Future domestic heating systems and their potential role in integrating variable renewable energy

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CITIES Workshop Korea

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SETTING THE SCENE
Domestic Heat Technology

European heat decarbonisation strategy in the residential sector, simplified…

1. Decarbonise supply

2. Insulate

3. Electrify using efficient HPs

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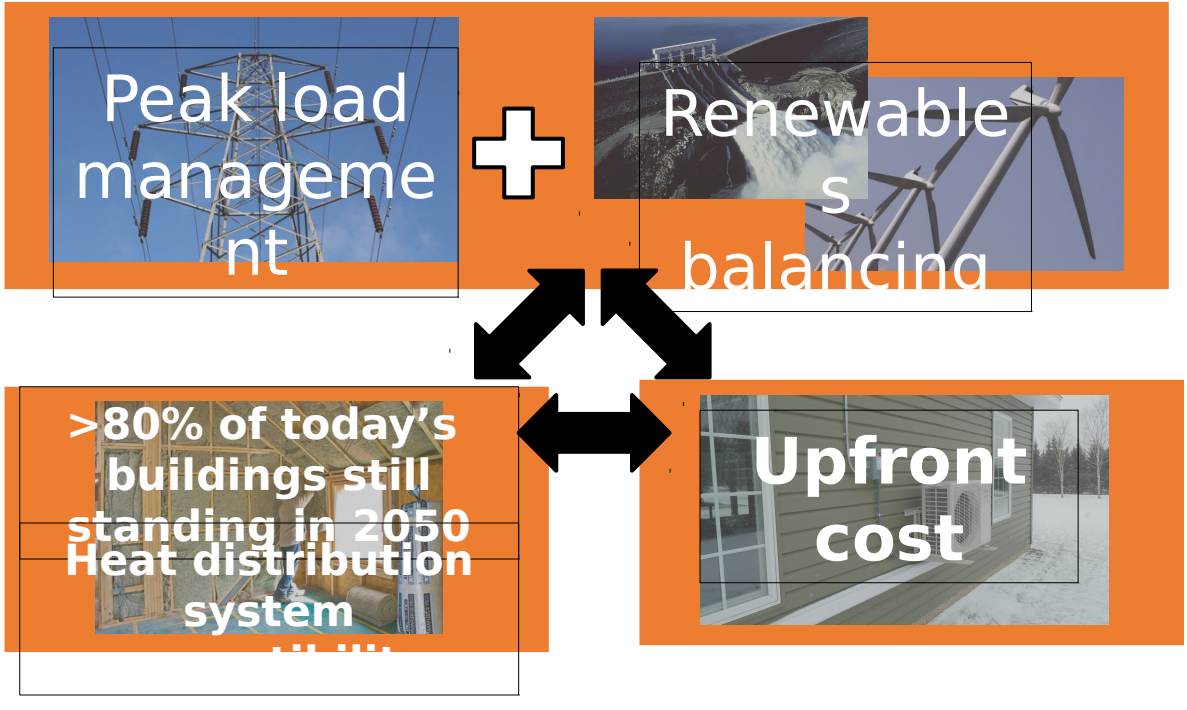
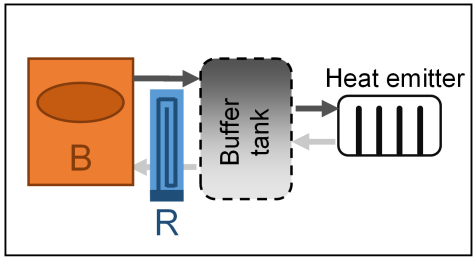
Planning and operations is a dynamic process in an integrated energy system

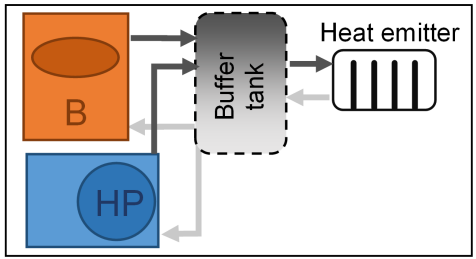


Hybrid heaters an overlooked alternative?

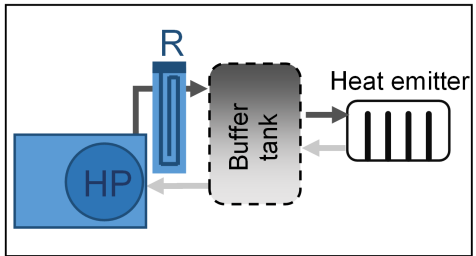
a. Hybrid B-R



b. Hybrid HP-B



c. Hybrid HP-R



- Hybrid heaters are composed of 2 appliances
- Enabled by ICT, hybrids can switch between those appliances during operation depending on market conditions.
- Different combinations feasible
  - Gas boiler – resistance heater (HP-R)
  - Heat pump - Gas boiler (B-HP)
  - Heat pump – resistance heater (HP-R)

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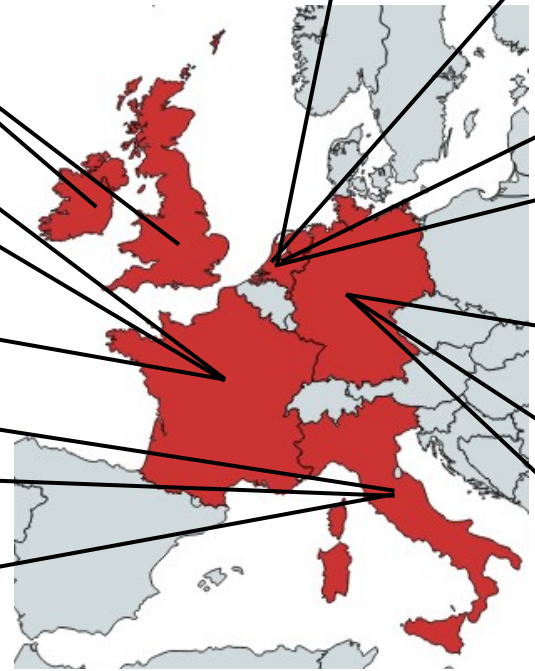
Hybrid heaters are available commercially since about 2010



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COSMOGAS MADE IN ITALY

MHG

RIELLO

DAIKIN Japan

Carrier USA

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Hybrid gas boiler - heat pump

An example of a outdoor dual fuel split unit installation matched with a cased coil

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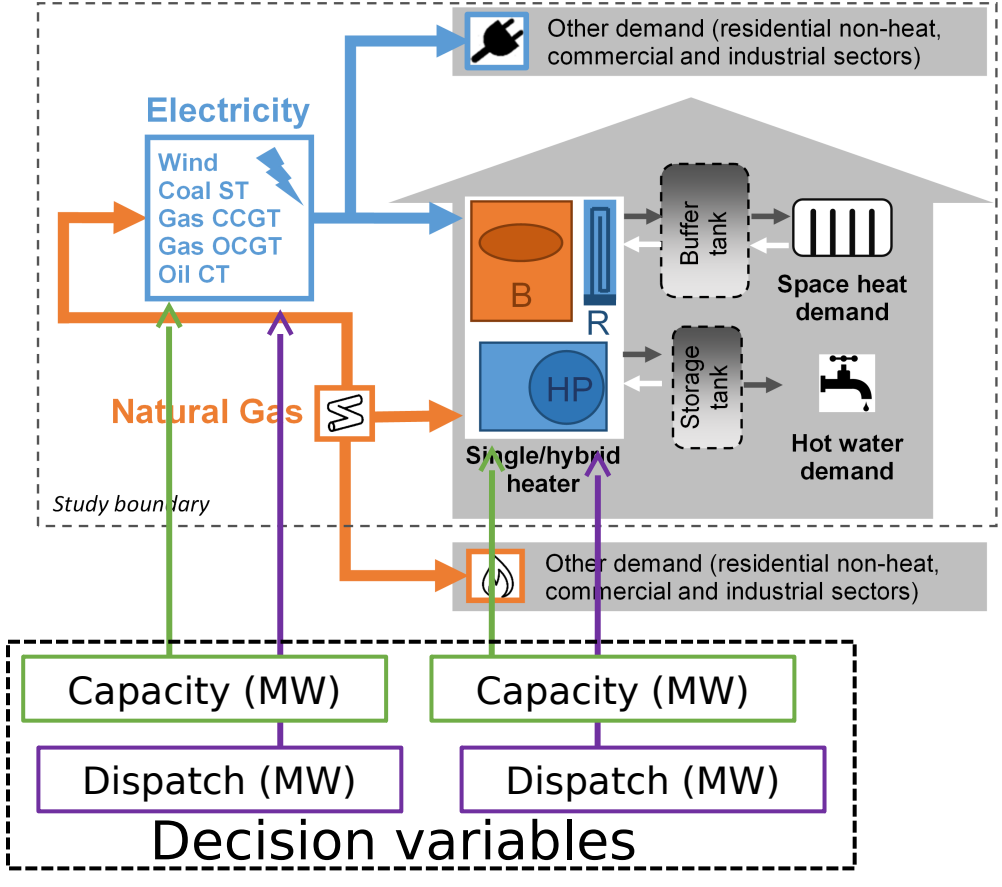
QUANTIFYING THE SYSTEM BENEFITS OF DEPLOYING DIFFERENT DOMESTIC HEATING TECHNOLOGIES

Power-gas-heat system planning model



Model

One stage planning
Hourly resolution
Linear

Test System

Ireland
Planning horizon: 2030
Wind capacity: 6000 MW (40% energy)
Heaters installed in 25% of Irish households

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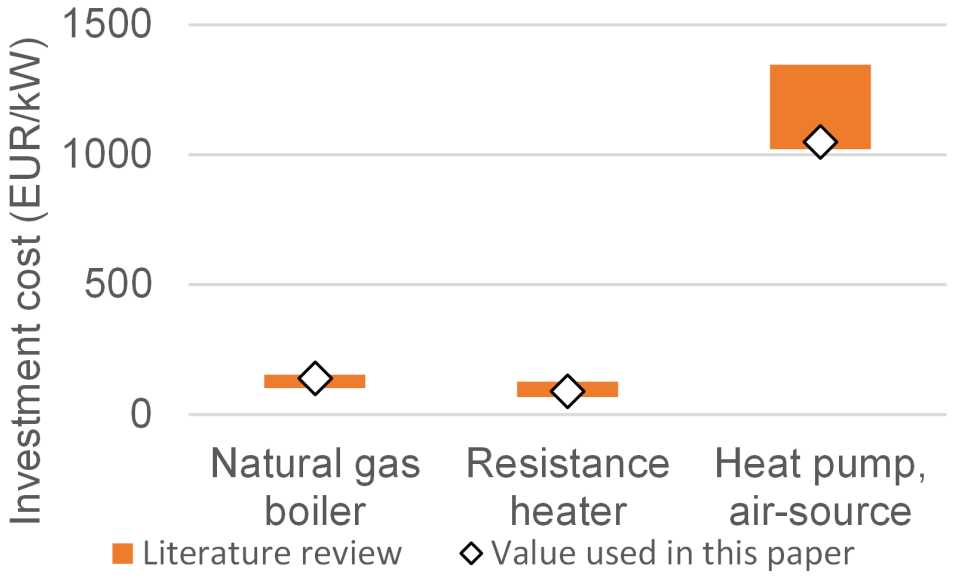
Heat pump investment cost barrier



Are consumers rational enough invest in a system that delivers long-term savings?

Source: ETSAP, Delta E&E

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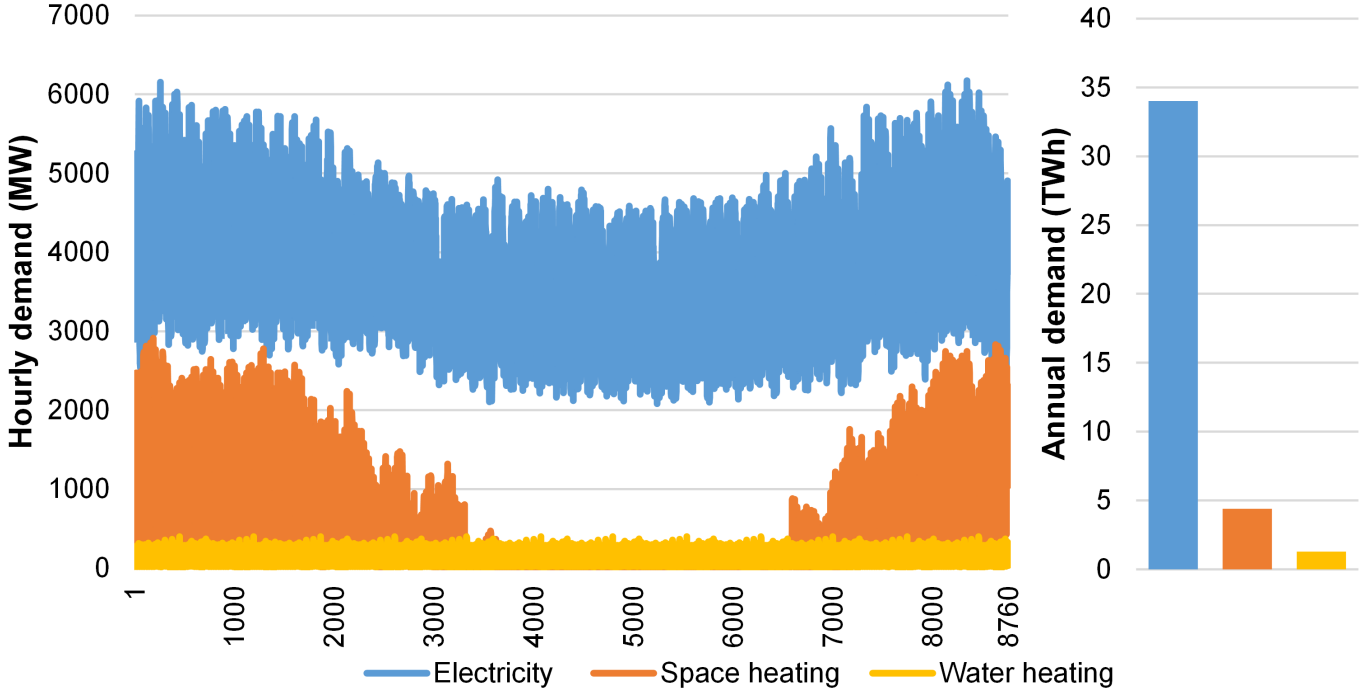
Heat load for 25% of Irish households compared to TOTAL elec. load



New market for electricity utilities?
Increased peak load?
Decreased asset utilisation?

Source: Eirgrid (2014), CER (2011)

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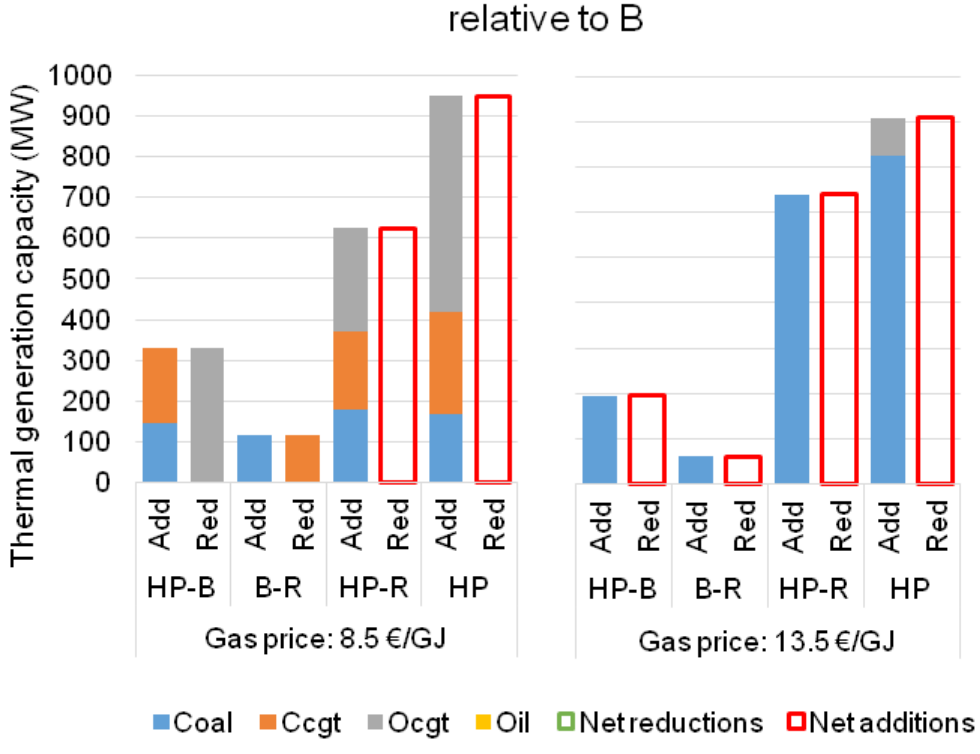
Power generation capacity



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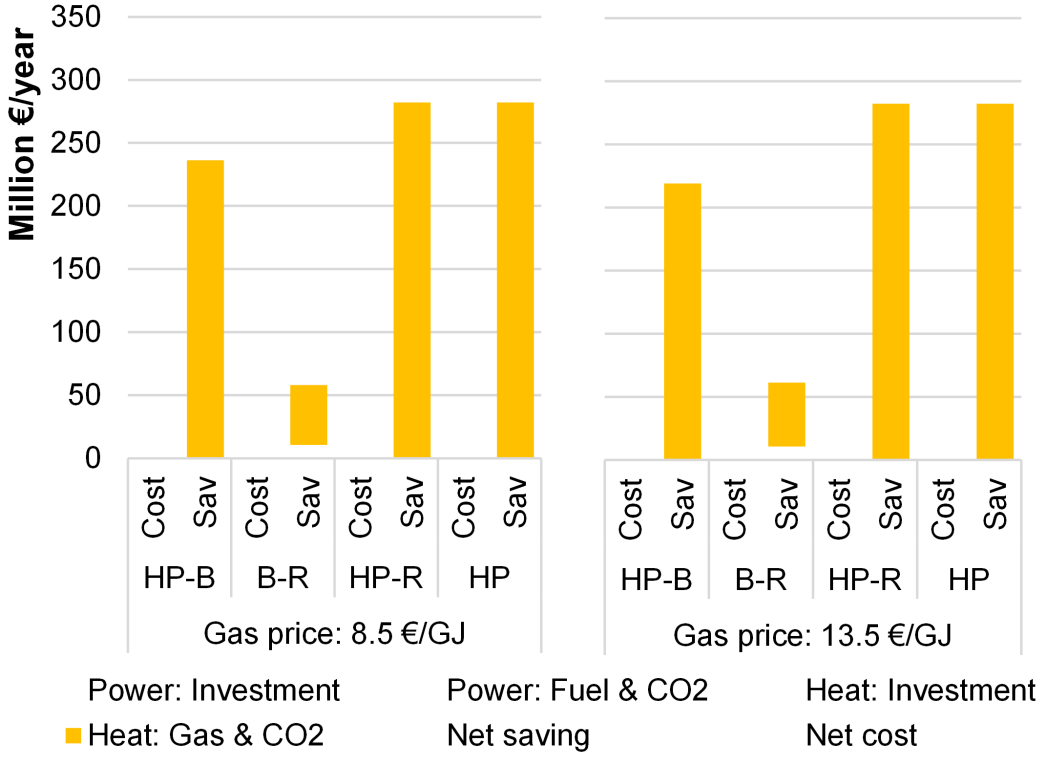
Economic assessment – cost breakdown



Compared to gas boiler deployement

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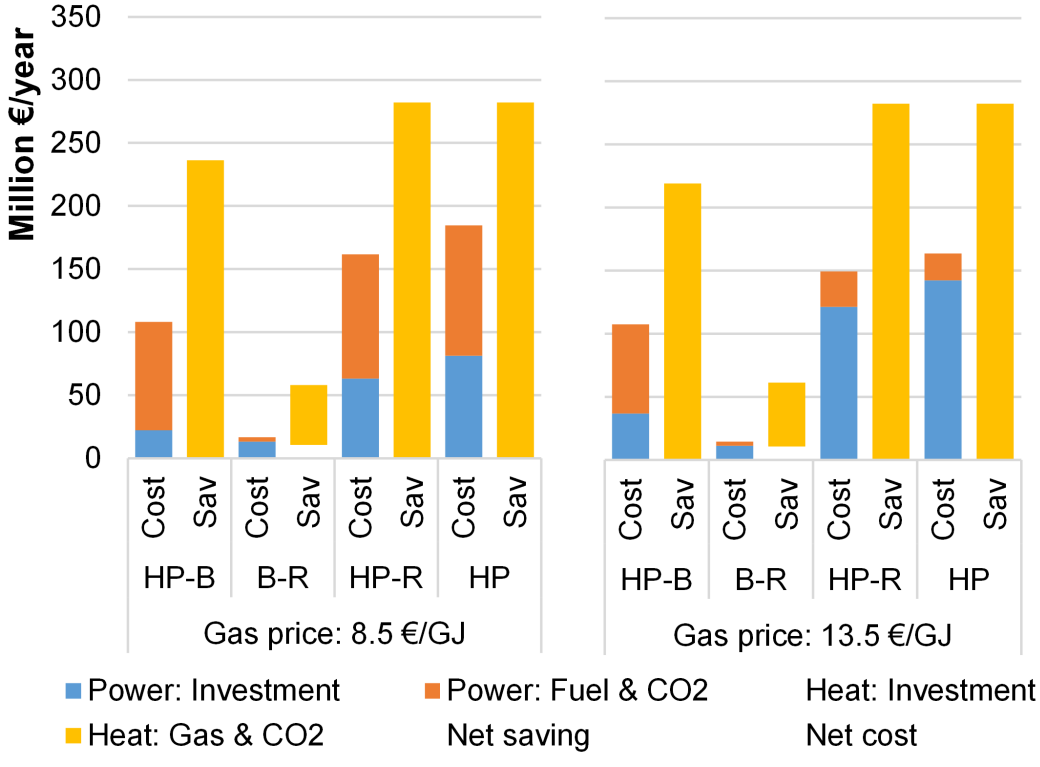
Economic assessment – cost breakdown



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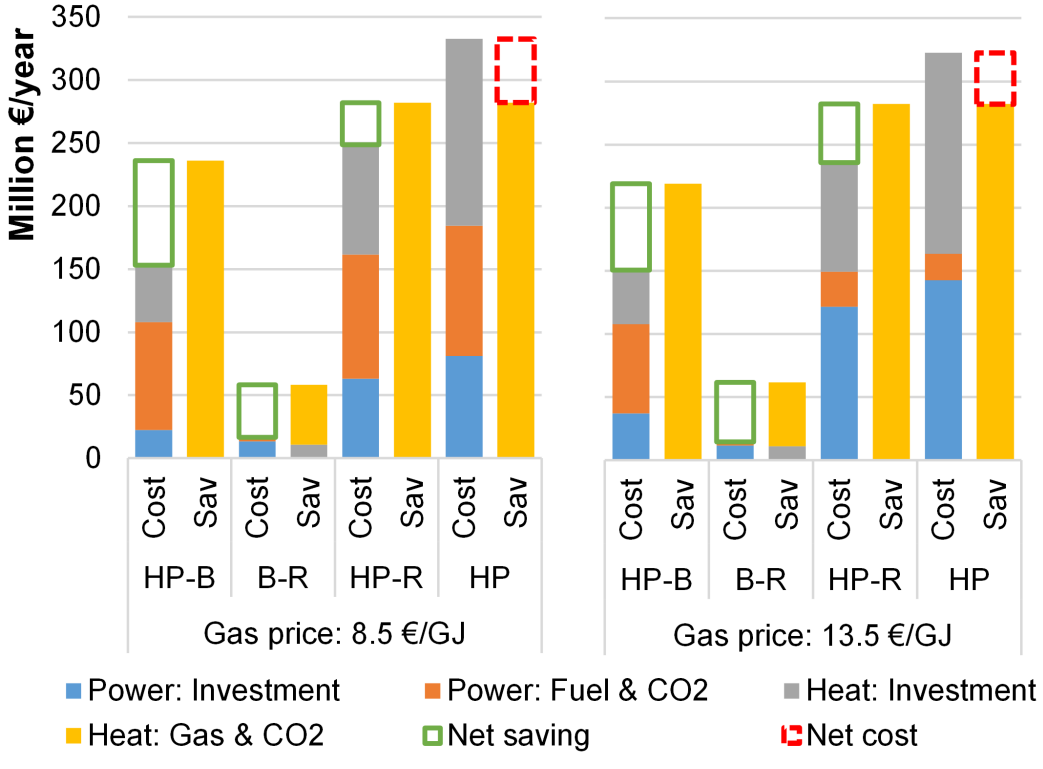

Compared to gas boiler deployement

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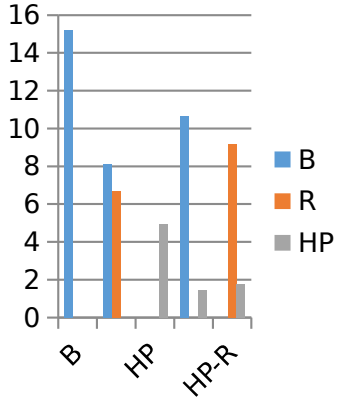
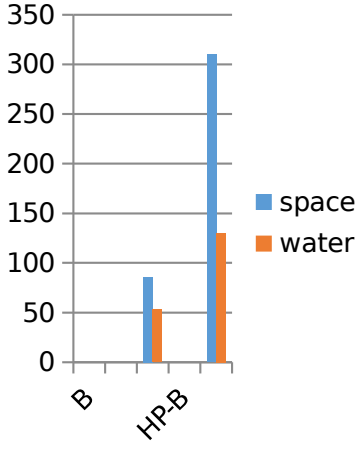
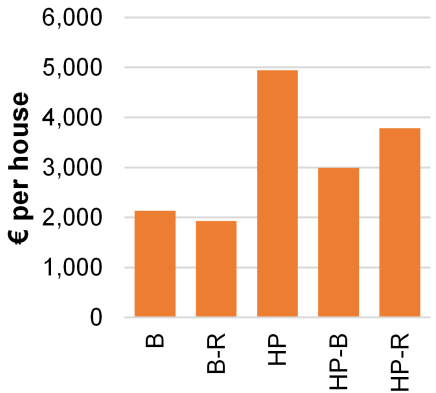
Consumer side

Heater capacity (kW)



Storage volume (litre)





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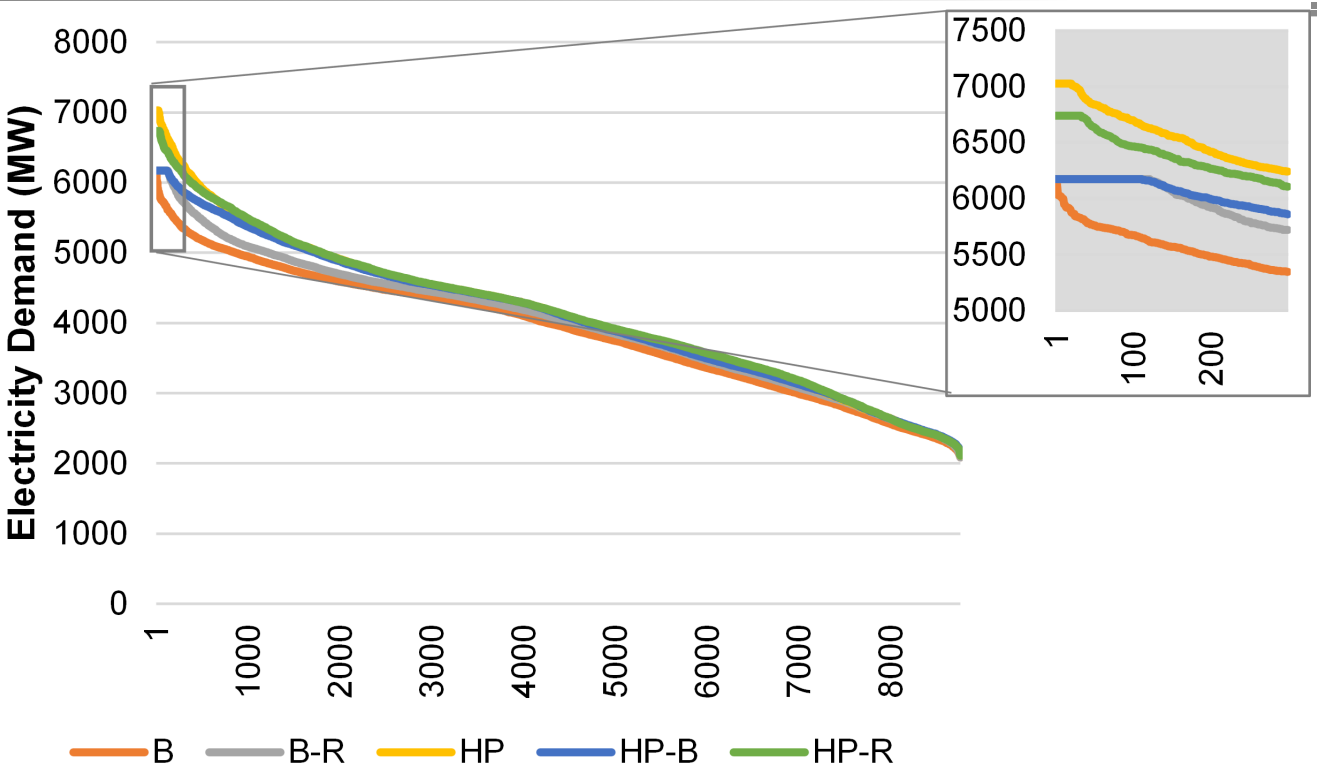
Overall assessment

- Hybrid heaters can provide planning benefits by integrating gas, electricity and heat without district heating network, only through intelligent integration of individual technologies.
- **HP-B system**
  - Least-cost system
  - Heater investment savings (smaller HP)
  - Power investment (lower electric peak) and fuel savings (efficient HP)
  - Large gas and CO2 savings compared to gas boiler, small increase in gas and CO2 emissions compared to HP
- **B-R system**
  - Reduced wind curtailment, but increased coal usage
- **HP-R system**

Electricity load duration curve



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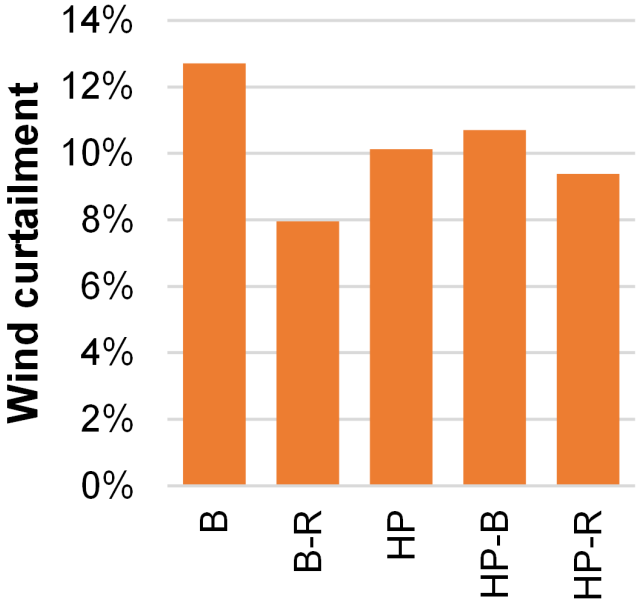
Wind curtailment



Electric loads increase flexibility and lower curtailment

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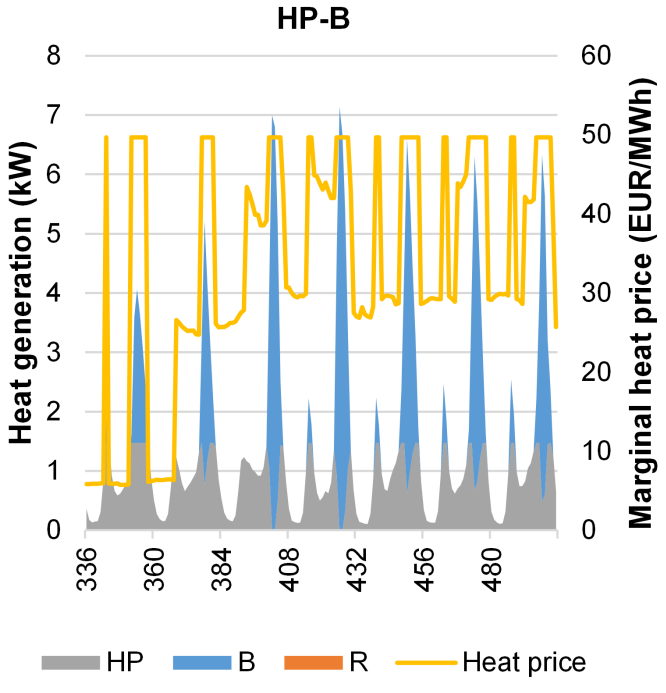
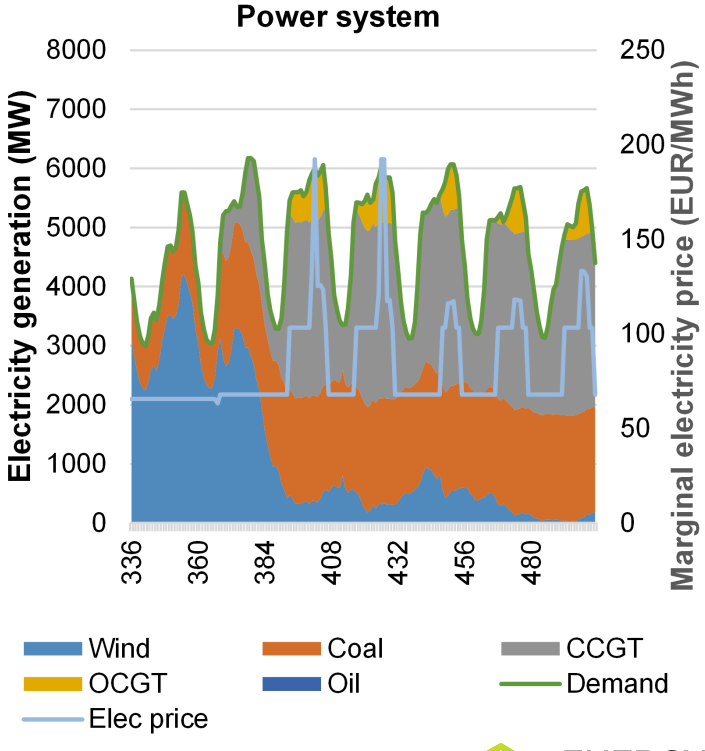
HP-B operation during low wind week





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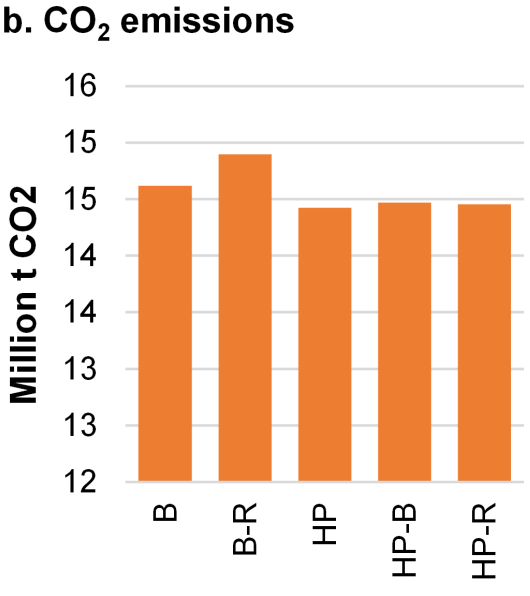
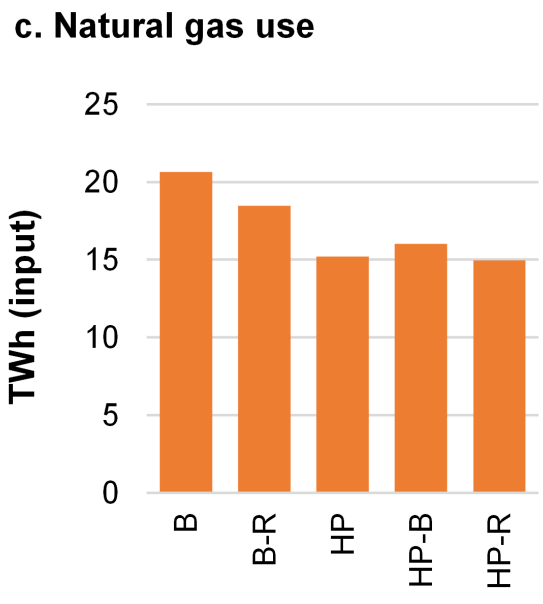
Strategic assessment
Gas imports and CO2 emissions





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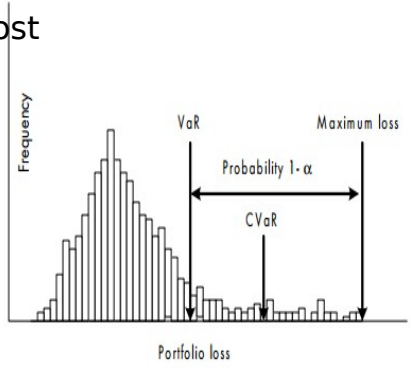
Portfolio theory

- Define optimal portfolio as optimal ratio between risk and cost
- Mathematical formulation on the concept of diversification
- Determine Efficient Frontier (return/total cost versus risk)
- Energy planning application: examine volatility (not shocks)



Conditional VaR (CVaR)

- Represents downside risk
  - Represents risk averseness of decision-makers (losses loom larger than gains)
  - Distribution profiles with skewness (i.e. non-synmetrical) and kurtosis (i.e. ‘fat tails’)
- probability weighted average of the possible losses conditional on the loss being equal to or exceeding the specified VaR
- average of the (1-beta) largest outcomes of the losses distribution
- Convex, can be formulated as LP optimisation

Note: If normal distribution of scenarios, optimal portfolio allocation should be same for all methods

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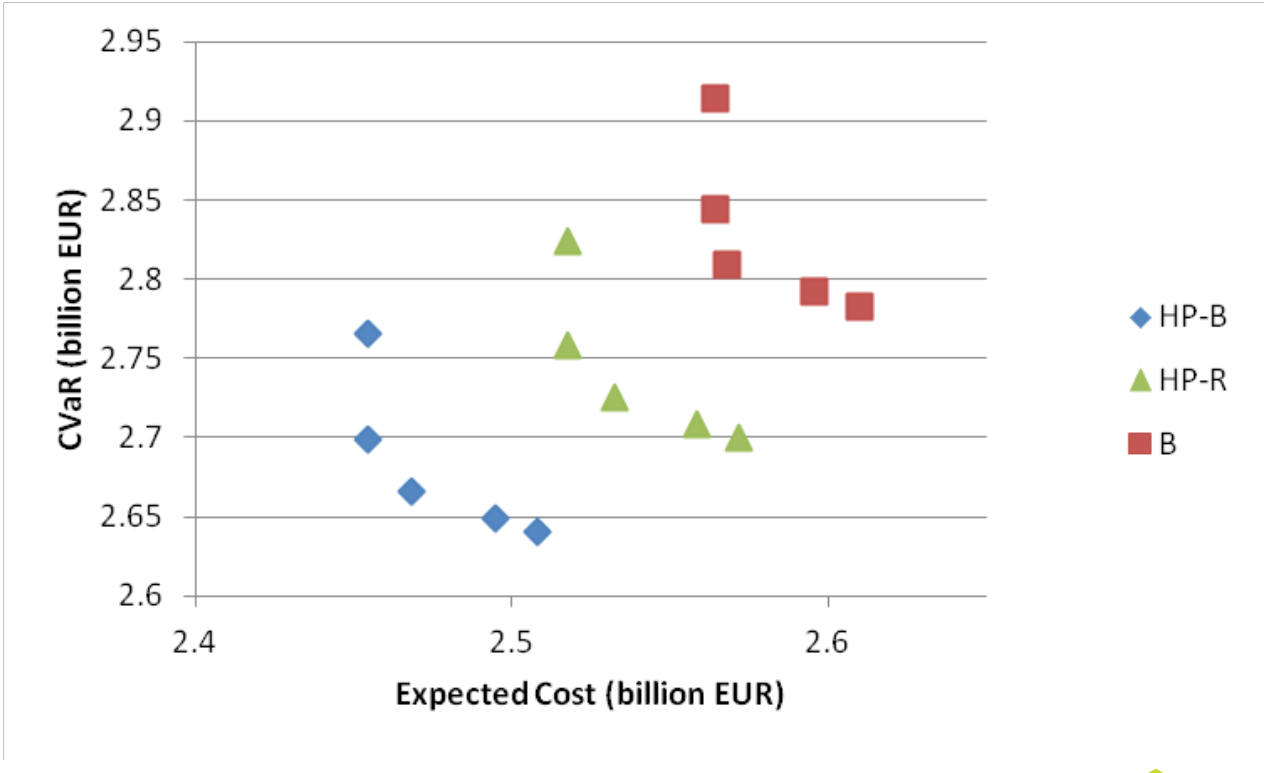
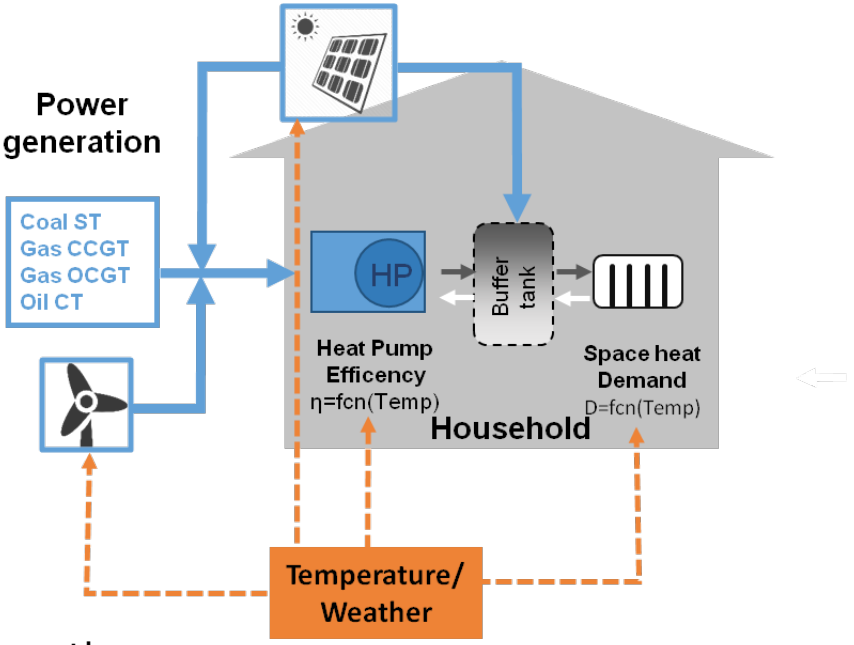
Efficient Frontier



Gas-electricity-heat system



Key research questions

- How does weather impact the electricity-heat system, if coincidal impacts are considered?
- How is security of supply impacted if moving from gas to electric heating?

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Adequacy and security of supply

- Gas system, EU Regulation 994 (2010)
  - Infrastructure standard (Art. 6)
    - Enough infrastructure to meet 1-in-20-year peak demand when the capacity of the largest infrastructure is deducted (N-1)
  - Supply standard (Art. 8)
    - Gas companies must be able to supply the country's "protected customers" (at least reducential and as littles as possible beyond that) in case of:
    - 1-in-20-year 7 day peak period
    - 1-in-20-year 30 day peak period
    - 30 day disruption of largest infrastructure in average winter conditions
- Electricity system, EU regulation leaves it to member countries to develop national standards (Directive 2005/89 and third Energy package)
  - Loss of load expectation (LOLE) is common metric. LOLE is the average number of hours per year in which supply is expected to be lower than demand under normal operation of the system.
  - **Ireland** targets 8 hours **LOLE** per year (Ireland's Adequacy Standard), France targets the same standard of 3 hours per year, and the Netherlands 4 hours per year.

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Thank you for your attention

Questions and discussion

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