Supporting material 1: comparison of different types of low carbon heating from a householder perspective

The tables below illustrate the many differences between the various heating technologies, many of which are at different stages of commercialisation. They are not intended to facilitate comparison between the technologies; different systems will be needed across the UK.

Assumptions:

- The data presented in the tables below is predicated on the household already operating a pre-existing natural gas-fired central heating and hot water system.
- Options for those properties not currently on the gas-grid are discussed elsewhere.
- Not all properties on the gas grid will use solely natural gas for all their heating, hot water and cooking requirements. For example, some may have a gas boiler for heating and some hot water, and use a gas hob for cooking, but may also use electric showers and have an electric oven
- The costs set out above do not include system costs (e.g. costs to the DNO). Such costs are likely to vary significantly by region and will need to be socialised appropriately

Low carbon gas based technologies

Table 1 – Examples of low carbon gas-based domestic heating technologies

	Condensing boiler (natural gas)	Blending biogas e.g. biomethane or bioSNG	20% hydrogen blending	100% hydrogen appliances	H_2 or natural gas fuel cell systems (heat & electricity)
Image NB. *Images are purely representative of technologies where available. They do not represent any endorsement of the products shown.*			 [1]	 [2]	 [3]
How it works	Boiler burns natural gas (mostly methane) to generate hot water piped to radiators (and possibly also a hot water tank depending on boiler type)	Boiler works in exactly the same way as a conventional natural gas boiler, but instead burns natural gas blended with biomethane or bioSNG	Boiler burns natural gas blended with 20% hydrogen in exactly the same way as a conventional boiler	Boiler burns 100% hydrogen in the same way as a conventional natural gas boiler to generate heat and hot water	Fuel cells react methane or hydrogen (from the grid) with oxygen (from the air) to produce both heat and electricity
Technological readiness	Readily available now; millions already in domestic use across GB	Technology readily available now; limited only by biogas availability and	Technology readily available now; demonstrations underway to assess viability of 20%	BEIS Hy4Heat programme is examining the potential for hydrogen-only appliances, with demonstration trials of domestic	Not commercially available yet. H_2 models are still at demonstration level;

[1] Image from https://www.boilerguide.co.uk/manufacturers/baxi (accessed May 2019)
[2] Image from https://hydeploy.co.uk/about/technology/ (accessed June 2019)
[3] Image from https://news.panasonic.com/global/stories/2017/45928.html (accessed May 2019)

	Condensing boiler (natural gas)	Blending biogas e.g. biomethane or bioSNG	20% hydrogen blending	100% hydrogen appliances	H_2 or natural gas fuel cell systems (heat & electricity)
		relevant incentives to use biogas for blending	H_2 blending through HyDeploy programme[4]	appliances planned for 2020 onwards[5]	natural gas versions are undergoing field-tests.[6]
Installation time	Assumption that a natural gas boiler heating system is already installed in the home	No changes required if a natural gas boiler heating system is already installed	No changes required if a natural gas boiler heating system is already installed	<1 day in the home to replace or convert boiler plus other gas appliances; a longer period off-gas while the local area is switched	Unknown
Possible disruption to household during installation	Assume already installed	Assume already installed	Assume already installed	All gas appliances will need replacement or conversion, plus possible additional disruption from pipework outside the home	Unknown
Appliance cost (CAPEX/unit)	£500-2500 (depending on boiler type and size) A report for BEIS assumed an average cost of £850 per boiler[7]	£500-2000 (depending on boiler type and size)	£500-2000 (depending on boiler type and size)	H21 reports assume a cost of £500 per boiler or appliance.[8] Other reports suggest £2500-1000 cost per hydrogen boiler, depending on the numbers deployed[9]	Anticipated as 4x that of a conventional natural gas boiler[10] Assumed cost of £2500/kW[11]

[4] HyDeploy; see https://hydeploy.co.uk/
[5] BEIS Hy4Heat (2019) https://www.hy4heat.info/2019
[6] Vaillant (2018) Fuel cell – the next step in heating technology
[7] Element Energy for BEIS (2018) Hydrogen Supply Chain Evidence Base
[8] Northern Gas Networks (2018) North of England Report
[9] Element Energy for BEIS (2018) Hydrogen Supply Chain Evidence Base
[10] Kiwa (2016) Report for: DECC Desk study on the development of a hydrogen-fired appliance supply chain
[11] Committee on Climate Change (2018) Hydrogen in a low carbon economy

	Condensing boiler (natural gas)	Blending biogas e.g. biomethane or bioSNG	20% hydrogen blending	100% hydrogen appliances	H_2 or natural gas fuel cell systems (heat & electricity)
Installation cost	£640-1440 depending on boiler type and location in home[12]	£640-1440 depending on boiler type and location in home	£640-1440 depending on boiler type and location[13]	£425-625[14] for hydrogen-ready boiler conversions Although if extra internal gas pipework is required, it will cost £500 extra (work still on-going on assessing how many properties will require internal pipe replacement)	Unknown
Conversion cost (e.g. decommissioning of old appliances, including boilers, hobs, ovens, fires etc)	N/A	None; current gas appliances will continue to work	In theory none; current gas appliances should continue to work, although this is being tested in HyDeploy's live trails at University of Keele's campus[15]	Combined cost of converting existing gas appliances estimated at ~£3000[16]	Unknown. If methane-fired, current gas appliances will continue to work; if H_2-fired all gas-fired appliances will need replacing or converting.
Lifetime cost (including cost of appliance and installation; and on-going fuel costs and operating costs)	Currently between £10,000[17] and £12,000[18] By 2030 projected cost is over £10,000, due to	Appliance and installation costs will be the same as for conventional natural gas boilers. Fuel costs will slightly higher as the costs	Appliance and installation costs will be the same as for conventional natural gas boilers. Fuel costs will be slightly higher as	Appliance and installation costs are forecast to be similar or slightly higher than for conventional natural gas boilers, especially once mass deployment has been	Unknown

[12] Which? https://www.which.co.uk/reviews/boilers/article/buying-a-new-boiler/boiler-prices-how-much-does-a-new-boiler-cost (accessed May 2019)
[13] Which? https://www.which.co.uk/reviews/boilers/article/buying-a-new-boiler/boiler-prices-how-much-does-a-new-boiler-cost (accessed May 2019)
[14] Element Energy for BEIS (2018) Hydrogen Supply Chain Evidence Base
[15] https://hydeploy.co.uk/ (Accessed July 2019)
[16] Policy Exchange (2018) Fuelling the Future
[17] Element Energy for BEIS (2017) Hybrid Heat Pumps Final Report
[18] Data given to this inquiry

	Condensing boiler (natural gas)	Blending biogas e.g. biomethane or bioSNG	20% hydrogen blending	100% hydrogen appliances	H_2 or natural gas fuel cell systems (heat & electricity)
	slighter higher projected gas costs[19] Current operating costs are around £520 a year for an average household (12MWh gas demand)[20], which will rise to about £586 by 2030[21]	of producing biogases are 2-3 times[22] more expensive than producing natural gas, but it is unlikely to be blended above 20% due to availability of feed stocks[23] so it impact on prices will be limited	hydrogen costs between 2-4 times[24] more than producing natural gas and it will be blended to 20% so it will have a limited impact on prices. Current trails of hydrogen blending ensures participants won't pay more for their heat, though	reached (see above). Fuel costs will be higher as hydrogen costs between 2-4 times more than producing natural gas (depending on how the hydrogen is produced[25]), and more needs to be burnt to provide the same amount of heat[26]. H21 suggests an average domestic gas bill would be £837 per year in 2050 for converting most of the North of England to hydrogen, if costs are spread over all UK gas consumers. This compares to a projected average domestic gas bill for 2050 of £780[27] in the absence of hydrogen.	

[19] Element Energy for BEIS (2017) Hybrid Heat Pumps Final Report
[20] Evidence given to this inquiry
[21] Element Energy for BEIS (2017) Hybrid Heat Pumps Final Report
[22] Carbon Connect (2018) Producing Low Carbon Gas
[23] National Grid (2016) The Future of Gas: Supply of Renewable Gas
[24] Carbon Connect (2018) Producing Low Carbon Gas
[25] Carbon Connect (2018) Producing Low Carbon Gas
[26] Committee on Climate Change (2018) Hydrogen in a low carbon economy
[27] Northern Gas Networks (2018) H21 North of England

2. Electricity based technologies

Table 2 – Examples of electrical domestic heating technologies

	Air source heat pumps (ASHP)	Ground source heat pumps (GSHP)	Electric heating (direct and storage)
(image) NB. *Images are purely representative of technologies where available. They do not in any way represent any endorsement of the products shown.*	[28]	[29]	[30]
How it works	Heat is extracted from the outside air and absorbed into a fluid. The temperature of the fluid is increased using a compressor (powered by electricity) and used to heat radiators, underfloor heating and hot water tanks.	Pipes buried in the ground (usually the garden) extract residual heat into a fluid which is passed into a heat exchanger. From this it can provide heat to radiators, underfloor heating and hot water tanks.	Use electricity to directly heat the home, either as radiant heat or to heat hot water. Storage heaters use off-peak electricity to heat up during the night and release the heat as needed during the day. Infrared panels use electricity to produce radiant heat which heats objects directly rather than the air.
Technological readiness	Commercially available now	Commercially available now	Commercially available now
Installation time	~2 days for installation of the ASHP itself; supporting infrastructure (e.g. insulation, underfloor heating, larger radiators) will require additional time.	Very dependent on the pipework; this can be vertical or horizontal and will require significant groundwork and associated time.	Usually in off-grid homes so will be replacing a similar heating system; <1 day depending on the system.

[28] Centre for Sustainable Energy; https://www.cse.org.uk/advice/renewable-energy/air-source-heat-pumps (accessed May 2019)
[29] Image from: https://www.homebuilding.co.uk/ground-source-heat-pumps-need-know/ (accessed May 2019)
[30] Image from https://www.bestelectricradiators.co.uk/electric-central-heating/ (accessed May 2019)

	Air source heat pumps (ASHP)	Ground source heat pumps (GSHP)	Electric heating (direct and storage)
		Installation of the pump itself ~2 days. Supporting infrastructure (e.g. insulation, underfloor heating etc.) will require further additional time.	
Possible disruption to household during installation	ASHPs produce lower-grade heat so need a well-insulated property and possibly the installation of larger radiators or underfloor heating to work optimally. A tank is needed for hot water storage. The unit itself is attached to the outside of the building as is a similar size to a domestic washing machine.	As with ASHPs, GSHPs also need a well-insulated property and the installation of either larger radiators or underfloor heating to work optimally. A tank is needed for hot water storage. Significant groundworks are required to lay the pipes. Some heat pump units may need a dedicated plant room.	Very little depending on the system being replaced.
Cost (CAPEX plus installation)	£6500 (in 2025)[31] ASHP only (see conversion cost, below)	£10,000-18,000 installed[32] GSHP only (see conversion cost, below)	Varies; electric radiators and infrared heating panels range from £200-£500 each[33] plus installation.
Conversion cost (e.g. decommissioning of old appliances)	The above cost is for purchase and installation of the ASHP itself; additional costs will likely be incurred for insulating the property to the necessary standard and installing either underfloor heating or larger radiators. A hot water tank will also be needed. Cooking appliances will need replacing with electric equivalents.	As with the ASHP, additional costs for insulation and either underfloor heating or larger radiators will likely be incurred. Similarly a hot water tank will be needed. Cooking appliances will need replacing with electric equivalents.	Usually installed in off-gas-grid properties; electric cooking appliances will be required.

[31] Committee on Climate Change (2019) Net Zero: The UK's contribution to stopping global warming
[32] Energy Saving Trust https://www.energysavingtrust.org.uk/renewable-energy/heat/ground-source-heat-pumps (accessed May 2019)
[33] Electric Radiators Direct https://www.electricradiatorsdirect.co.uk/electric-radiators-all-you-need-to-know (accessed May 2019)

	Air source heat pumps (ASHP)	Ground source heat pumps (GSHP)	Electric heating (direct and storage)
Lifetime costs (including cost of appliance and installation; and on-going fuel costs and operating costs)	Overall, one study estimates a central lifetime costs of an air source heat pump at around £17,000 over a 15 year lifetime for a typical semi-detached house. This is made up of capital costs (covered above) and operating costs which for an average householder (with a current 12MWh gas demand) would be £680 a year (not including RHI).[34] Other sources put this at £620 per year for a typical semi-detached house, rising to £681 by 2030[35].	Capital costs for a GSHP are between £10,000-£18,000 (covered above) and operating costs for an average householder (with a current 12MWh gas demand) would be £680 a year (not including RHI).[36]	Little available data

[34] Evidence given to this inquiry
[35] Element Energy for BEIS (2017) Hybrid Heat Pumps Final Report
[36] Evidence given to this inquiry

3. Hybrid technologies that use both electricity and gas-based fuels

Table 3 –Hybrid and low-carbon solid fuel heating

	Hybrid heat-pump system	Biomass heating
(image) NB. *Images are purely representative of technologies where available. They do not in any way represent any endorsement of the products shown.*	 [37]	 [38]
How it works	These work in the same way as air- or ground- source heat pumps, but also have a conventional gas boiler (potentially natural gas, biogas and/or hydrogen) to produce additional heat when needed.	Biomass boilers burn logs, wood chips, pellets or other solid biomass to generate heat for radiators, underfloor heating and hot water.
Technological readiness	Commercially available now.	Commercially available now.
Installation time	Retrofitted around the existing boiler.	2+ weeks[39]
Possible disruption to household during installation	Installation of a reasonably large external unit in addition to the existing boiler	A larger area is required to store solid fuel (e.g. wood pellets); best suited to off-grid homes

[37] Heat Pump Scotland; https://www.heatpumpsscotland.com/products/hybrid-heat-pumps/ (accessed May 2019)
[38] Image from https://www.greenmatch.co.uk/boilers/wood-pellet-boilers/domestic-wood-pellet-boilers (accessed May 2019)
[39] http://www.superhomes.org.uk/resources/biomass-boiler-costs/ (accessed May 2019)

Cost (CAPEX plus installation)	£7300 (with hydrogen; 2025) or £7500 (with biofuels; 2025)[40]	£8000-£15,000[41]
Conversion cost (e.g. decommissioning of old appliances)	None; existing gas appliances can still be used (some appliance conversion costs will apply for the 100% hydrogen model)	Little available data; likely to be installed in off-gas grid properties so other appliances are already likely to be electric.
Lifetime costs (including cost of appliance and installation; and on-going fuel costs and operating costs)	One report estimates a central lifetime cost for a hybrid heat pump in a typical semi-detached house by 2030 as around £13,000[42]. Current costs are estimates to be between £19,000 without the RHI[43]. This is made up of capital costs (covered above) and operating costs, which are put at around £480 per year for an average semi-detached house, rising to £537 by 2030.[44]	The lifetime cost will be higher than for natural gas, mainly due to the relatively high capital cost of the heating asset. The operating cost is dependent on fuel prices- biomass systems are typically cheaper than for electricity or LPG systems but more expensive than gas[45].

[40] Committee on Climate Change (2019) Net Zero: The UK's contribution to stopping global warming
[41] Energy Saving Trust (2019) https://www.energysavingtrust.org.uk/renewable-energy/heat/biomass (accessed May 2019)
[42] Element Energy for BEIS (2017) Hybrid Heat Pumps Final Report
[43] Evidence to this inquiry
[44] Element Energy for BEIS (2017) Hybrid Heat Pumps Final Report
[45] Energy Saving Trust (2019) https://www.energysavingtrust.org.uk/renewable-energy/heat/biomass (accessed May 2019)