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DECARBONISING THE UK RESIDENTIAL SECTOR

The dependence of national abatement on flexible and local views of the future

Oliver Broad, Graeme Hawker, Paul Dodds

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RESEARCH QUESTION

Current levels of decarbonisation required of the UK residential sector, and the pathways that lead there, are uncertain.
This is due in part to the potential of moving to tighter, maybe net-zero targets.
Equally, this is due to conservative views of technology deployment in energy system models.

https://www.gdhv.com/article/uk-housing-fit-future

① CONTEXT
The UK climate targets

② BACKGROUND
The residential sector

③ METHODS
Modelling approaches

④ RESULTS
The different pathways

⑤ CONCLUSIONS
Moving forward

CONTEXT. UK Climate Targets

Domestic climate policy framework

The Committee on Climate Change

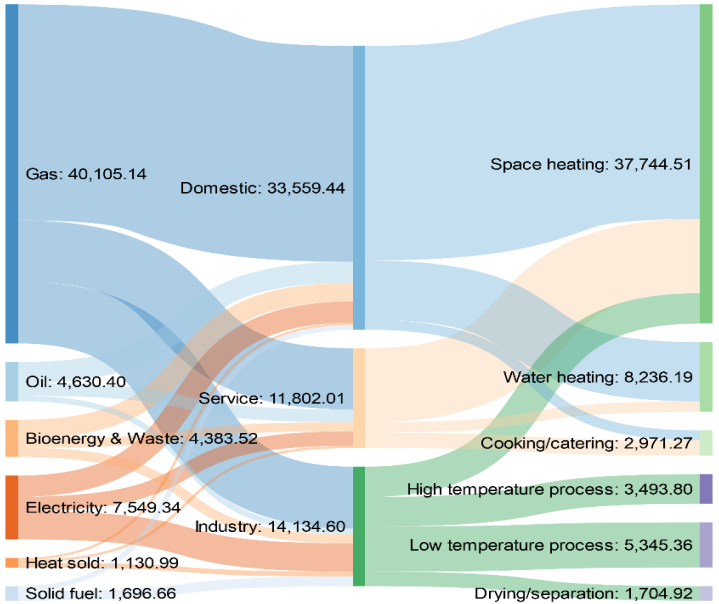
Long-term targets $MtCO_{2e}$	Reduce economy wide emissions by at least 80% by 2050 relative to 1990. *(May 2019 - recommended net-zero)*		
Legally binding carbon budgets	CB1	3,018 $MtCO_{2e}$	25%
	CB2	2,782 $MtCO_{2e}$	31%
	CB3	2,544 $MtCO_{2e}$	37% (2020)
	CB4	1,950 $MtCO_{2e}$	51% (2025)
	CB5	1,725 $MtCO_{2e}$	57% (2030)
A clear accountability framework with an independent review body	A legal requirement for government to introduce policies to meet the budgets An independent body established to advise Government on its budgets and how to meet them, and scrutinise delivery through annual progress reports.		

BACKGROUND. UK Residential sector

- 28 million households
  - 33% urban, 39% suburban, 28% rural
  - Large volume of ageing stock
  - Limited progress in improving efficiency
- Ageing T&D network
  - Constrained at local scales
- High natural gas penetration
  - Incumbent boiler technology
  - Widespread pipeline infrastructure
- Residential heat
  - 23% of final UK energy demand,
  - 76% is met using natural gas
- Electricity
  - 13% of UK heat in 2017,
- District heating just
  - 2% of total heat supply
  - 0.8% of domestic heat (growing fast)

UK Heat Consumption

(ktoe, Energy Consumption in the UK 2018)

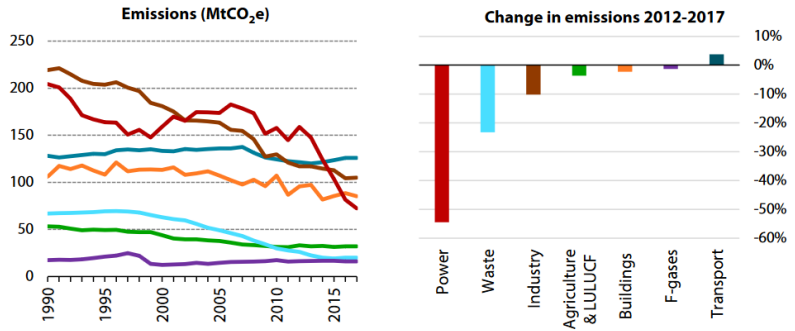


BACKGROUND. UK Residential sector

Progress across sectors is uneven

(The CCC Progress report to parliament, 2018)

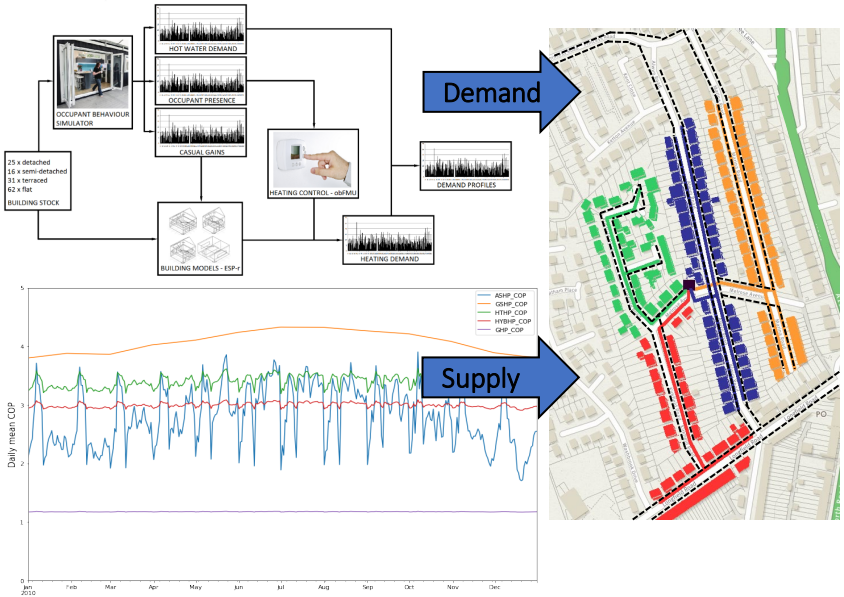
Figure 2. Emissions reductions have been focused in the power and waste sectors



Source: BEIS (2018) *2017 UK Greenhouse Gas Emissions, Provisional Figures*; BEIS (2018) *2016 UK Greenhouse Gas Emissions, Final Figures*.
Notes: The chart on the right-hand side shows changes in sectoral emissions between 2012 and 2017; buildings emissions in this chart are temperature-adjusted. 2017 emissions are provisional estimates and assume no change in non-CO_2 emissions from 2016.

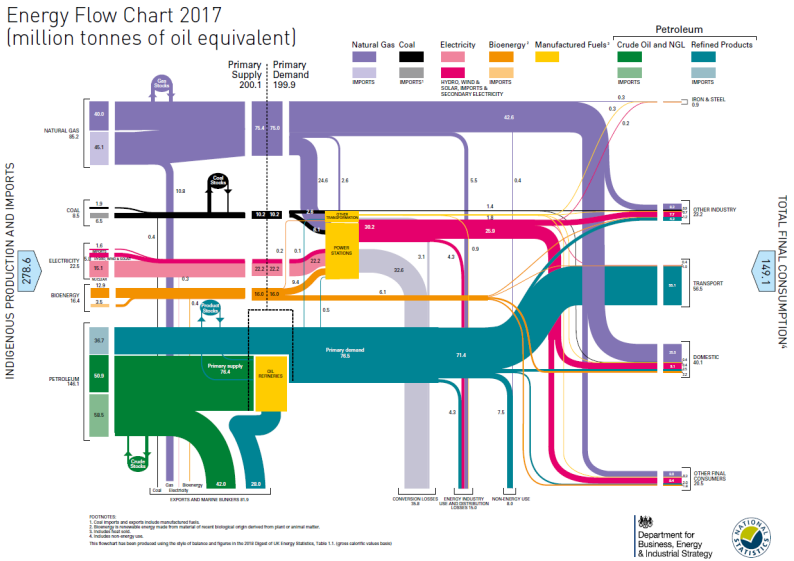
- Changes in emission levels between 2012-2017 range from -54% to +3%
- Low hanging fruit has been picked in the power sector
  - Carbon price floor
  - EU emissions regulations (EU ETS, EU IED)
  - Legislated coal phase out to 2025
- Industrial and waste sectors have progressed well but are now stagnating.
- Efficiency and retrofit measures in buildings have made small differences and struggle to make meaningful progress.
  - Boiler efficiency & design policies introduced condensing boilers in 2004.

METHODS. Exemplar energy models



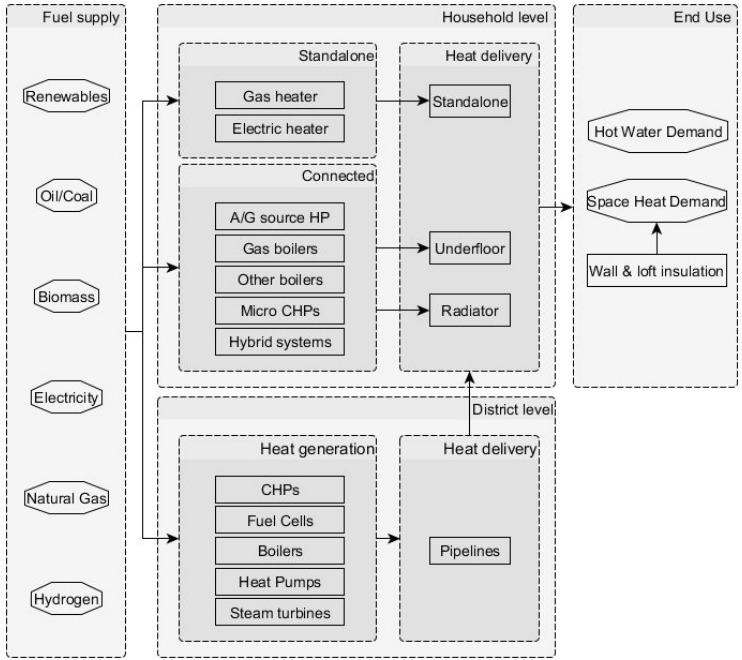
- Data references
  - Calibrated to 2010
  - Met. office T°C, BEIS technology data, Ofgem network costs
- Representative local network models
  - Urban, Suburban, Rural
- Heat demand simulation
  - Occupancy, casual gains, hot water, building fabric
  - Detailed household/node representation
- Heat supply option simulation
  - Technical capacity & cost
  - Additional network requirements
  - Detailed LV & transformer layout
  - Alternate technology package designs
  - Space heat & hot water

METHODS. The UK TIMES model



- Successor to UK MARKAL – strong policy background:
  - CCC 5th carbon budget 2015
  - Clean Growth Strategy 2017
- Single region, bottom-up, perfect foresight, dynamic, partial equilibrium, cost-optimization model
- Technology rich
- Modelling time:
  - 2010 base year, 5 year periods to 2050
  - 16 time-slices
- End-use sectors
  - Transport, Industry, Services, Agriculture and Residential.
  - Energy service demands
- Upstream processing and power
- GHG accounting across all sectors

METHODS. UKTM Residential Sector



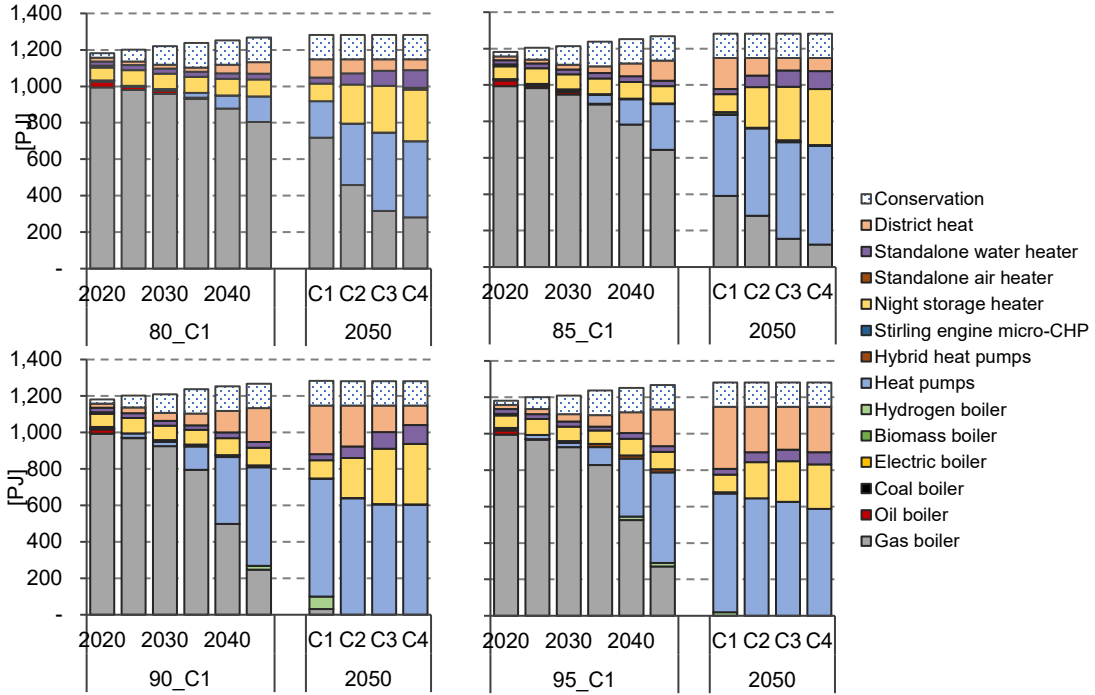
- Data references
  - Energy Consumption UK & DUKES (2010)
  - National Household Model (NHM)
- End use demand drivers
  - Growth in population & dwelling numbers
  - Heat (space, hot water) demand per dwelling
- Household structure
  - Existing: (Flat, House) X (Cavity, Solid walls)
  - Fixed demolition rate
  - New build
- Technology breakdown
  - Household & district level
  - Infrastructure & networks
  - Heat conservation: wall, floor, loft, insulation
  - Heat Production: ASHP, GSHP, Boilers, storage heaters, Micro CHP, local renewables
  - Heat delivery: under floor, radiator

METHODS. UKTM Scenario design

- What pathways can we use to decarbonize the residential sector? How do these shift under changing views of both targets and technology diversity?
- Dimension 1: Combined technology constraints affecting residential sector growth & structure
  - Absolute bounds on penetration (% of total energy supply)
  - Annual growth rate (%)
  - Absolute annual capacity addition (GW)
  - Levels halved from conservative starting point in four steps: C1, C2, C3, C4
- Dimension 2: System wide emissions constraint
  - Includes all sectors and covers CO_2, CH_4, N_2O and HFCs
  - Levels increased from 80 to 100% reduction by 2050 compared to 1990 levels in 5% steps.

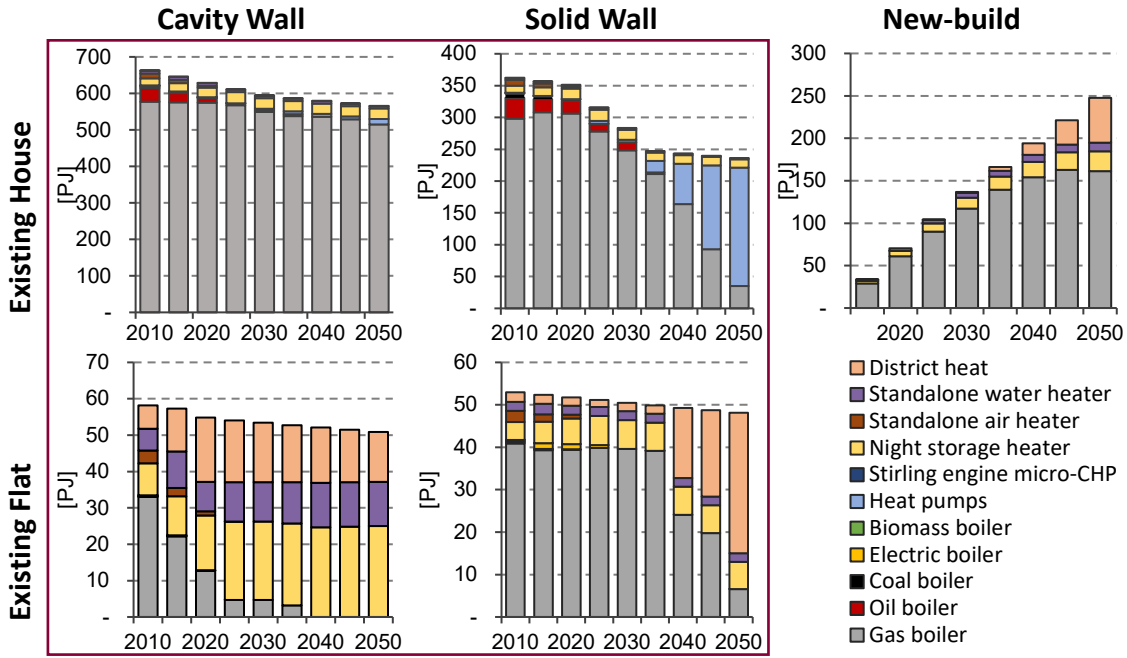
			GHG **emission reduction** (% of 1990)				
			80	85	90	95	*100* [a]
Combined **technology constraint level** (% of baseline case levels)	100 %	C1	80_C1	85_C1	90_C1	95_C1	*100_C1*
	83.3 %	C2	80_C2	85_C2	90_C2	95_C2	*100_C2*
	66.6 %	C3	80_C3	85_C3	90_C3	95_C3	*100_C3*
	50 %	C4	80_C4	85_C4	90_C4	95_C4	*100_C4*

RESULTS. UKTM. Technology shifts



- Energy conservation technologies are always cost effective.
- The role of gas in 2050 is dependent on levels of allowable technology diversity.
- The phase out of gas is inevitable under tight 2050 GHG targets.
- The 2050 technology portfolio is strongly dependent on assumptions around freedom of investment & allowable technology diversity
- These assumptions have strong implications for infrastructure requirements

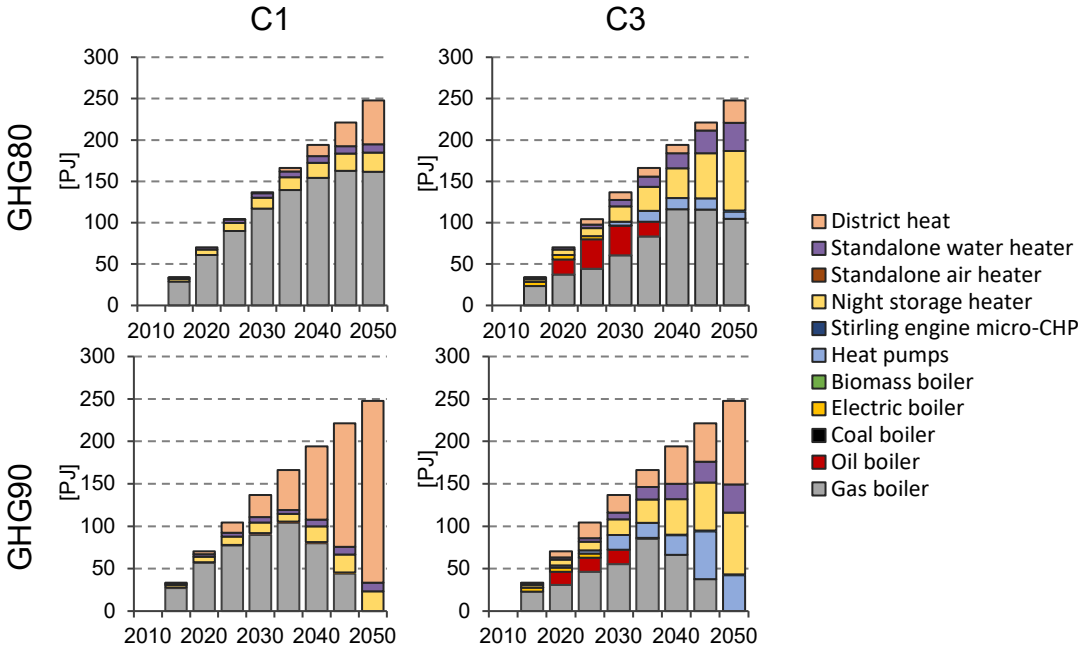
RESULTS. UKTM. House type detail



80_C1 baseline results

- The relative weight of different household types impacts overall results.
- Technology portfolios differ across the UK housing stock.
- New-build gas installations stall after 2040
- Flats and new build rely rather on district heating and storage heaters.
- Houses maintain high levels of gas and incursions of ASHP.

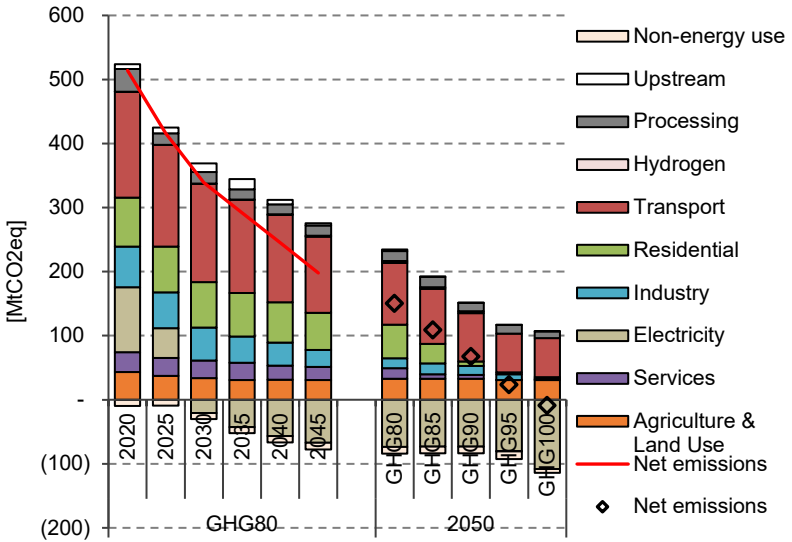
RESULTS. UKTM. New build



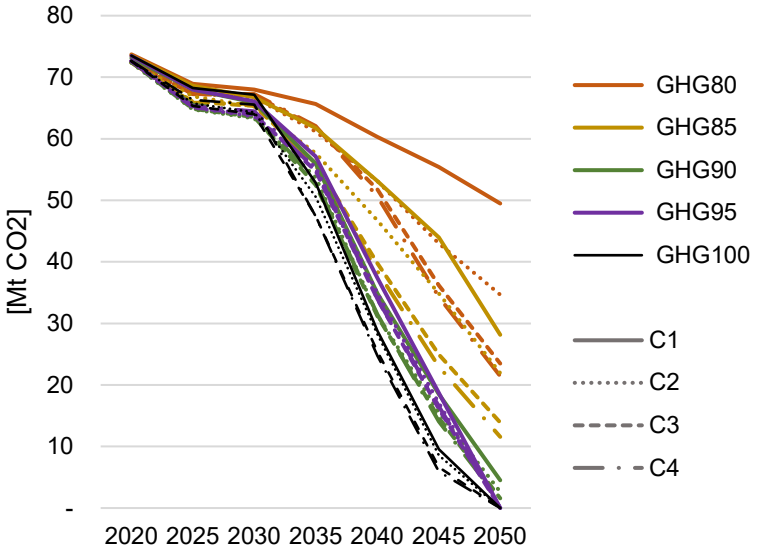
- New build houses clearly highlight the types of dynamics seen in other house types:
  - Changes in GHG target or portfolio freedom decreases penetration of natural gas.
  - New infrastructure investment (DH) is important, but can be cost effectively mitigated by modular electric
  - There is an important role to play for HP systems

RESULTS. UKTM. Emissions in context

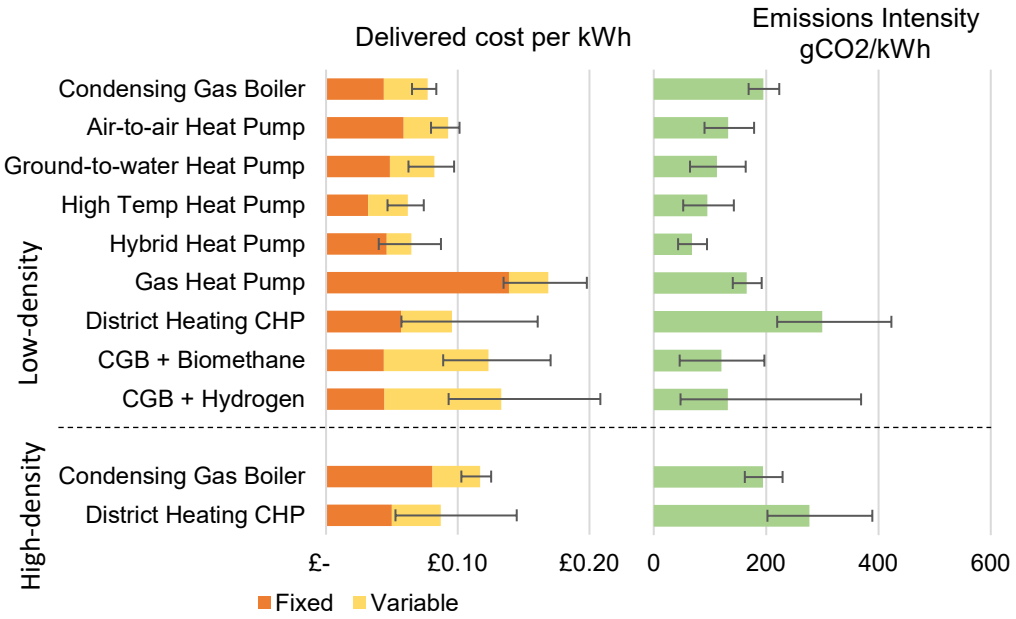
System Emissions pathways



Residential Emissions pathways



RESULTS. EXEMPLAR. Costs & Emissions



- Gas boilers
  - Well known technology
  - Medium to high costs & emissions
  - Clean gas solutions very uncertain
- Electric solutions
  - Potential for low emissions
  - Comparable cost range
  - Gas not an option
- DH options
  - Can be competitive
  - But cannot rely on gas CHP.

Conclusions

- A “fabric-first” approach to housing stock refurbishment is cost-effective and important in practice.
  - This has a significant impact on reinforcement requirements
- Electrical systems could provide high shares of future residential heat – both at household and district levels.
- Phasing natural gas out is inevitable
  - It could target easy to electrify areas first with hybrid systems supporting wider reinforcements.
  - It should not be installed in new homes past ~2035
  - Failing to do this could lead to overcapacity of both network and end-use
- We are an international outlier in relying on one carrier
  - Diverse portfolios of locally relevant technologies support fast residential heat decarbonisation and flexibility in hard-to-treat sectors.

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Contact Us

Thank you for your attention

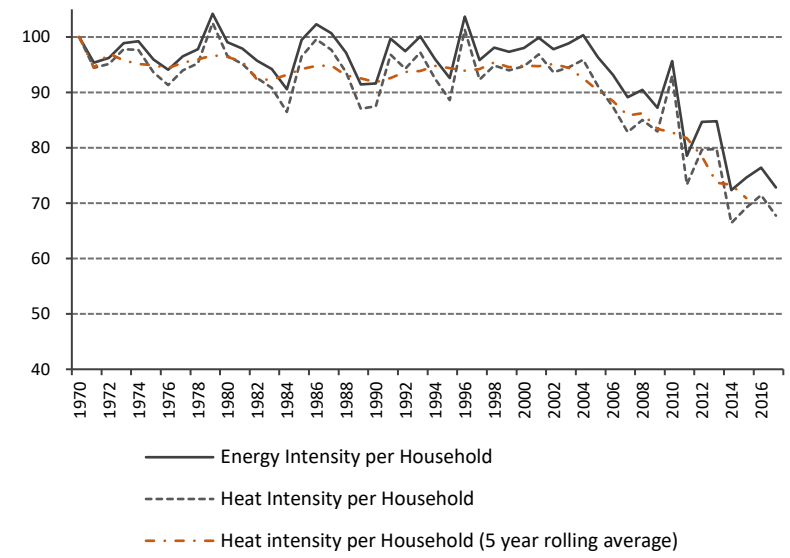
Oliver Broad
UCL Central House, 14 Upper Woburn Place, London WC1H 0NN
+44 (0) 2 031 089 846
o.broad@ucl.ac.uk

Graeme Hawker
University of Strathclyde, Faculty of Engineering, Royal College Building, 204 George St, Glasgow G1 1XW
+44 (0) 1 414 447 232
graeme.hawker@strath.ac.uk

BACKGROUND. UK Residential sector

UK Heat consumption per household

(1970=100)



Household energy intensities have dropped consistently since 2004:

- Related to boiler efficiency & design policies: introduction of condensing boilers.
- Very weather dependent (2010)
- Not accompanied by widespread refurbishments
- This has, in part, been compensated by increases in household numbers

Additional sensitivity scenarios

These are results prepared for the last UKERC meeting. Scenarios look at increasing the level of constraints on penetration levels of Heat Pumps and Natural Gas systems.

They are not representative of “real world” constraints – simply sensitivities

Technology type	House type	Upper bound
Heat pumps	House cavity wall	82%
	House solid wall	79%
	Flat cavity wall	13%
	Flat solid wall	10%
	New all	68%
Natural gas	House cavity wall	93%
	House solid wall	89%
	Flat cavity wall	63%
	Flat solid wall	83%
	New all	90%

X

Reduction
0%
10%
20%
30%
40%

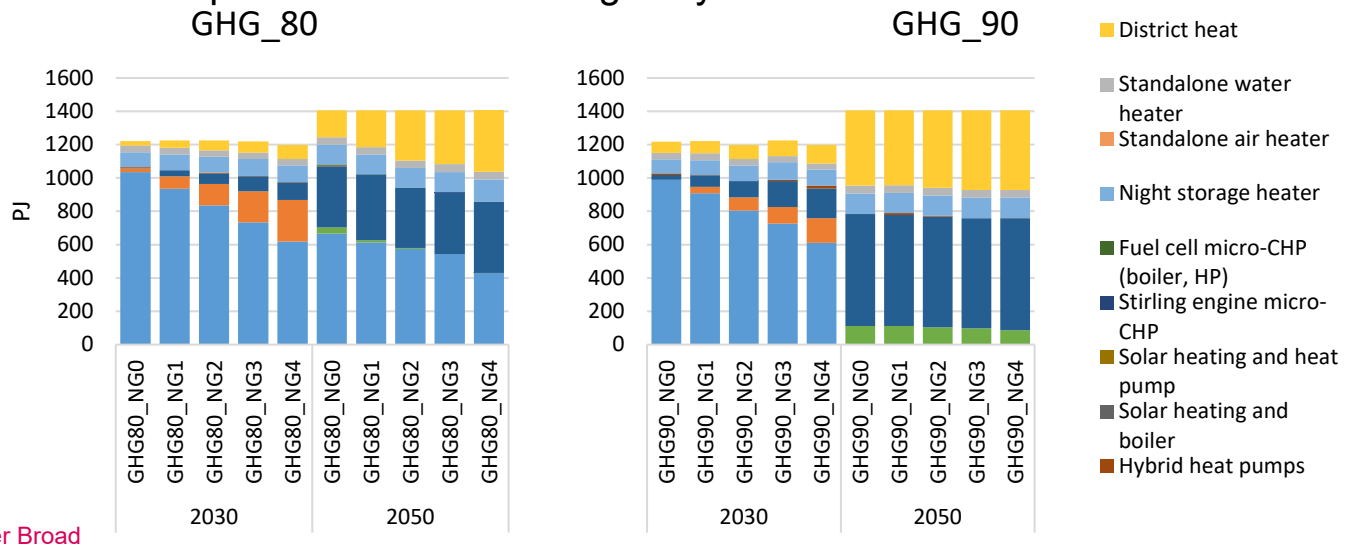
X

Emissions
80% drop
90% drop

Additional sensitivity scenarios

Natural Gas sensitivity

- All housing aggregated
- Drop in allowable penetration of natural gas systems



Additional sensitivity scenarios

Heat Pump sensitivity

- All housing aggregated
- Drop in allowable penetration of heat pumps