Local pathways to low-carbon domestic heat: exploring the options in the UK

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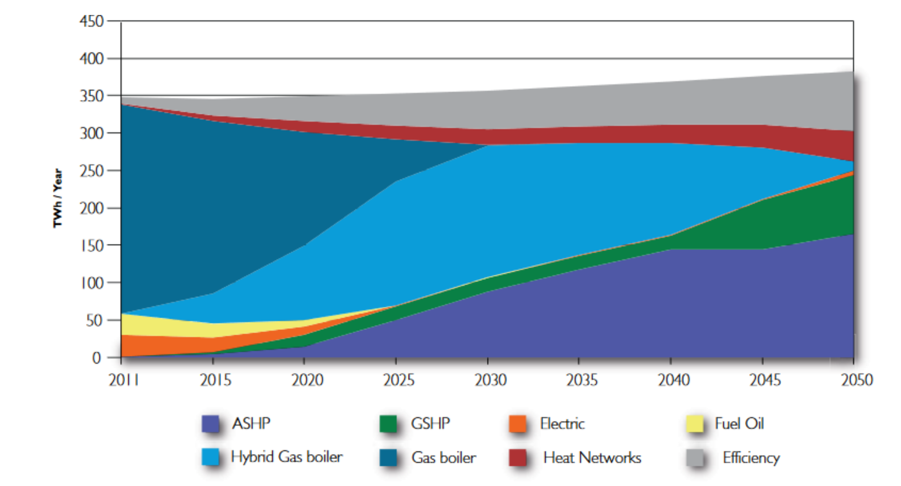
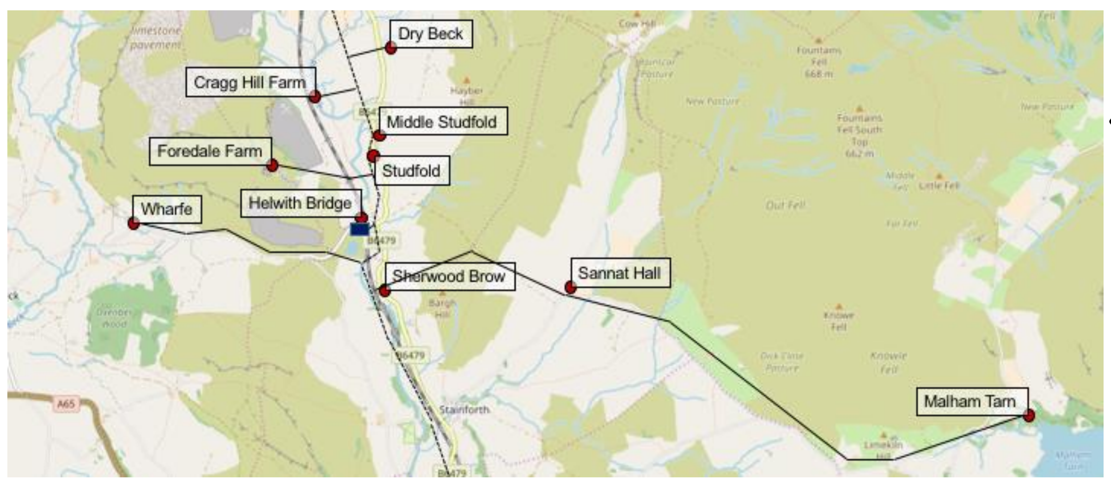
Heat futures in the UK

Currently, natural gas is the predominant source of domestic heat provision. Take-up of heat pumps and district heating remains at a minimal penetration of around 0.5%. In total, only around 2.5% of heat comes from low carbon sources, compared with more than 45% of electricity. As heat accounts for around 40% of UK energy consumption and 20% of GHG emissions, the decarbonisation of the heat sector is seen as vital for the UK to reach UK emission reduction targets. Different trajectories in heat provision using parallel energy vectors (electricity, gas, alternative gases, heat networks) imply a range of infrastructure impacts. In order to explore the form of different local energy systems under decarbonisation scenarios, this work seeks to:

- Capture the broad forms of 'last-mile' network: Urban, Suburban, Rural (on/off gas grid) seen as exemplar of the UK energy system;
- Downscale whole system-derived technology mixes and construct demonstrative local energy systems representing key use cases;
- Using multi-carrier optimisation, determine the impacts of heat decarbonisation on current and future system actors.



DECC: The Future of Heating: Meeting the Challenge



Disaggregate UK energy system by archetype

Rural

Highly spatially diverse system - Off gas grid, high fuel costs and low building efficiency

Urban

High density system with large potential for non-heat impacts such as EVs

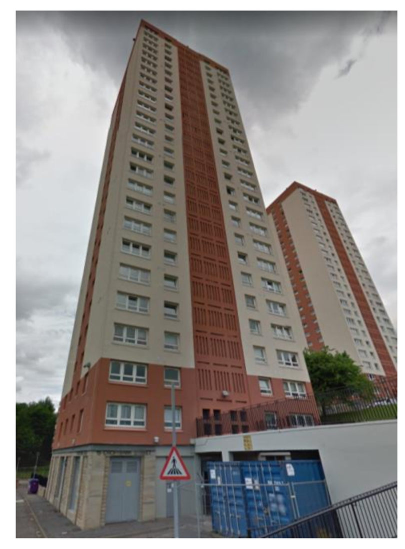
2 tower blocks in Glasgow:

26 floors, 208 properties

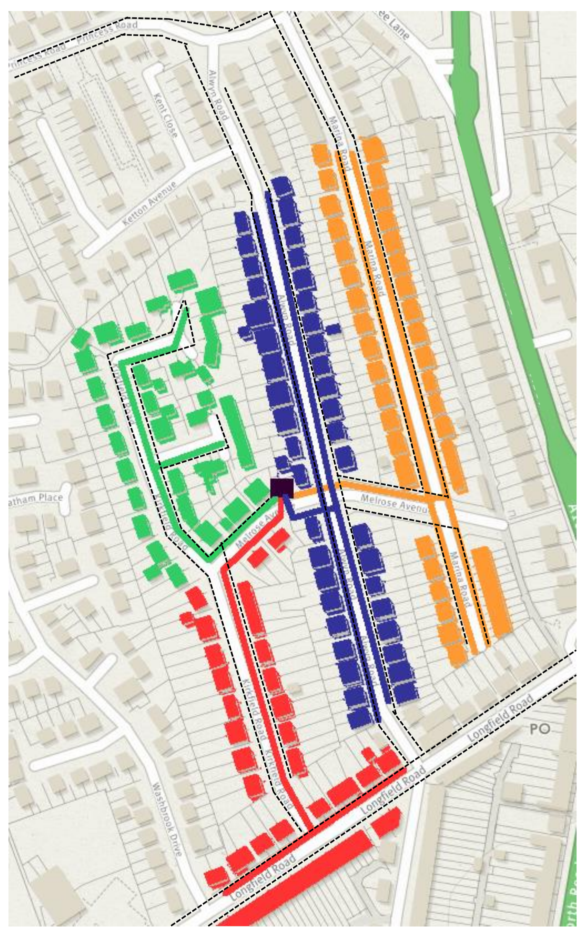
Secondary LV transformer located in base of each tower

Gas supplied domestic boilers for space and hot water

Opportunities for heat networks and high efficiency, but low availability of space



Suburban



292 properties

- mixed semi-detached/terraced
- 1930s stock, low energy efficiency

697 residents mean = 2.4/house

Electricity network:

- 500kVA transformer
- 4 LV feeders

Gas network:

- Ageing cast iron
- Some new PE

Nodal Optimisation Framework

Resource / Sink → Store → Vector

Storage conversion losses

Vector conversion losses and parasitics

Transport between nodes (network)

Arbitrary weighting that can be used later to enact multi-criteria analysis

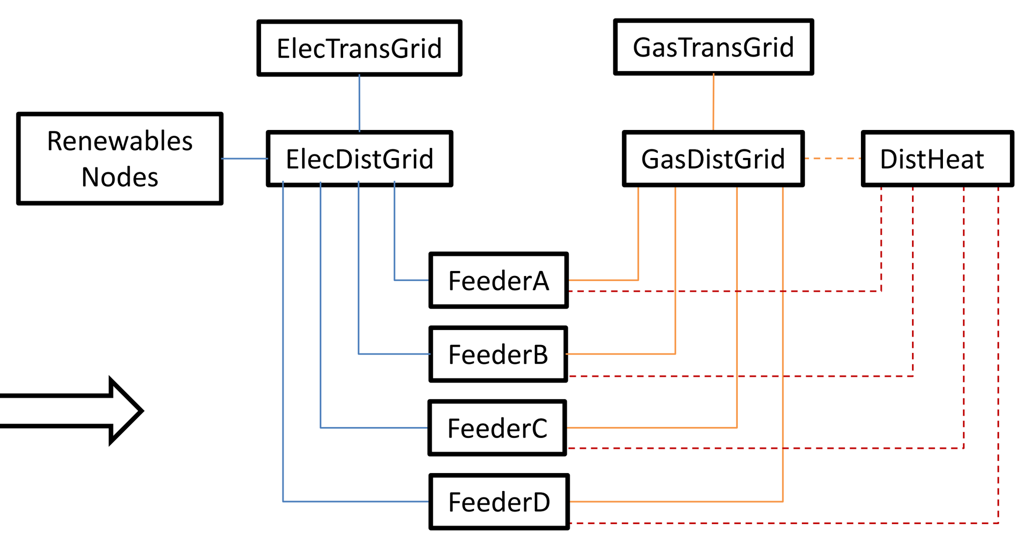
Costs of technology y at node x

$$min: \sum_{x}\left[\sum_{y}\left[weight(y)\times\left(CAPEX_{tech}(x,y)+\sum_{t}OPEX_{tech}(x,y,t)\right)\right]\right.$$
$$\left.+\sum_{v,x'\in X}CAPEX_{network}(v,x,x')+\sum_{v,x'\in X,t}OPEX_{network}(v,x,x',t)\right]$$

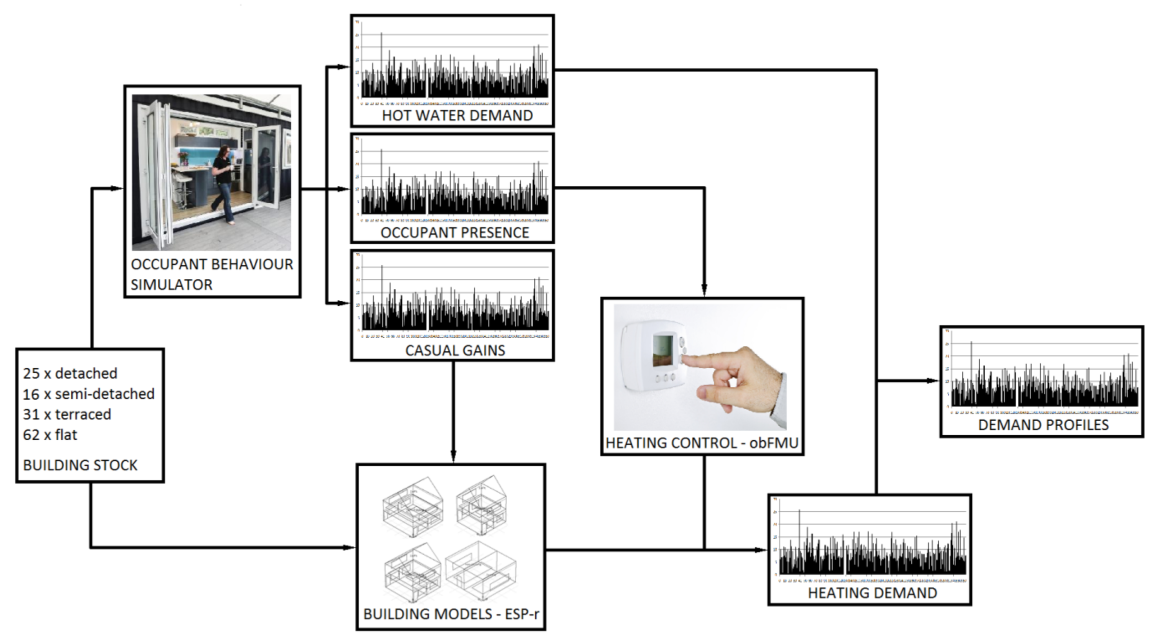
Costs of network for vector v between nodes x,x'

Subject to:

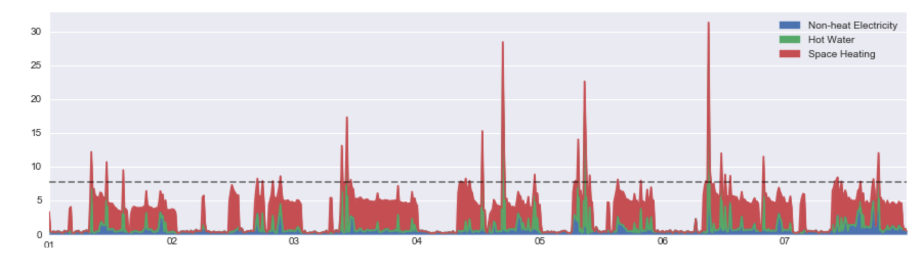
- Nodal energy balancing
- All energy demands met within security criteria
- Time-coupled storage dispatch
- Static/dynamic technology parameters



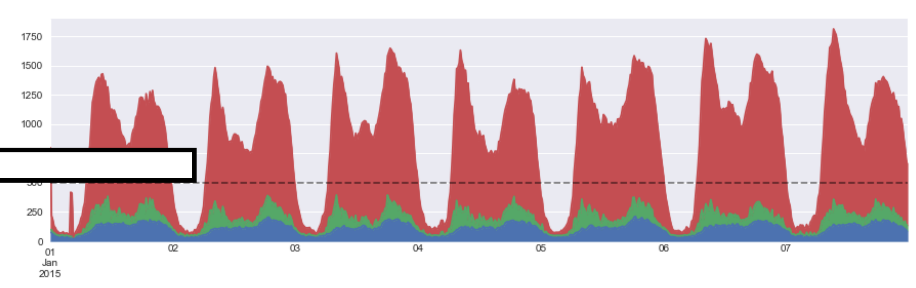
Stochastic Demand Modelling



Deterministic 3D building thermal model (ESP-R) coupled with stochastic human behavioural simulation, houses populated based on National Housing Survey:



1 house

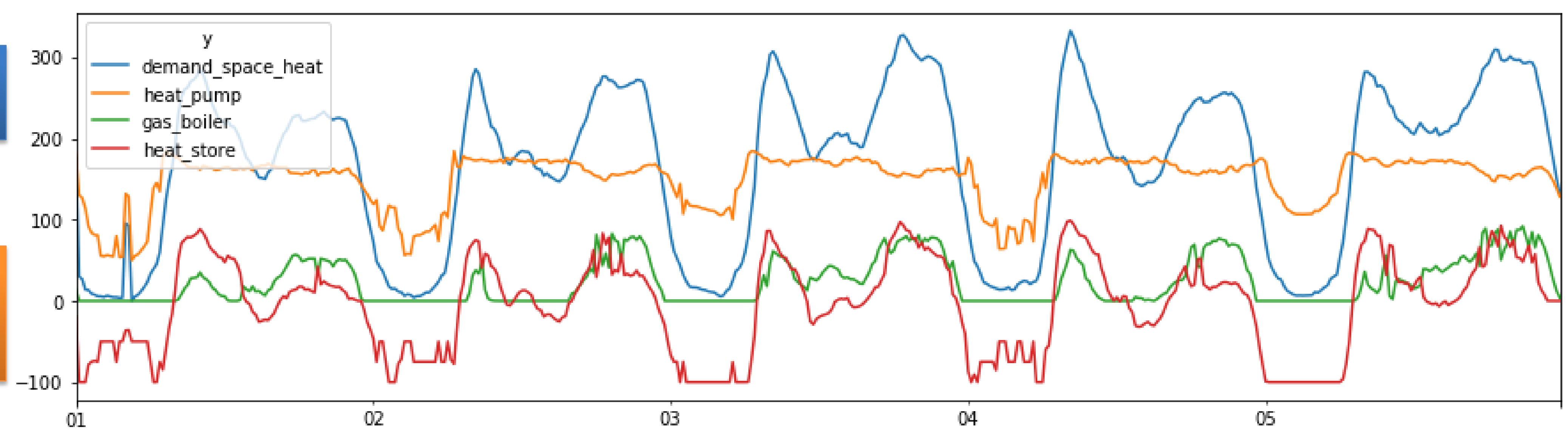


292 houses

Decarbonised heat provision under last-mile infrastructure constraints – Suburban Example

Raw demand buffered through efficiency measures

ASHP utilised up to constraint level of local network (net of non-heating electricity demand)



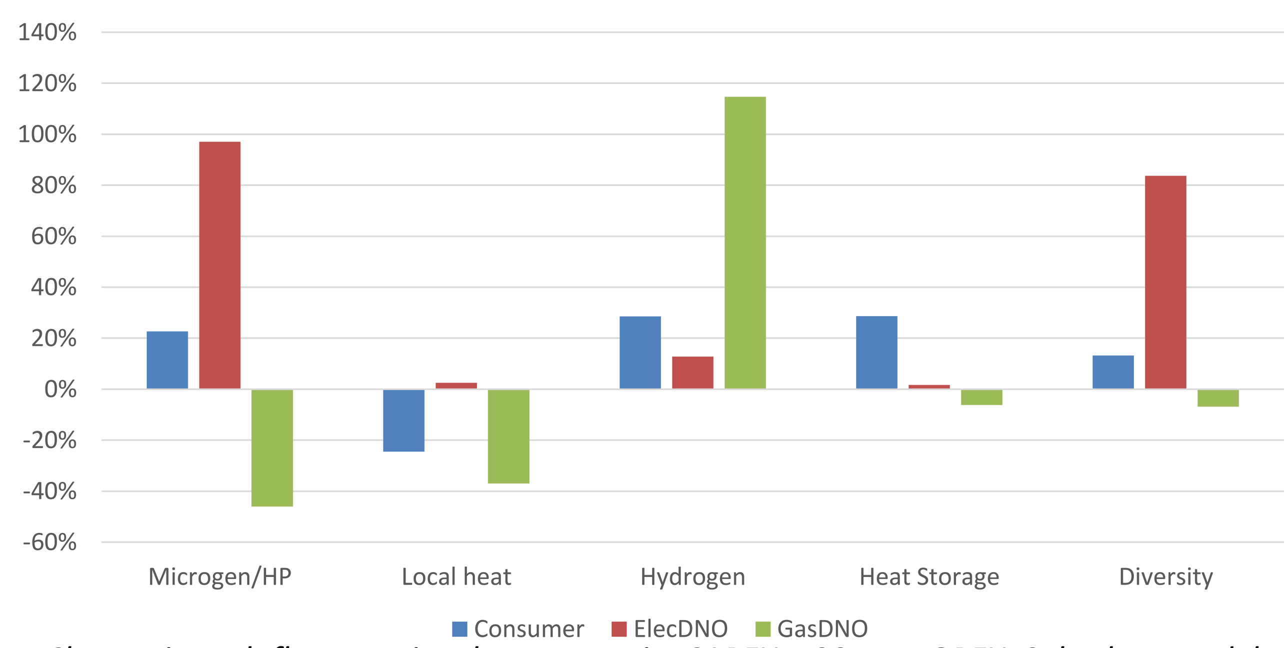
Gas used to infill system peaks – low load factor and minimised emissions

Thermal storage increases utilisation of ASHP during off-peak periods where network capacity is available

Impacts on System Actors

Different future technology mixes imply a range of impacts on incumbents, especially network operators, and requires significant coordination by local authorities. Certain trajectories may also imply significant stranded assets, such as if gas is used as a bridging technology, or electrification eventually supplanted by hydrogen systems. The need for consumer investment is at odds with the knowledge that the majority of domestic consumers (87%) will not change their existing heating provision unless significant financial benefits will be accrued, and only then if they have funding available. All trajectories to decarbonisation involve non-incremental change for some actor at some level, for example:

- Domestic consumers investing in a change of heating technology;
- CHP and district heating systems requiring critical volume of buy-in;
- Increasing electrical demand requiring infrastructure reinforcement both locally and at higher voltages;
- Natural gas to hydrogen conversion requiring regional switch-over and potential huge costs for transmission.



Change in cash flows against base scenario, CAPEX + 20 year OPEX, Suburban model

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Fabric-Integrated Thermal Storage in Low Carbon Dwellings

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