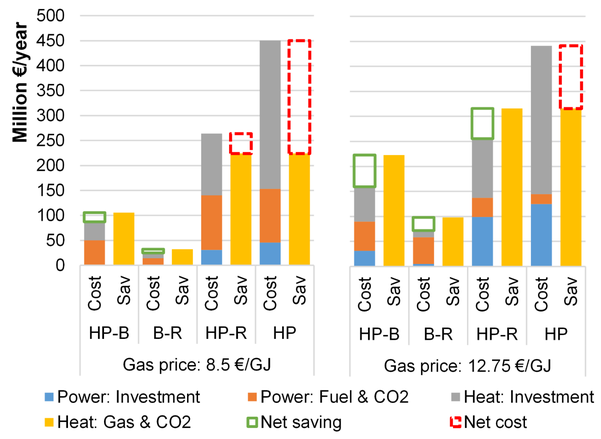


Figure 2: Cost breakdown for deployment of different heating technologies (B-R, HP, HP-B, HP-R) relative to gas boiler (B)

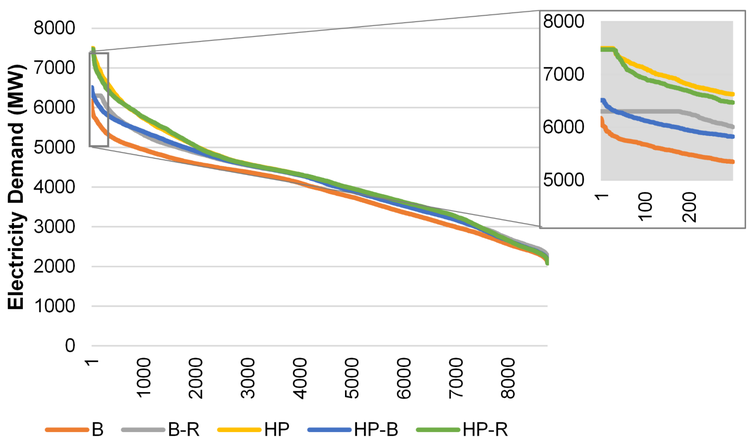
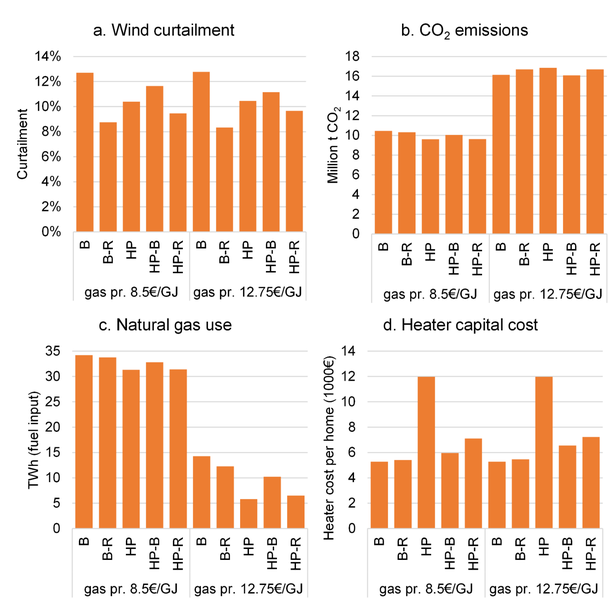
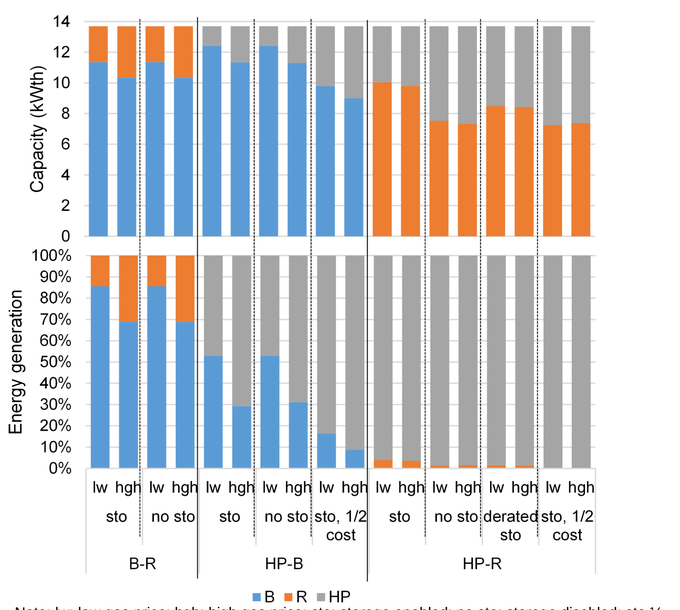


Figure 3: Load duration curves for deployment of different heaters



Note: CO_2 emissions and natural gas use cover the whole system (power and heat)

Figure 4: Strategic and non-economic indicators



Note: lw: low gas price; hgh: high gas price; sto: storage enabled; no sto: storage disabled; sto ½ cost: storage enabled and HP spec. investment cost halved; de-rated sto: storage enabled but with 10% stationary losses

Figure 5: Capacities and generation share of appliances of hybrid heaters (for well-insulated buildings and a carbon price of 30 €/ton)

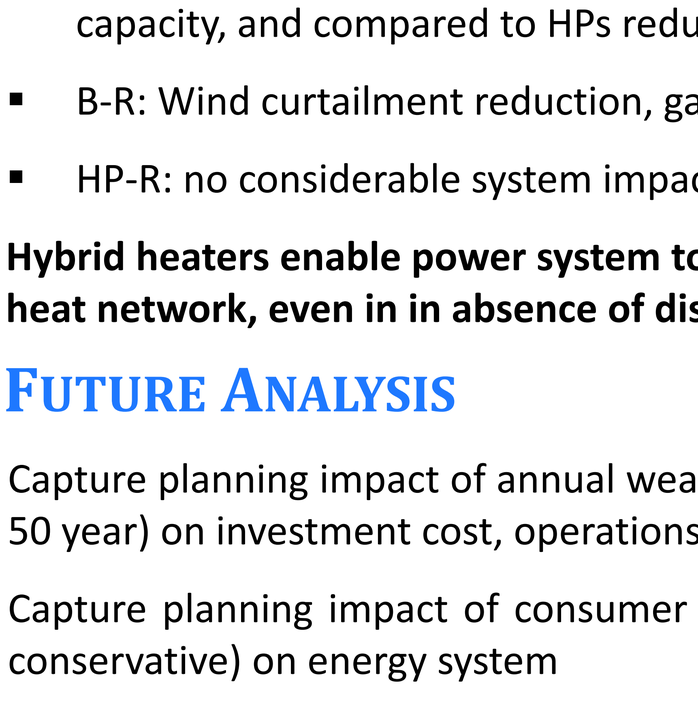
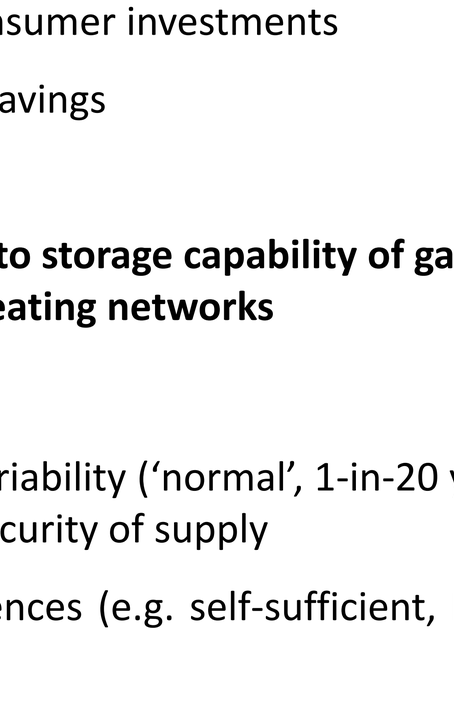


Figure 6: Operation of hybrid HP-B and power system dispatch during the week with lowest annual wind output



Note: lw: low gas price; hgh: high gas price; de-rated sto: storage enabled but with 10% stationary losses

Figure 7: Storage capacities build for different technologies (for well-insulated buildings and carbon price 30 €/ton)

Conclusions

- **Integrating gas, electricity and residential heating sectors through hybrid heating technologies equipped with smart controls could provide overall energy system planning and operational benefits, but results differ based on characteristics of underlying hybrid heating technologies**
  - HP-B: minimises total system cost, reduces electric peaks and generation capacity, and compared to HPs reduces consumer investments
  - B-R: Wind curtailment reduction, gas fuel savings
  - HP-R: no considerable system impacts
- **Hybrid heaters enable power system to tap into storage capability of gas and heat network, even in in absence of district heating networks**

Future Analysis

- Capture planning impact of annual weather variability ('normal', 1-in-20 year, 1-in-50 year) on investment cost, operations and security of supply
- Capture planning impact of consumer preferences (e.g. self-sufficient, ICT-savvy, conservative) on energy system

Related publications

Heinen, S., Burke, D. and O'Malley M.J. "Electricity, gas, heat integration via residential hybrid heating technologies - an investment model assessment", Energy, in press, 2016.

Acknowledgement

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