RESIDENTIAL SPACE HEAT ELECTRIFICATION IN A SYSTEM WITH HIGH PENETRATION OF WIND

A PLANNING ANALYSIS

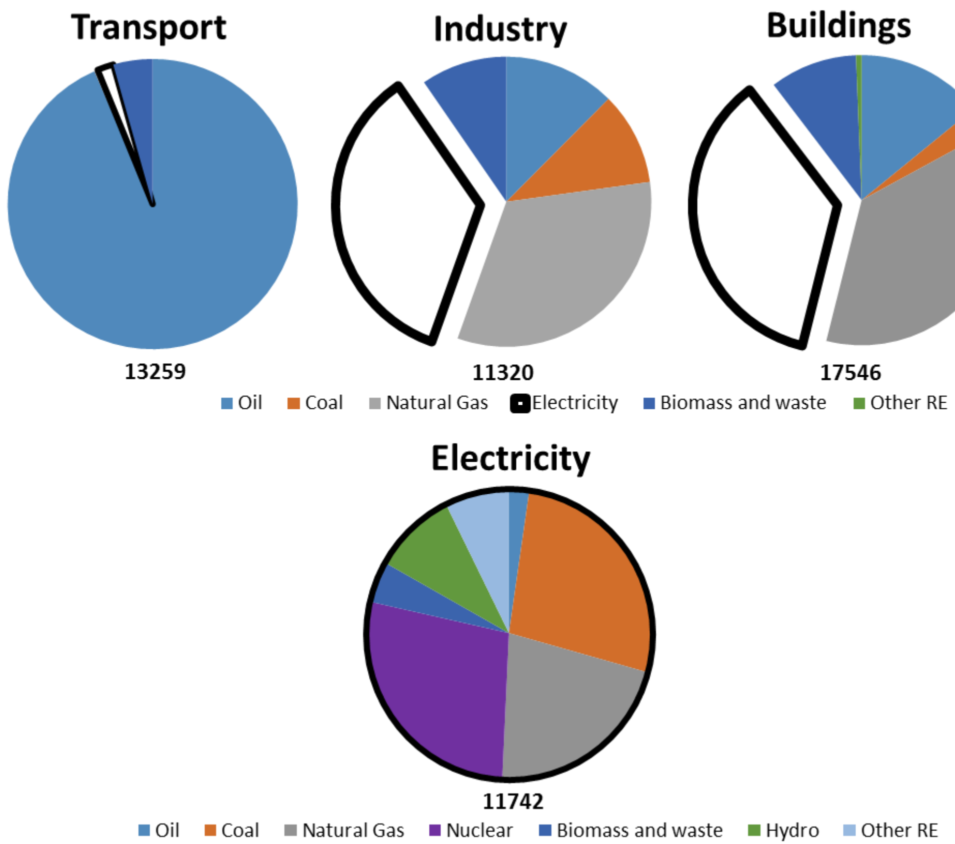
Steve Heinen

Energy Centre Research Seminar, University of Auckland

13th December 2016

CONTEXT AND MOTIVATION

Heat, the sleeping giant



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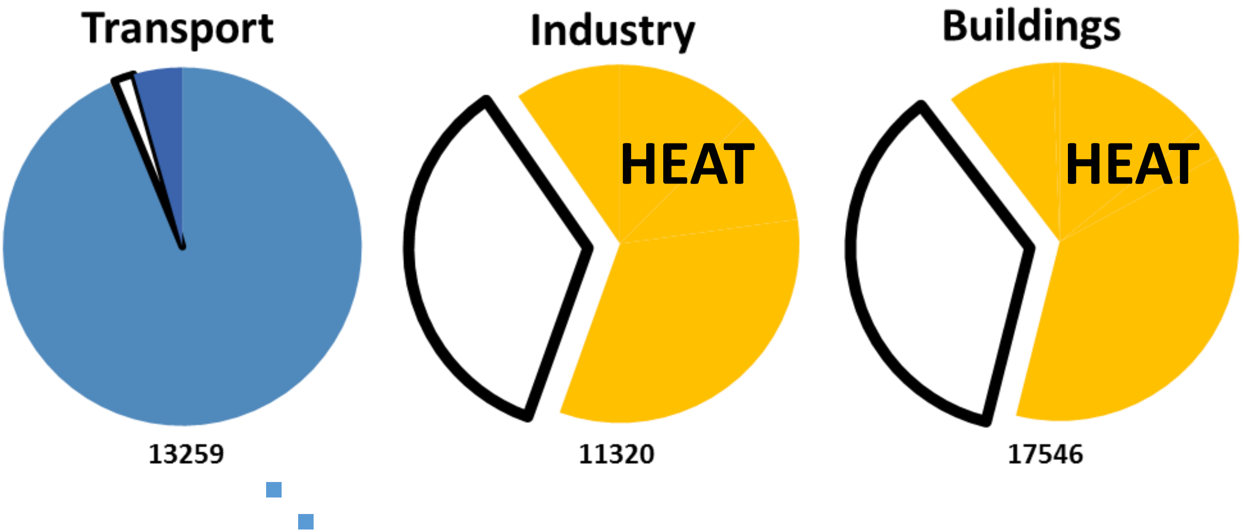
Heat is a huge energy demand



but often doesn’t show up as such in energy balances that focus on supply i.e. fuels

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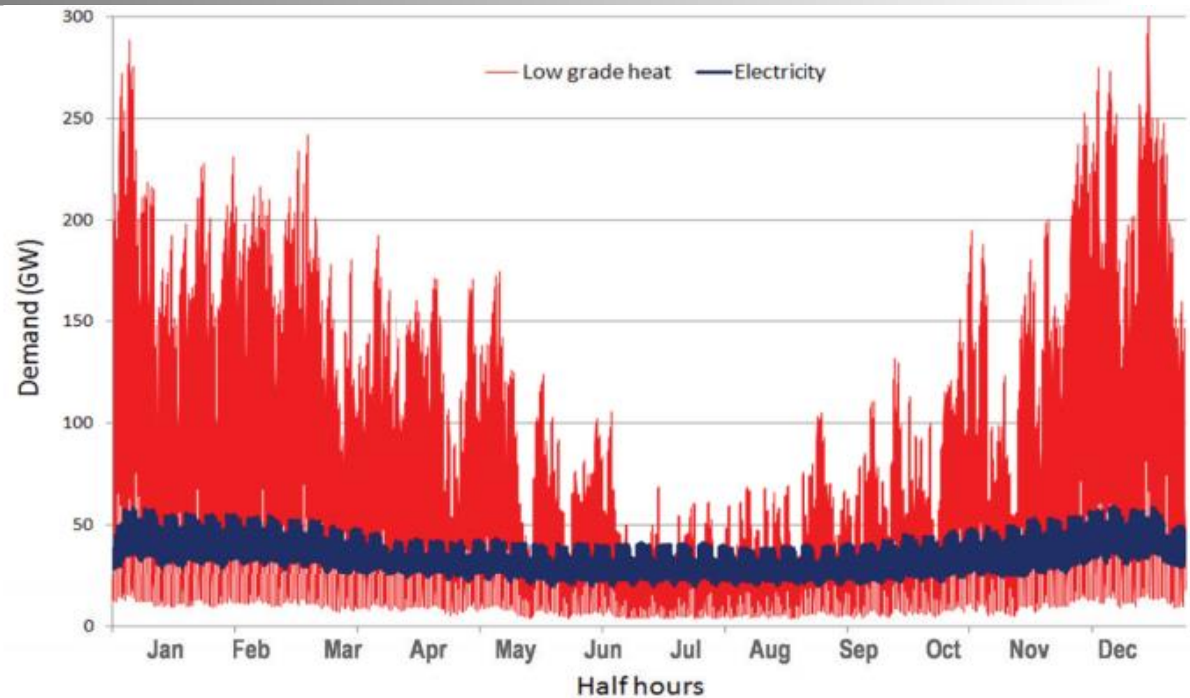
European heat decarbonisation strategy in the residential sector, simplified...

1. Decarbonise supply

2. Insulate

3. Electrify using efficient HPs

Heat variability UK, 2010



New market for electricity utilities?

Increased peak load?

Decreased asset utilisation?

Source: Robert Sansom (Imperial College), Winter Peak Heat Demand

RESEARCH APPROACH

Electrifying heat in a system with high wind penetration increases weather dependence

Weather
Wind
Temperature

SUPPLY
Wind variability

DEMAND
Heat variability

Electricity
System
Adequacy

The correlation between wind and temperature is very complex <u>AND</u> low wind and low temp. can coincide and stress adequacy

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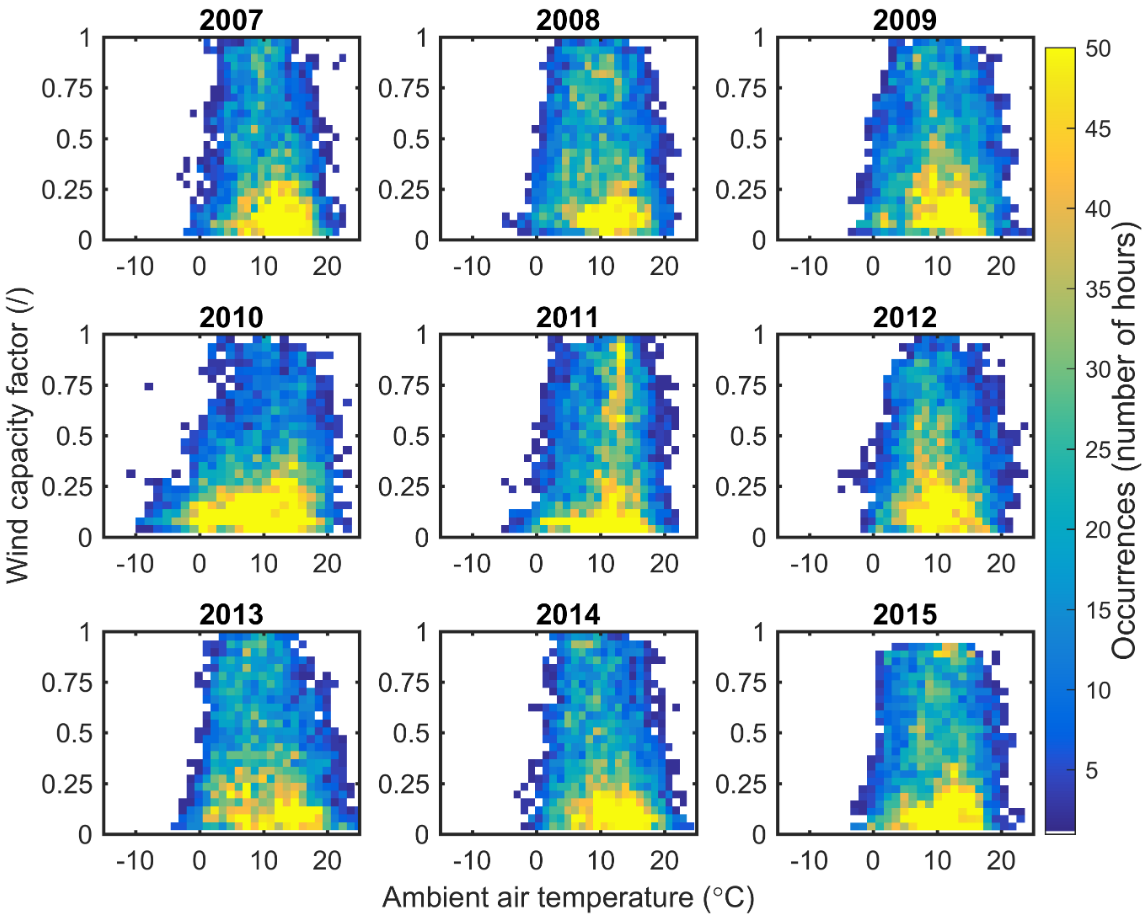
Coincidental weather patterns: Wind and temperature



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The building thermal inertia and pre-heating

- It takes time to heat up and cool down a building

  → thermal building inertia

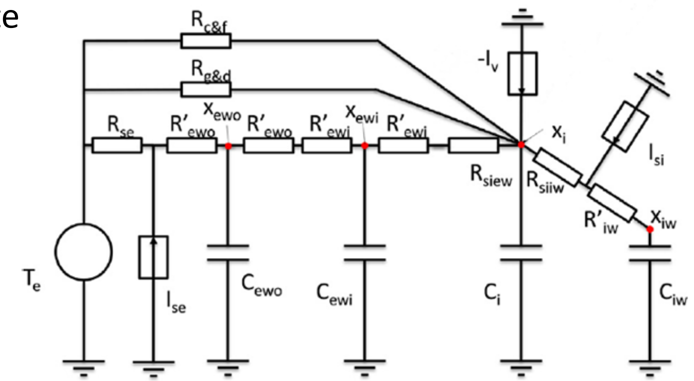
- Heating
  - Occupant conform level set by thermostat must be met, but electricity use can be decoupled
    - Building is a thermal battery
    - Can retain heat, depending on level of insulation
- Flexibility to shift electricity demand if heat demand during electric peaks or if excess wind is available

Representing building as analogous electric circuit

- White Box Model
  - Detailed physical model
  - Computationally prohibitive to integrate into investment model
- Black Box model
  - Statistical model
  - Does not capture physical behaviour
- **RC model or lumped parameter model**
  - Computationally efficient
  - R ([K/W]) : thermal resistance to heat flow through a building material,
  - C ([J/K]): represent thermal storage or capacitance within a building construction assembly. Here 4 main thermal capacitances (i.e. outer lead of external walls (ewo), inner leaf of external walls (ewi), indoor air and furnishings (i), and internal walls (iw))

State space representation:

$$\dot{x}(t) = A \cdot x(t) + B \cdot u(t)$$



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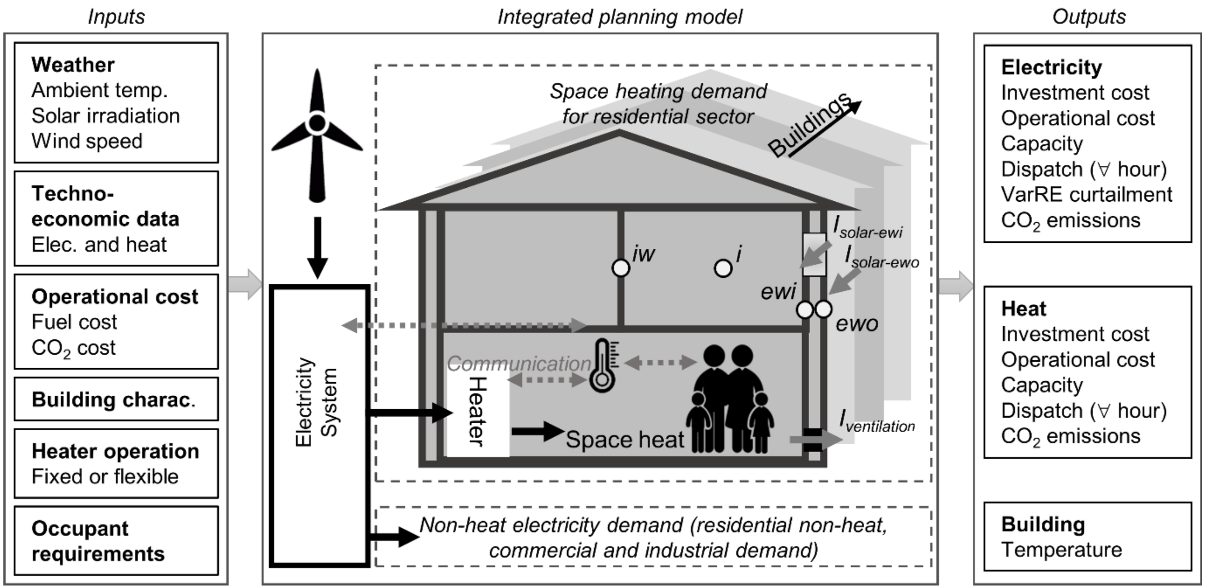
Methodology



Test system

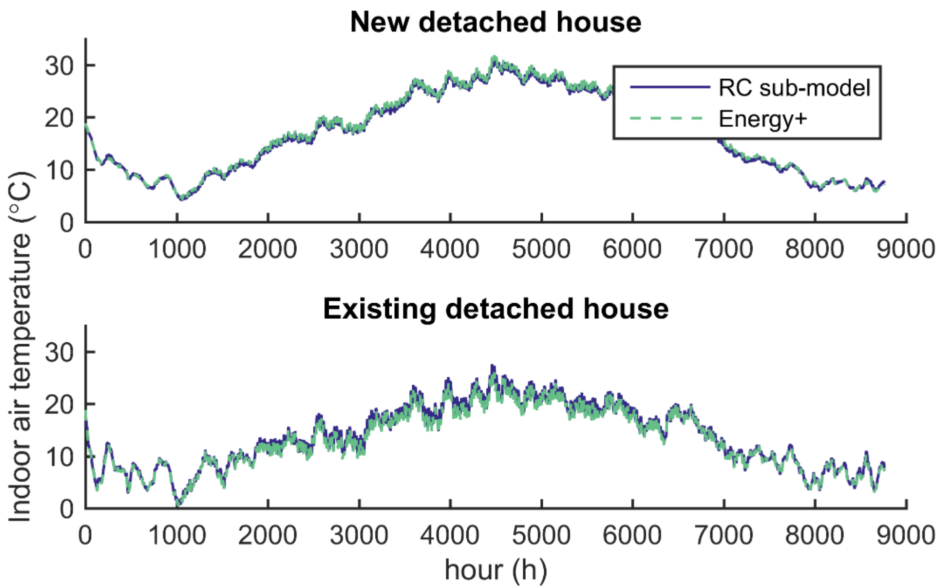
- Ireland
- Horizon: 2030
- Hourly resolution
- 25% of res. building heat electrified

Least-cost optimisation objective

$$\text{Min}(\text{InvC}_{\text{Power}} + \text{InvC}_{\text{Heat}} + \text{OpC}_{\text{Power}} + \text{OpC}_{\text{Heat}})$$

Heat demand determined internally based on constraint on indoor air temperature

Heat demand validation



RC sub-model performance is validated against a detailed thermodynamic ENERGY+ simulation

RMS error , 1%

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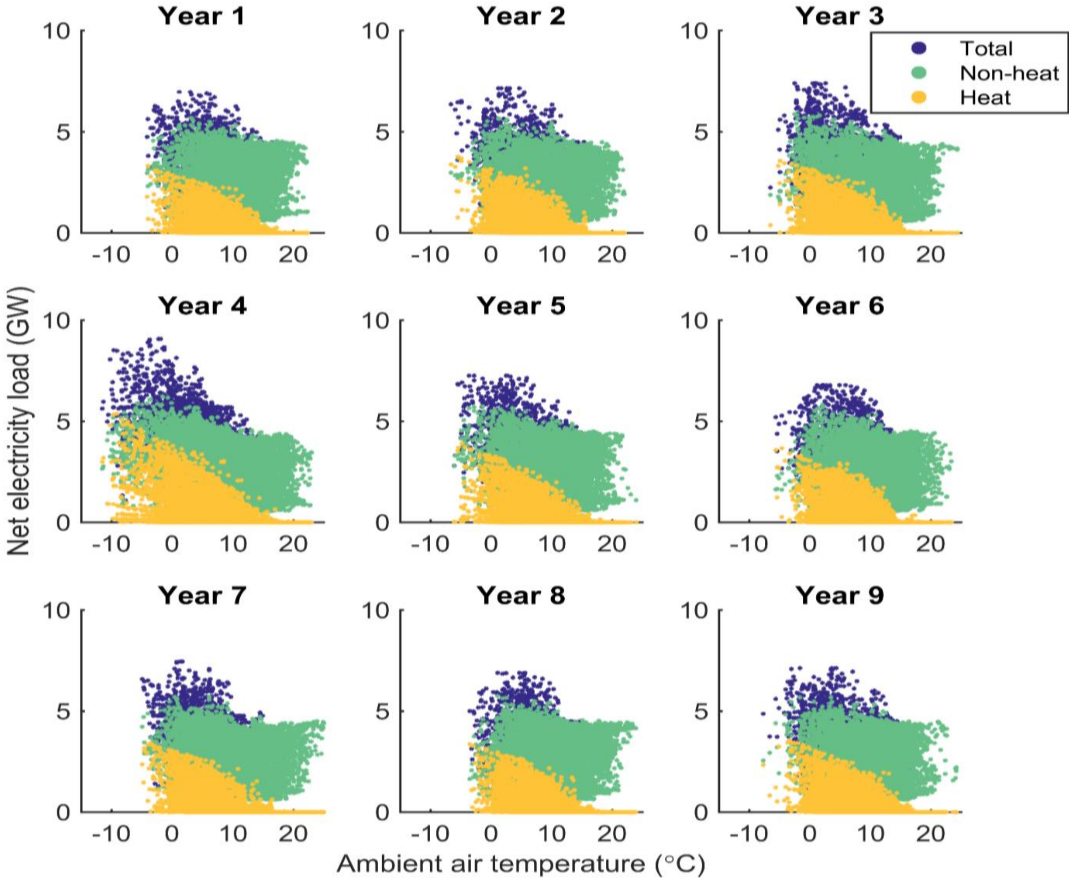
RESULTS:
WEATHER IMPACTS

Net demand in test system with 40% wind and 24% of residential heat electrified



The absolute peak does not occur during the coldest hours

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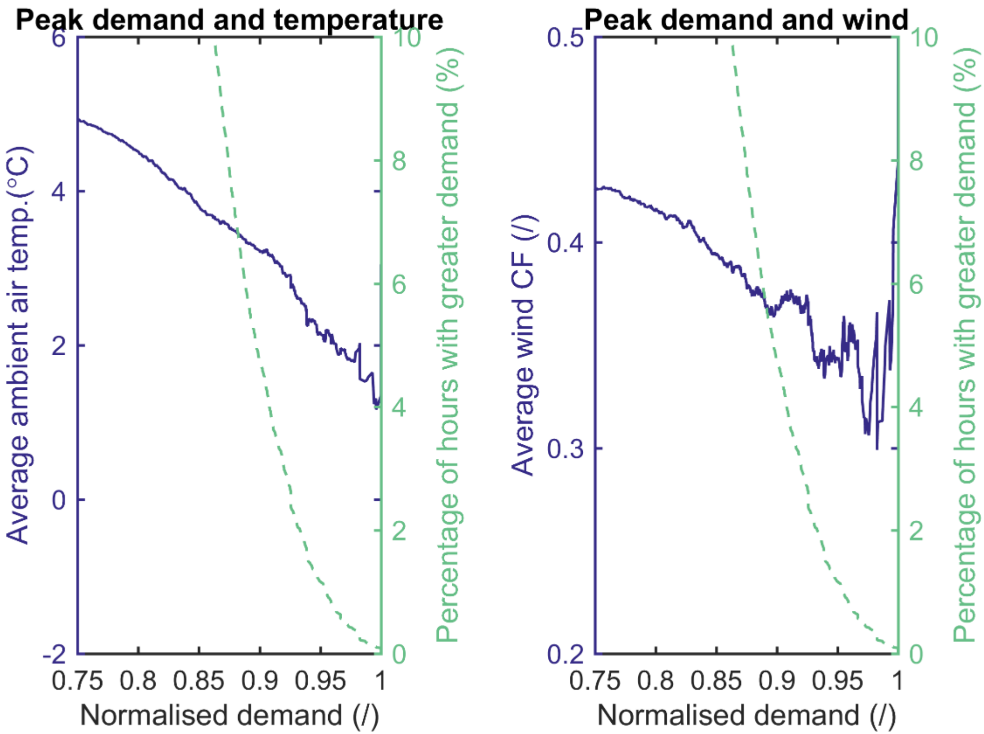
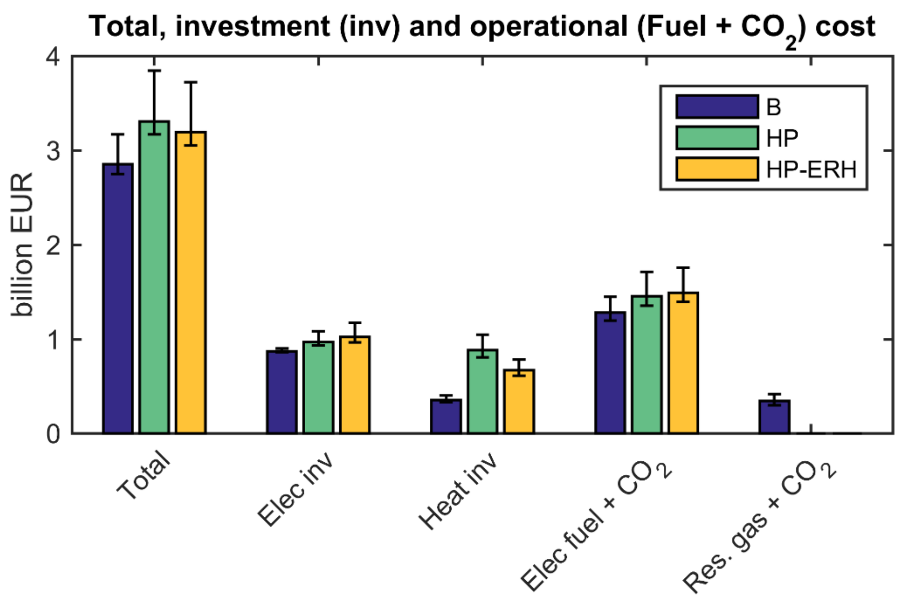
Wind and weather impact on peak demand



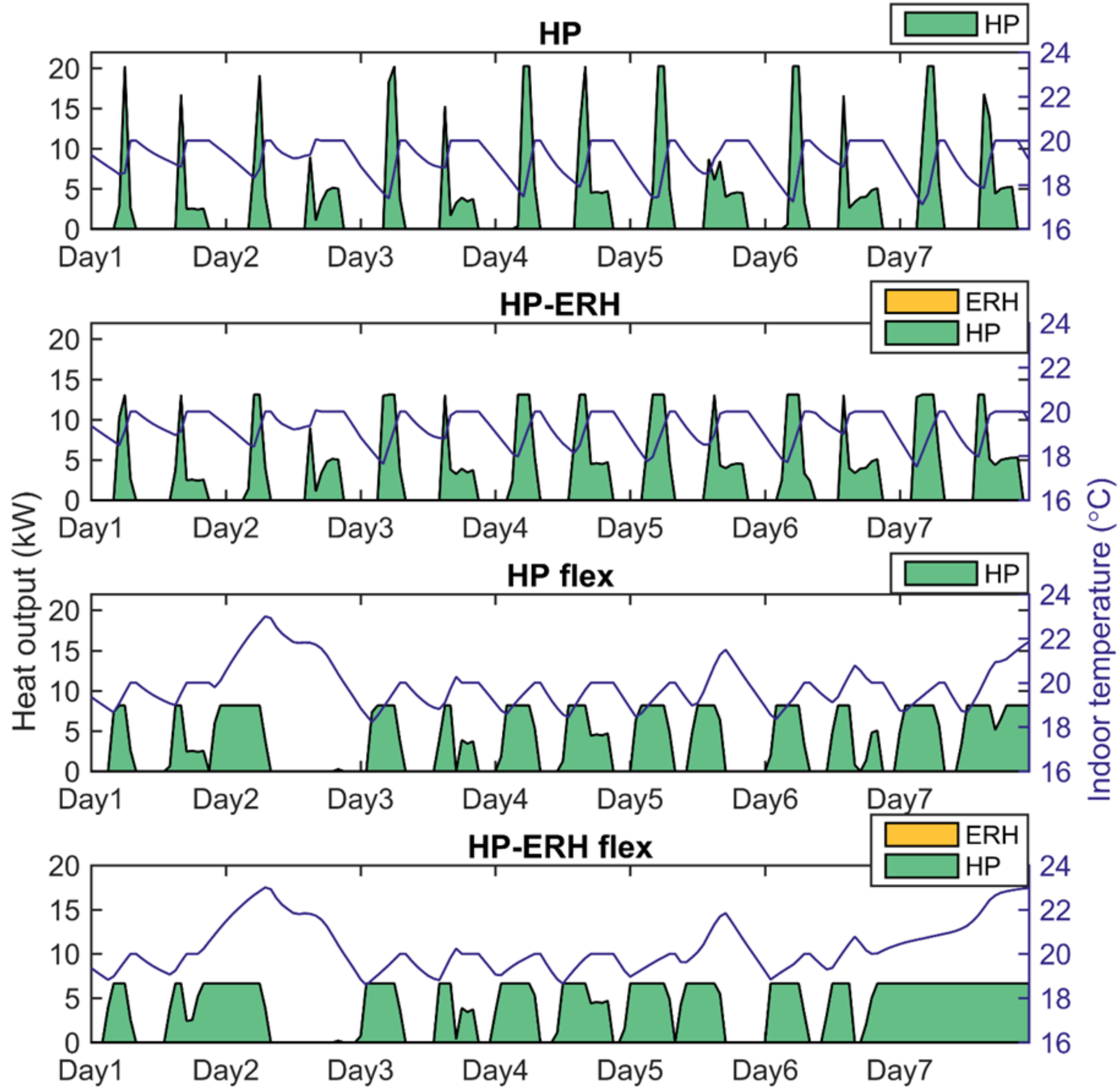
Total cost sensitivity to weather years increases



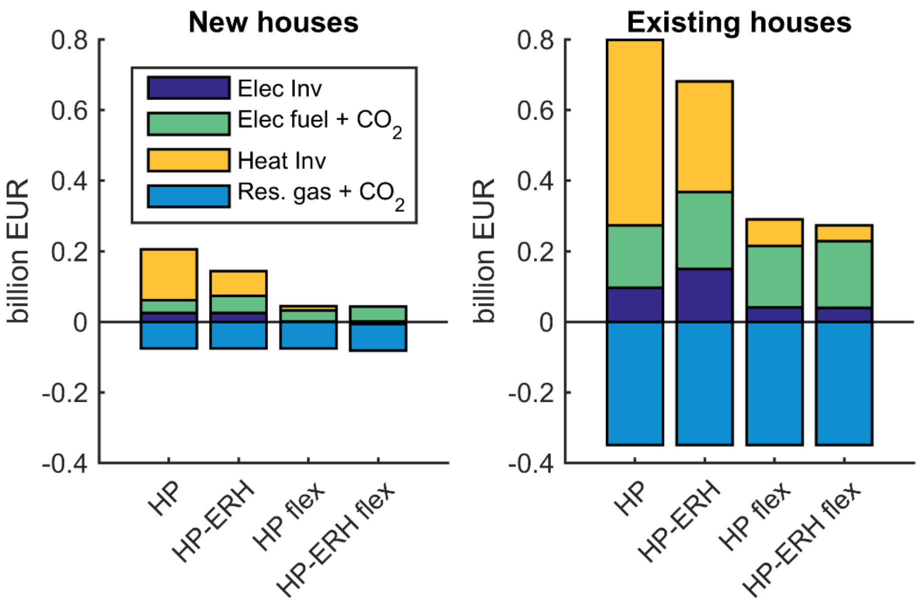
For 9 weather years considered, 15% between minimum and maximum for gas boiler and 21% for HPs and HP-ERHs

RESULTS:
BUILDING THERMAL INERTIA

Operation during windiest week of the year



Investment benefits of flexible operation



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Conclusions

Weather

- Coincidental weather impacts define net load peak and adequacy (which drive infrastructure investments)
- Weather impacts investment cost and reliability standard that take this into account are required for cost –efficient infrastructure design

Thermal inertia

- Pre-heating decouples partially electricity demand and heat demand without impacting occupant comforts
- Reduces generation capacity investment needs and wind curtailment (i.e. lowers operational cost)

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Thank you for your attention

Acknowledgement

- CITIES project, Denmark (Project Ref. 1305-00027B/DSF)
- Fonds National de la Recherche, Luxembourg (Project Ref. 6018454)

Related Publications

- Heinen, S., Burke, D. and O'Malley, M. **Electricity, gas, heat integration via residential hybrid heating technologies - an investment model assessment,** Energy. 2016
- Heinen. S., Hewicker, C. Jenkins, N., McCalley, J., O'Malley, M., Pasini, S. Simoncini, **Flexibility in Gas Systems**, IEEE Power & Energy magazine Special Edition on system flexibility (forthcoming in Jan 2017)
- Heinen. S., Kang, C., Kiviluoma, J.,Patteeuw, D., Madsen, H., Naegler, T., Qazi, H., Strbac, G. and Zhang, N., **Flexibility from heating and cooling**, IEEE Power & Energy magazine Special Edition on system flexibility (forthcoming in Jan 2017)
- Heinen, S., Turner, W., Cradden, L., McDermott, F., and O'Malley, M., **Electrification of residential space heating considering coincidental weather events and building thermal inertia: A system-wide planning analysis**, Energy (under review)

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