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Summary of some aspects of domestic heat decarbonisation options

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This is a summary of some aspects of dwellings, retrofit, heat supply, and implementation and financing for heat decarbonisation.

Net zero emission and primary energy

The assumed context is that that decarbonisation is mainly achieved with zero emission renewable (mostly wind and solar) and nuclear electricity. Fossil fuels, even with carbon capture, cause greenhouse gas emissions which would have to be balanced by absorption with commercially unproven or constrained processes.

Housing – form, ownership, heat load

Heat	**re**

About 37% of dwellings are privately rented or social housing and because these dwellings are smaller than average and a higher fraction are flats, they account for about 27% of the total domestic heat demand. Conversely, the 63% owner occupied dwellings are generally larger with more external envelope and higher heat loads. There are complex relationships between dwelling type and wealth. In general, larger dwellings are owned by wealthier people but there are issues; for example, many retired people on low fixed incomes live in and own large, erstwhile family houses with high capital value and large heat loads per capita. This has implications for who can afford decarbonisation technologies.

	Type	Owner	Private rent	Social	by type	Non-owner
all terrace	28%	58%	26%	16%	19%	8%
semi-detached	25%	75%	13%	12%	32%	8%
detached	17%	93%	6%	0%	29%	2%
bungalow	9%	71%	9%	20%	11%	3%
converted flat	4%	27%	58%	15%	2%	1%
purpose built flat, low rise	14%	27%	31%	42%	6%	4%
purpose built flat, high rise	2%	22%	42%	36%	1%	1%
Total	**100%**				**100%**	**27%**
Tenure		**63%**	**20%**	**17%**		

Source: English Housing Survey, author estimates

Concerning heating options:

- District heating can be applied to all houses with little impact.

- About 80% of houses have gardens and access to environmental heat (air, ground) for heat pumps. Without gardens, environmental heat can be obtained from wall or roof mounted external units, but visual obtrusion and noise can be problematic. Space for energy storage may be limited.
- Hydrogen heating can be deployed in most dwellings, but a percentage are not connected to gas mains. The Grenfell fire and the changed Building Regulations (Amendment) 2018 has made the use of gas heating in high rise buildings problematic. This may also impact on lower rise buildings.

Future heat and cool demand

Some factors will reduce heat demand: building efficiency and climate change could have substantial impacts. Some factors may increase demand such as population and household growth, and space and hot water demand service levels. On balance, total domestic annual heat load may fall by 20-30% by 2050; but peak demands may not fall so much. Although space heating is the largest fraction, water heating with power showers causes high peak demands which are difficult to meet with heat pumps. Climate change, with perhaps a temperature increase of 2-4 ^{o}C around 2060 and more extreme heat episodes, will increase cooling needs and maybe therefore drive an expansion of residential cooling Reversible heat pumps and district heating and cooling can heat and cool, unlike hydrogen boilers.

Building efficiency vs heat supply

The reduction of about 80% in renewable generation costs in the past 15 years, with more reduction projected, have reduced electric heating costs and therefore changed the economic balance between retrofit and heat and energy supply. Over the past half century, deep retrofit (beyond measures such as for loft, cavity, and window efficiency) programmes have generally failed for reasons including capital financing and impact (disruption, visual amenity). Consideration might be given to more cost-effective, partial insulation of the highest heat load areas of a dwelling, such as the living room. Building efficiency will impact on the sizing of heating systems, both heat sources and emitters, this is especially important for heat pump maximum load, and the annual consumption of hydrogen.

Heat supply options

Heat supply options frequently proposed are forms of consumer central heating of some sort, but it is to be noted that lower energy, focused heating (and cooling) can be provided with more directed personal systems including heated/cooled panels and furniture.

- **HP: Air or ground source consumer heat pumps.** Reversible electric heat pumps can provide heating and cooling with an overall efficiency of about 250-300%. HPs can replace gas boilers when they die. Possibly later replace HPs with DH if it reaches the house. Network reinforcement will be required. Currently, millions of HPs are installed in Europe and globally.
- **DH: District heating/cooling**. Air/ground/water electric heat pumps (efficiency about 350%) may be the main heat sources but other sources are possible including hydrogen, bioenergy, geothermal, solar etc. DH can be scaled from

communal/block to city scales and can play a major role in balancing the electricity system with its storage and multiple heat sources. New heat networks will be required. Currently, millions of consumers are currently connected to DH in Europe and globally.

- **H2: Hydrogen.** [H2 can be made from natural gas but it will have relatively high GHG (CO_2, methane) emissions in and outside the UK which will have to be balanced by environmental carbon capture processes which are largely unproven or constrained. Gas imports degrade energy security.] Hydrogen with electrolysis (efficiency about 80%) using renewable electricity is zero emission. A hydrogen boiler (efficiency about 90%) would be similar to gas and does not provide cooling. Overall efficiency of electricity to heat about 75% so H2 uses four times more electricity per unit of heat than HP or DH and this increases costs and means zero emission generation capacity for heat has to be built at four times the rate. It is generally assumed that much of the existing gas distribution and consumer network can be used without substantial and costly modification: however, there are no extant H2 distribution and heating systems at scale, so technicalities and costs are uncertain.

Implementation

Experience with millions of consumers using HPs or DH in Europe and globally could provide useful guides to policies for these heat options. For example, in Scandinavia consumers can be offered choices of HPs or DH, with multiple tariff structures having different fractions of capital, and fixed and variable annual costs. Consumer heat pumps could replace gas boilers as they die, possibly as mandated, so the process does not have to be coordinated. HPs could possibly be replaced with connection to DHC.

DH and H2 have to be implemented on an area by area basis. The economics of these will depend on the percentage uptake of consumers in the area, which might have to be incentivised or possibly mandated.

Financing

Zero emission systems are capital intensive as zero emission fuels like biomass are constrained, and dynamic competition, such as between gas supplies, will be more limited. Capital costs are differently distributed across the system depending on heating vector, but in all cases the bulk - more than 80% - of costs are upstream of the consumer in the system – for primary production, intermediate conversion, storage and transmission and distribution.

The capital costs incurred at the consumers' premises will be paid by private or social landlords in 37% of dwellings, a proportion of which will be recouped through rent. Heat pumps have a higher capital cost of about 5 k£ at the consumer end than DH connection or an H2 boiler. One possibility is to provide a capital grant such as for EVs to cover some of this incremental cost for private owner occupiers, but like many such schemes, this may result in a cross-subsidy to wealthier people. A scheme such as the RHI is another example of reducing costs to the consumer.

The investment time horizon for most system components is long. Return on investment in upstream parts of the system may need securing in some way, such as through capacity or contract for difference payments, as currently occurs for electricity supply components such as renewable generators. It is perhaps possible to apply such mechanisms to the system components of heat supply.

Future electricity supply will become increasing capital intensive. The marginal cost of supply will become more volatile, ranging from near zero when there is renewable or nuclear surplus to very high when rarely used capacity (e.g. of heat storage) is required. A question is the degree to which consumers (individual consumers, DH operators, hydrogen electrolysers, etc.) will be exposed to this volatility through electricity prices (as opposed to costs). Marginal DH and H2 costs will likely show lower volatility because of their storage or heat supply flexibility (DH). These upstream costs will ultimately be paid by consumers via tariffs for fixed and variable charges for the public supply of electricity, heat or hydrogen. These may be adjusted by public policy and regulation, such as to protect low income consumers. DH and H2 networks would not be national scale unlike electricity and gas supply and so some regulation would have to be devised or extended for these to account for less competition or variations in local systems.

Using current energy prices (future gas and electricity costs are not considered) and assuming capital costs for gas heating of 5 k£ and heat pump 10 k£, we may estimate illustrative costs to the consumer of heating options, and the percentage of average annual household expenditure these represent. We see that heat pump heating might increase consumer expenditure by 1-2% as compared to gas heating. It is to be noted that gas heating is susceptible to insecurity as imports increase, and gas price shocks such as occurred following the Fukishima disaster, and this caused problems for those on low fixed incomes, especially old people. Hydrogen made from natural gas would be more sensitive to gas price due to the inefficiency of conversion.

			Public supply				
	% household expenditure annual	**Total** £/a	£/a Fixed	**Variable** p/kWh	kWh Gas	kWh heat	£/a
Gas boiler: Eff 85%							
Gas	1.7%	510	95	3.4	12208	10377	415
Electricity	2.0%	593	82	17.4	2943		511
	3.7%	**1102**	177				926
Boiler capital	0.8%	250					
Total	**4.5%**	**1352**					
Heat pump COP 2.5	**0.0%**				kWh		
	0.0%				Ele		
Elec non heat	2.0%	593	82	17.4	2943		511
Heat pump ele	2.4%	720		17.4	4151	10377	720
	4.4%	**1313**					
Heat pump capital	1.7%	500					
Total	**6.1%**	**1813**					
Heat pump extra cost	**1.5%**	**461**					

Decarbonisation is likely to increase costs in the short term, and government policy will partially determine the exposure of different consumers to these capital and supply costs. Of course, short term energy system investments will mitigate climate change and its severe health, social, environmental and economic impacts which will have much greater costs. Unlike Covid, there is no vaccine that will stop climate change once it occurs so current investment is needed to obviate future costs.

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