Smart integration of future domestic heaters in energy systems with high shares of variable renewables

An investment model assessment

Steve Heinen (Steve.Heinen@ucd.ie)

St Patrick's Day 2016

University of Auckland

Energy Centre Research Symposium

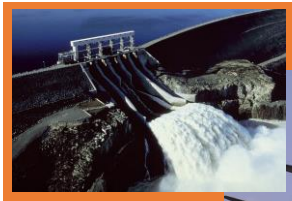
ENERGY INSTITUTE UCD

UCD DUBLIN

SETTING THE SCENE
Residential heating and system integration

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

1. Decarbonise supply

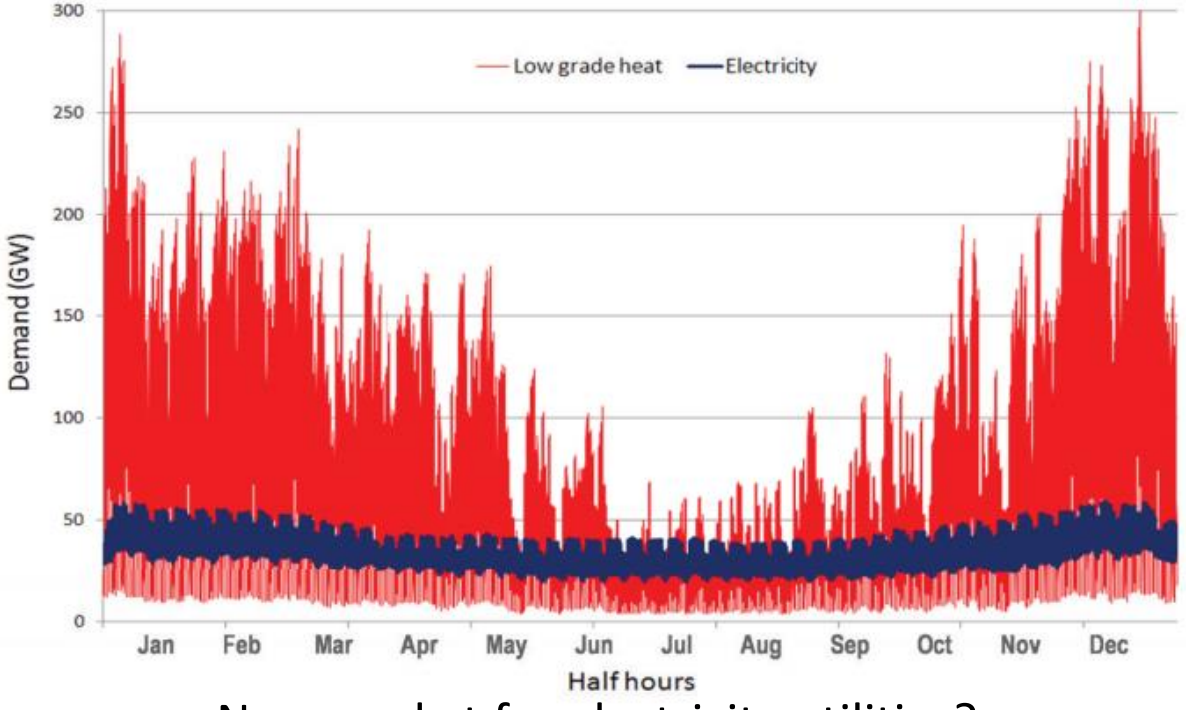


2. Insulate

3. Electrify using efficient HPs

ENERGY INSTITUTE UCD

Heat demand in the UK, 2010



New market for electricity utilities?

Increased peak load?

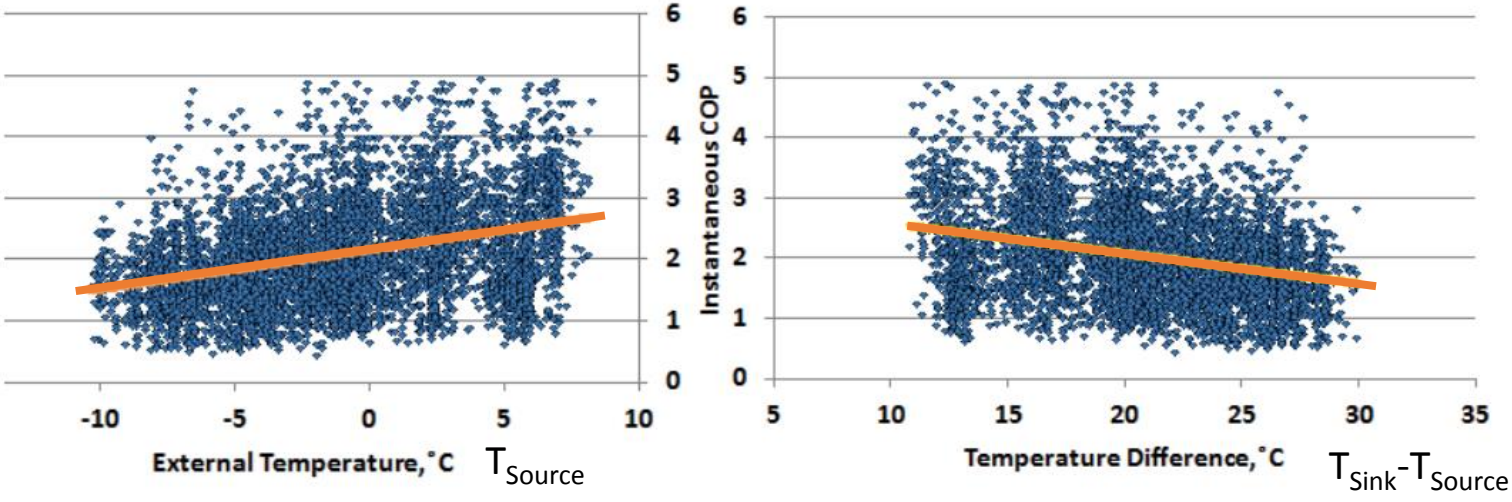
Decreased asset utilisation?

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

ENERGY INSTITUTE UCD

Heat pump efficiency

$$COP_{Carnot} = \frac{Q_{Sink}}{W} = \frac{T_{Sink}}{T_{Sink} - T_{Source}}$$

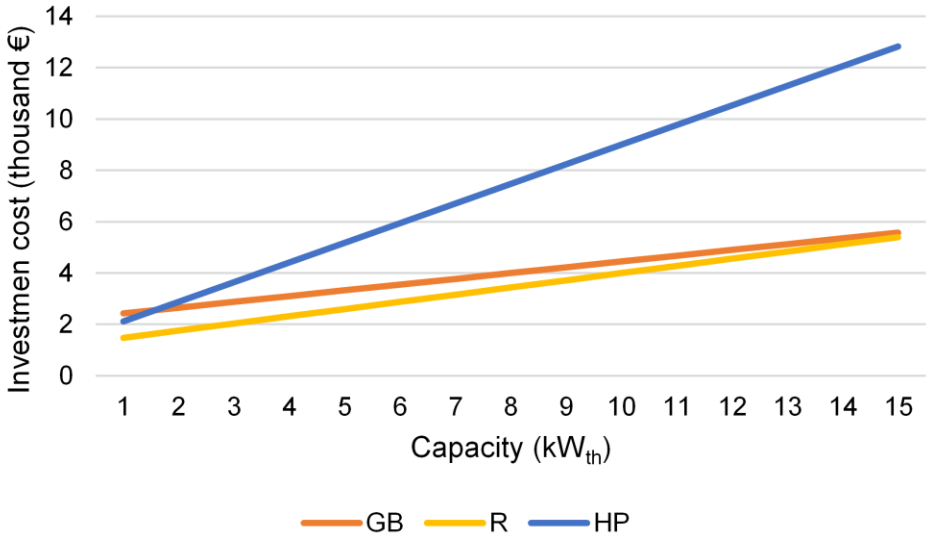


Underperformance during cold temperature spells?
Low-temp heat distribution system?

Source: Munuera et al. (2013), The role of energy efficiency in decarbonising heat via electrification

ENERGY INSTITUTE UCD

Heat pump investment cost

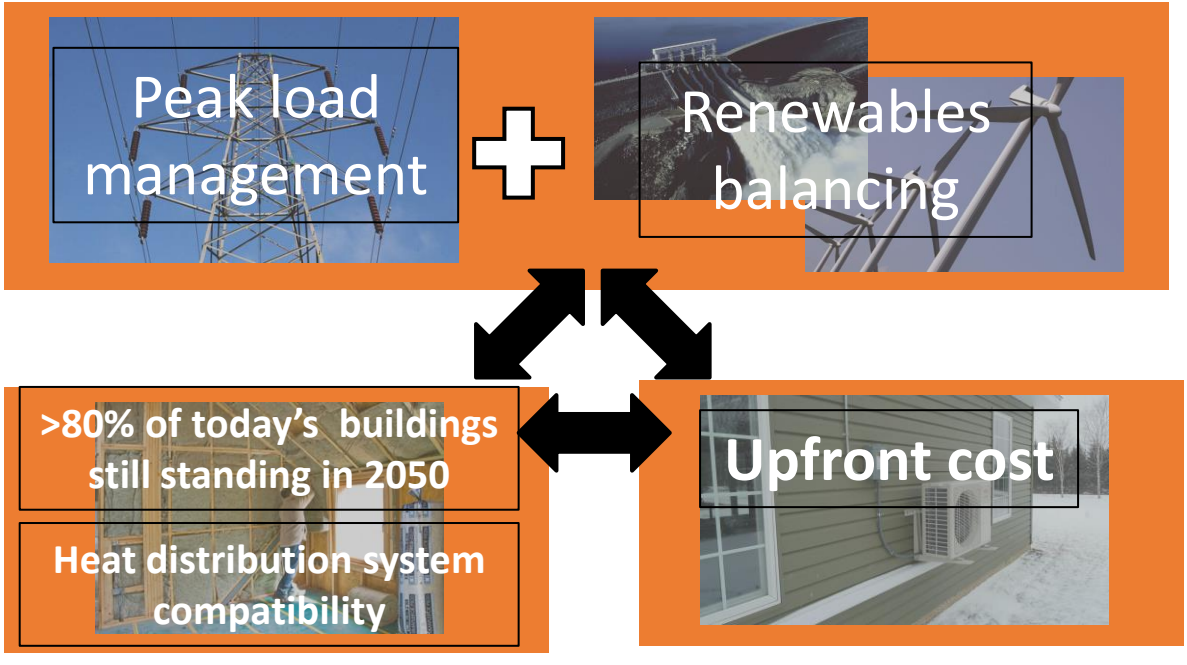


Are consumers rational enough and have access to finance to invest a high upfront sum that delivers long-term savings?

Source: Energinet, COWI

ENERGY INSTITUTE UCD

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



ENERGY INSTITUTE UCD

Hybrid gas boiler - heat pump

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

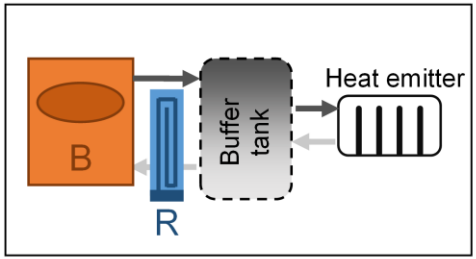
ENERGY INSTITUTE UCD

Hybrid heaters are available commercially since about 2010

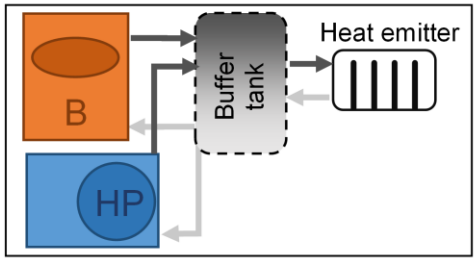
itho
Techneco energiesystemen
WORCESTER Bosch Group
Buderus
atlantic
remeha
ARISTON
JUNKERS
Vaillant
BAXI
COSMOGAS MADE IN ITALY
VIESMANN
RIELLO
MHG
DAIKIN Japan
Carrier USA
ENERGY INSTITUTE UCD

Hybrid heaters an overlooked alternative?

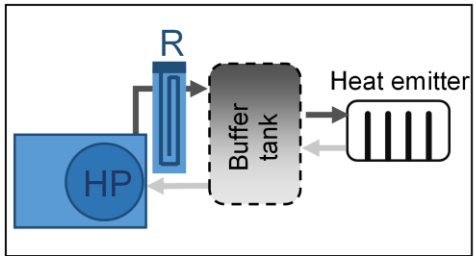
a. Hybrid B-R



b. Hybrid HP-B



c. Hybrid HP-R



Hybrid heaters are composed of 2 appliances

Different combinations feasible

- Gas boiler – resistance heater (HP-R)
- Heat pump - Gas boiler (B-HP)
- Heat pump – resistance heater (HP-R)

Enabled by ICT, hybrids can switch between those appliances during operation depending on market conditions.

→ **Can hybrid heating deploying provide system-wide planning benefits?**

ENERGY INSTITUTE UCD

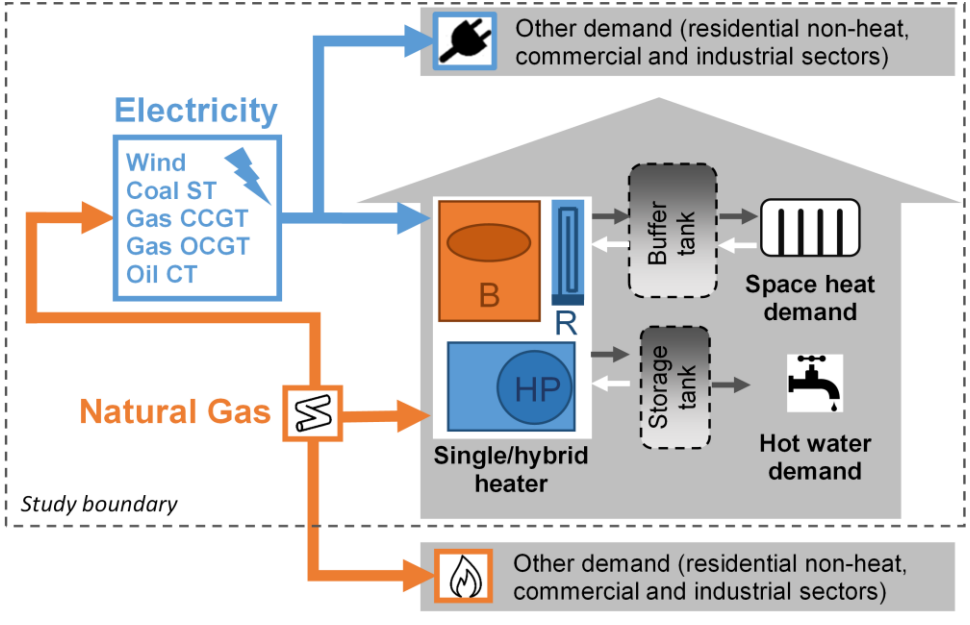
INVESTMENT PLANNING ANALYSIS
Research framework and methods

Research target

- Quantify the planning and operational cost of deploying different residential heating systems for the integrated power-heat system
- In particular, relative to business-as-usual i.e. gas boiler for heat
- Target audience
  - Policymaker and regulator
  - Utilities
  - Technology manufactures and smart aggregators

ENERGY INSTITUTE UCD

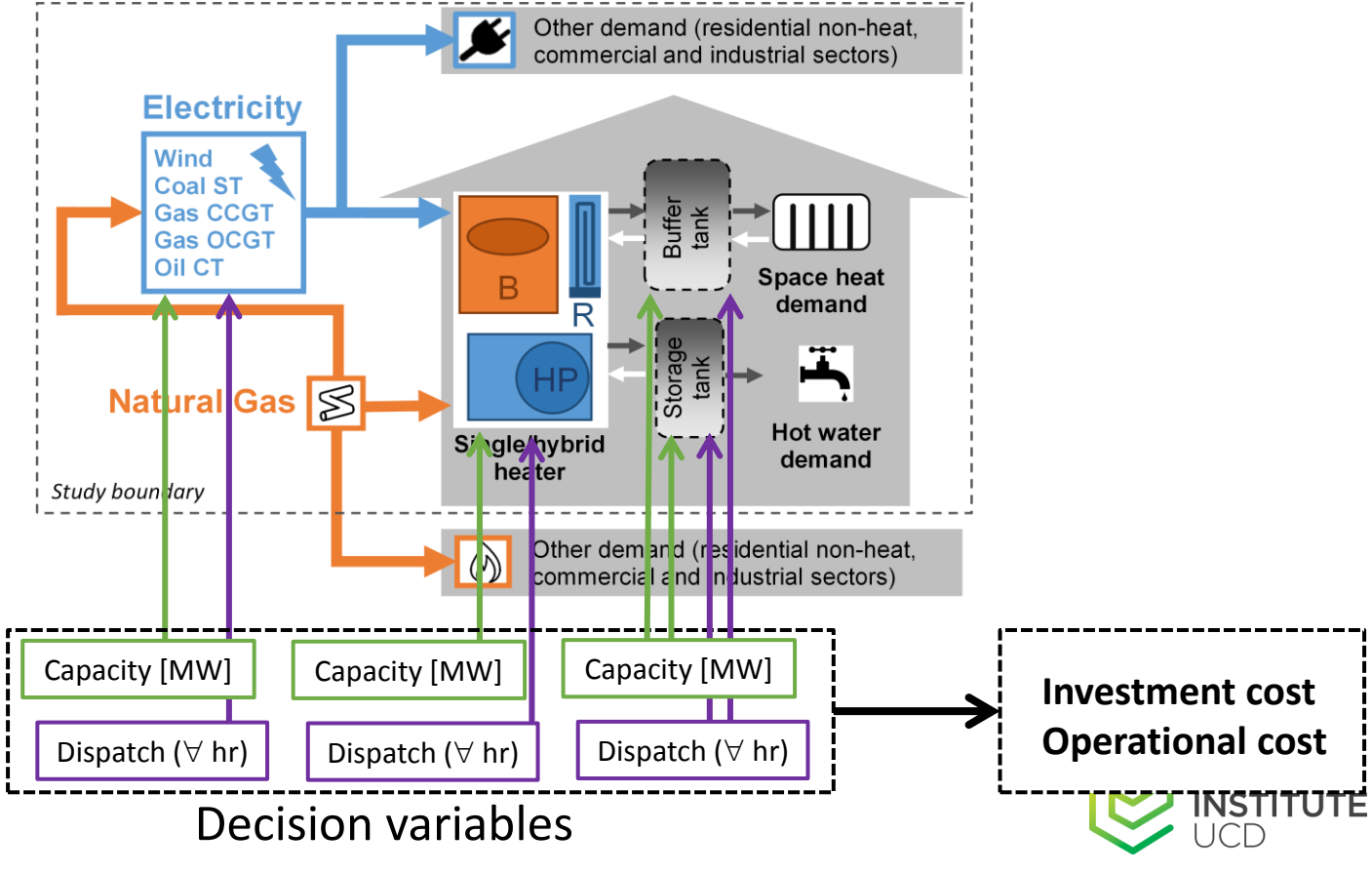
Power-gas-heat system



What is the cheapest way to build and operate this system?

ENERGY INSTITUTE UCD

Power-gas-heat system



Model formulation and test system

- Linear one stage planning/capacity expansion
- Hourly resolution for full year

- **Objective Function:**

$$\min\{\text{TotalCost}\}$$

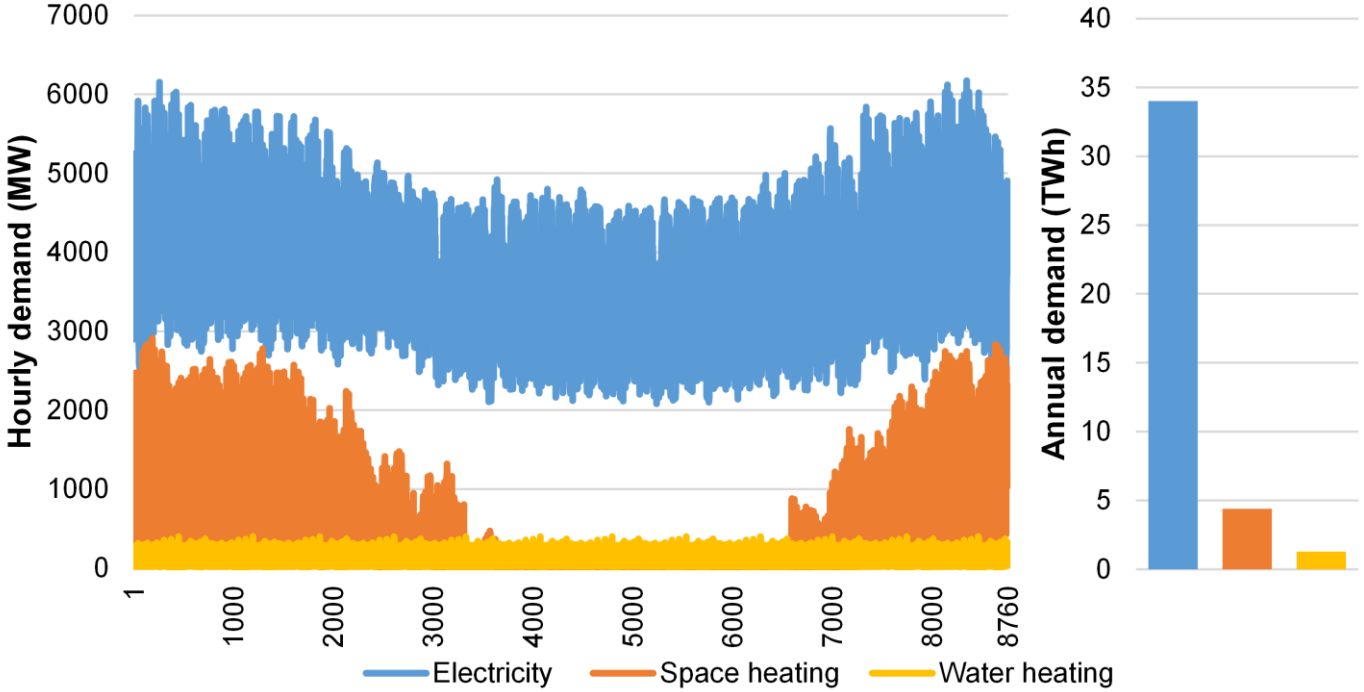
$$\Leftrightarrow \quad \min\{\text{Inv}(\textit{Heat+Power}) + \text{Fuel}(\textit{Heat+Power}) + CO_2(\textit{Heat+Power})\}$$

Heat includes heater and (optional) thermal storage

- **Main constraints**
  - Energy and capacity balance for generators, heaters and storages
  - Adequacy constraint
  - Wind penetration based on SNSP (0.75)
- **Test System**
  - Ireland 2030 with 6000 MW wind (40% energy)
  - Heaters installed in 25% of Irish households

ENERGY INSTITUTE UCD

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



New market for electricity utilities?

Increased peak load?

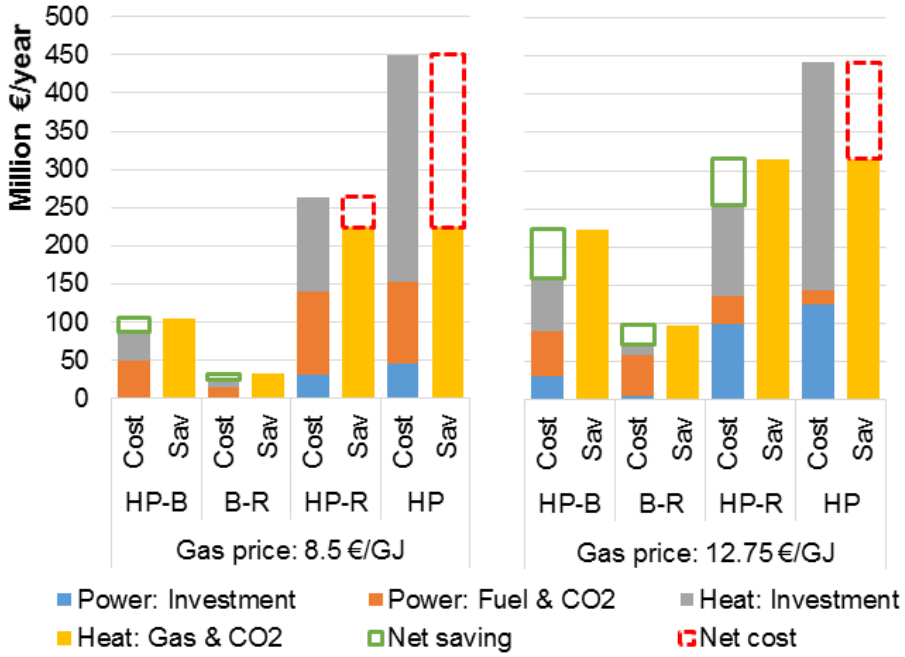
Decreased asset utilisation?

Source: Eirgrid (2014), CER (2011)

ENERGY INSTITUTE UCD

INVESTMENT PLANNING ANALYSIS
Results

Economic assessment – cost breakdown

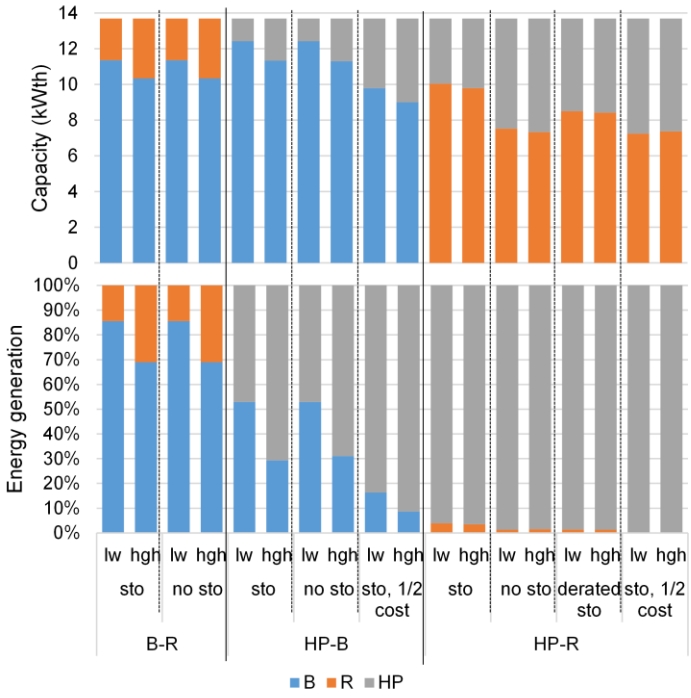


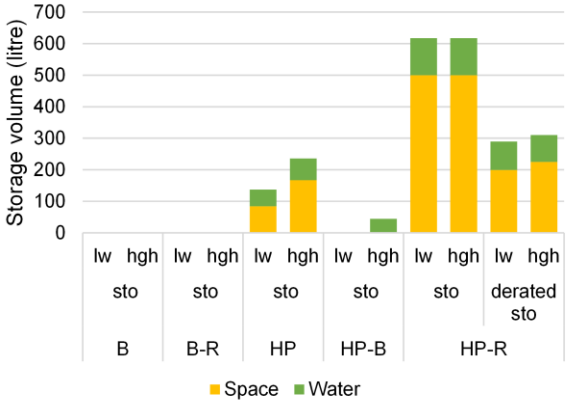
Compared to gas boiler deployment

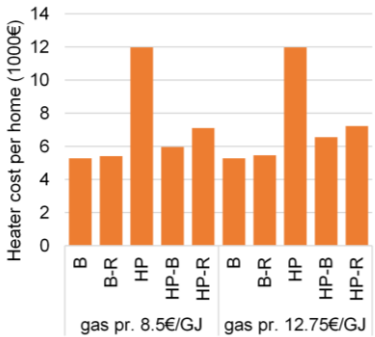
Heinen, S., Burke, D. O'Malley, M., Electricity, gas, heat integration via residential hybrid heating technologies – an investment model assessment, Submitted to ENERGY

ENERGY INSTITUTE UCD

Consumer side



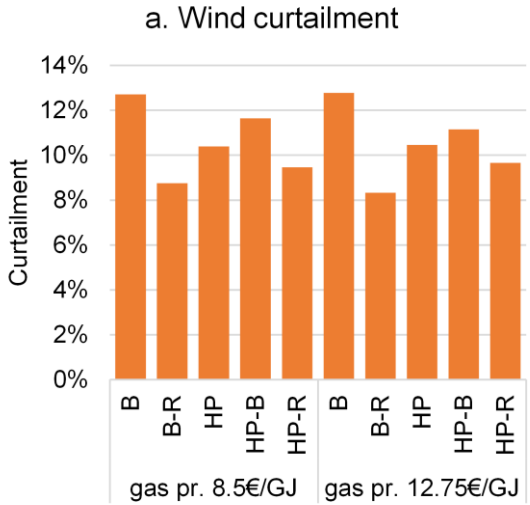




Heinen, S., Burke, D. O'Malley, M., Electricity, gas, heat integration via residential hybrid heating technologies – an investment model assessment, Submitted to ENERGY

ENERGY INSTITUTE UCD

Wind curtailment

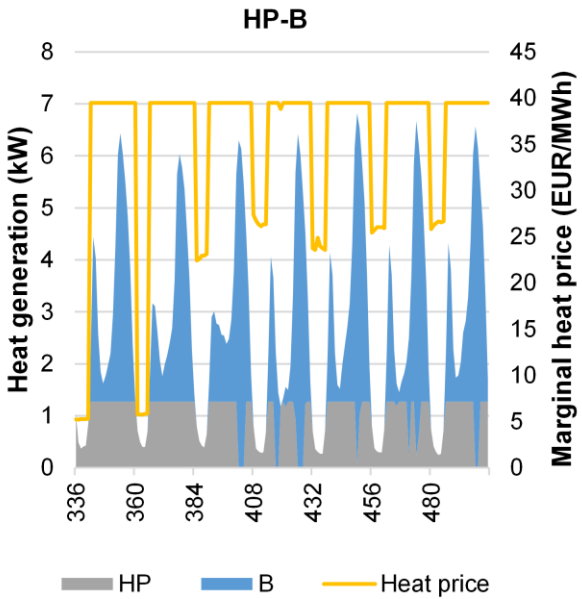


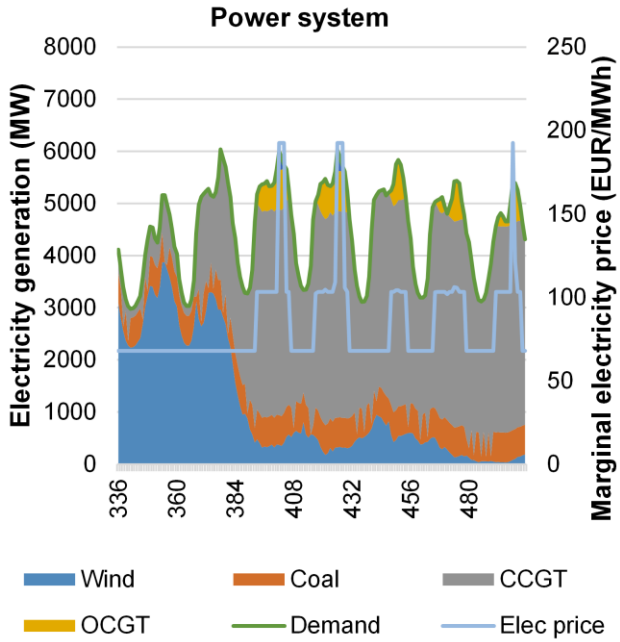
Electric loads increase flexibility and lower curtailment

Heinen, S., Burke, D. O'Malley, M., Electricity, gas, heat integration via residential hybrid heating technologies – an investment model assessment, Submitted to ENERGY

ENERGY INSTITUTE UCD

HP-B operation during low wind week





Heinen, S., Burke, D. O'Malley, M., Electricity, gas, heat integration via residential hybrid heating technologies – an investment model assessment, Submitted to ENERGY

ENERGY INSTITUTE UCD

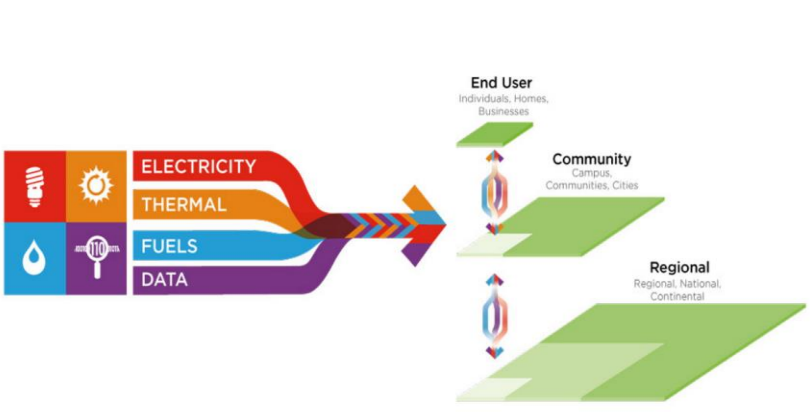
Overall assessment

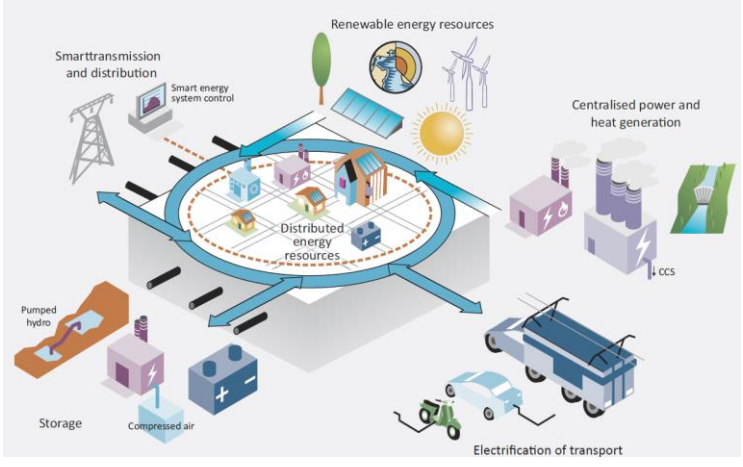
- Hybrid heaters can provide planning benefits by integrating gas, electricity and heat without district heating network, only through smart integration of individual technologies.
- **HP-B system**
  - Least-cost system
  - Heater investment savings compared to HP (smaller HP)
  - Power investment (lower electric peak) and fuel savings (efficient HP)
  - Gas and CO_2 savings compared to gas boiler, small increase in gas and CO_2 emissions compared to HP
- **B-R system**
  - Cheap, high return on investment
  - Reduced wind curtailment, but increased coal usage
- **HP-R system**
  - Heater investment reduction compared to HP
  - Minor power system benefits

ENERGY INSTITUTE UCD

THE BIGGER PICTURE:
ENERGY SYSTEMS INTEGRATION

What is energy systems integration?



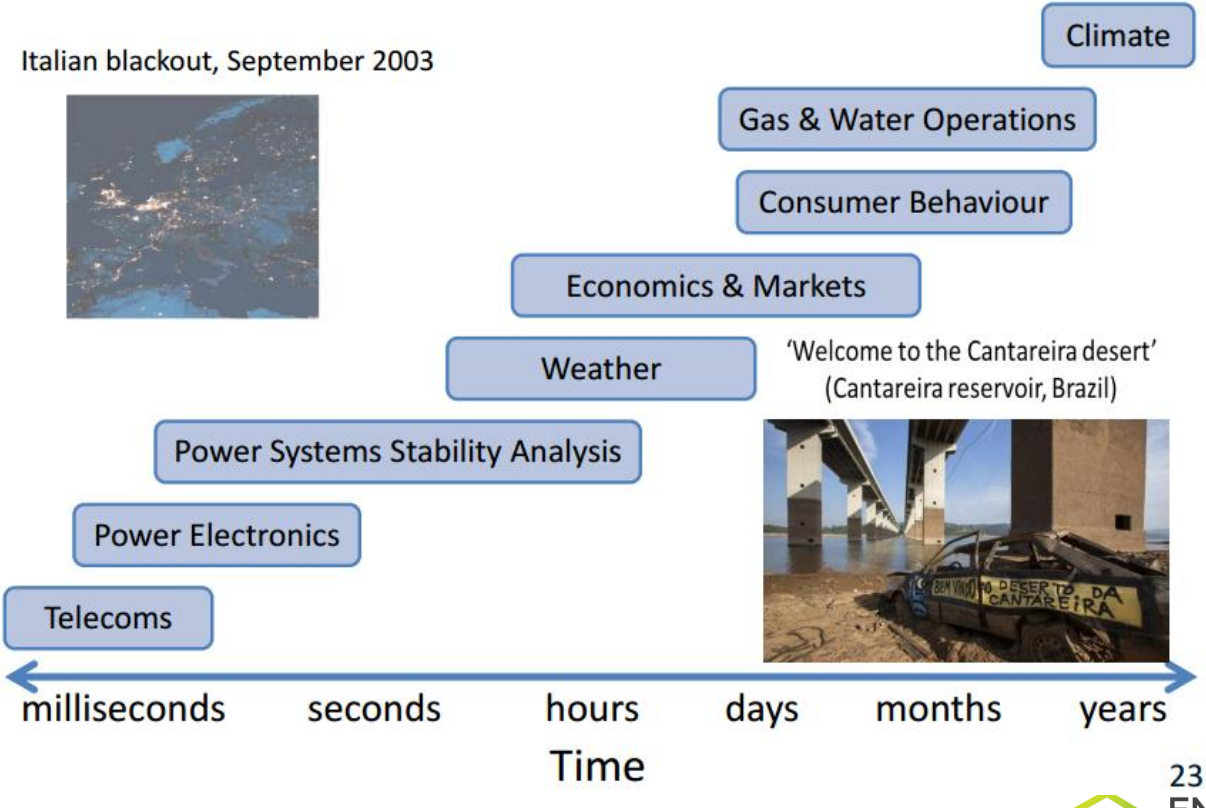


- optimization of energy systems across all scales and across multiple pathways (electricity, gas, heat, and liquid fuels)
- increase reliability and performance, and minimise cost and environmental impacts
- most valuable at the interfaces where the coupling and interactions are strong and represent a challenge and an opportunity
- control variables are technical, economic and regulatory

Source: NREL, Energy Systems Integration – a convergence of ideas, 2012;
IEA, Energy Technology Perspectives, 2014

ENERGY INSTITUTE UCD

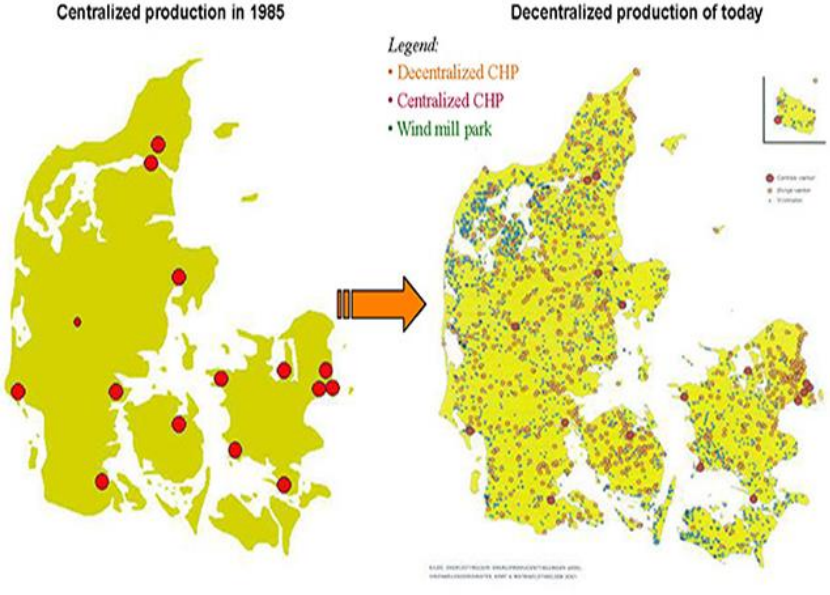
Energy analysis across fuels, disciplines and timescales



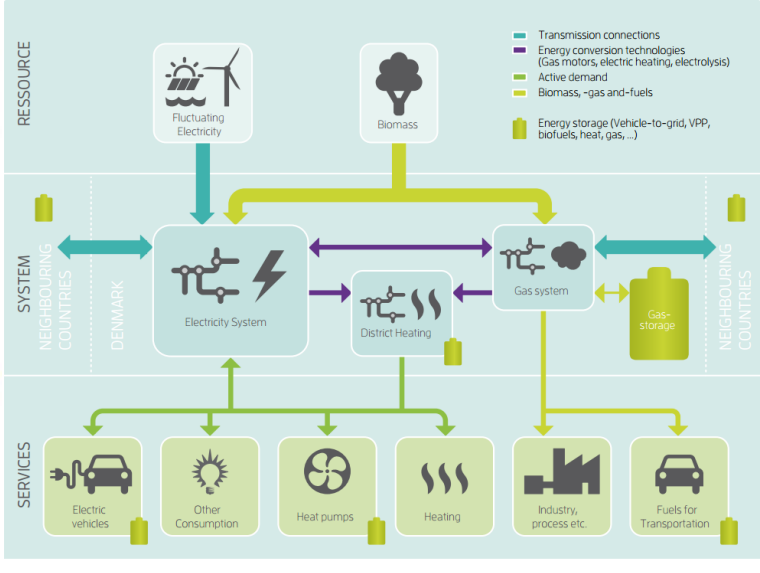
ENERGY INSTITUTE UCD

Denmark – ESI leader

Last 20 years



Next 20 years



ENERGY INSTITUTE UCD

- Activities in 2015
  - Key Research Challenges of Energy Systems Integration, UK, March 2015
  - Energy Systems Integration courses, Boulder (CO, US) and Leuwen (Belgium)
  - ICT Enabling Thermal Energy Flexibility in Integrated Energy Systems, Korea, Oct 2015
- Activities in 2016
  - **Energy Systems Integration Course May 16-20 in Dublin**
  - Consumer Workshop (tbc), Stanford

www.iiesi.org

ENERGY INSTITUTE UCD

energyinstitute.ucd.ie

erc electricity research centre

erc.ucd.ie

Thank you for your attention

Questions?

Steve.Heinen@ucd.ie

Special thanks to my PhD supervisor **Prof Mark O'Malley**

Fonds National de la Recherche Luxembourg

Supported by

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

CITIES
Centre for IT Intelligent Energy Systems