Value of Home-Scale Heating and Heat Stores

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motivations

- huge CO2 & energy use in existing homes, needs to be zero carbon
- retro fit home efficiency looks difficult
- DHN: for low heat density areas high costs, plus development complexity
- what's the best zero carbon home heating systems? how to measure?

methods

heating system:

- stakeholders
- requirements & weightings (AHP)
- concepts generation (FMA)
- concepts rankings (Pugh)
- rankings sensitivity

outcomes

- are there robust top concepts?
- what factors influence top concepts?
- what value does storage have?

future work

top heating system concepts:

- drill down into storage subsystems
- identify impacts of storage parameters on heating system ranking

Stakeholder overview

stakeholder	roles and viewpoints
government	responsibility for policy, subsidies, planning, CO_2e targets.
home occupiers (including future occupiers)	use, and usually pay running costs for, space heating and DHW; thermal comfort and convenience; safety; aesthetics.
home owners (including landlords, bank, and future owners)	pay for heating technology capex, and it affects house value.
insurance companies	heating technology potentially changes risks to houses.
heating system trade (including manufacturers, installers and maintainers of system)	for hardware and training, would like: • large market so development effort is worthwhile • reliable market to reduce development risk • low technical risks • time to prepare • simple, reliable and safe to install.
energy utilities (including electric & gas network operators and power generators)	heating technology is likely to change fuel/energy supply type, amount and time of day, financial and technical impacts.
neighbours	potential NIMBYs; concerned about noise, visual impact, local emissions

Stakeholder requirements

	requirements	stakeholder interest					
1	*low carbon*	climate targets					
2	*large technical potential*	good ROI (public sector)	availability of maintenance engineers; home value	good ROI and training (private sector)			
3	*commercial by 2027*	climate targets, optimise deployment					
4	*low cost*	limit subsidy costs	fuel bills	heating system capex, install and maintenance	extra network & power generation costs		
5	*safe*	over-arching role	personal H&S*	home value*	changing risk*	installers*	personal H&S, home*
6	*easy to install and maintain*	hassle					
7	*low use of valuable space*	lack of space	home value				
8	*quiet*	enjoyment of home and garden	home value	enjoyment of home and garden			
9	*thermal comfort in rooms & DHW when needed*	comfort	home value				
10	*easy to control/understand*	ease	home value				
11	*looks good*	in-home & outside	home value	outside			

*these interests are subsequently allocated to government, see text

stakeholder group legend (colour coded)

government	home occupiers	home owners	insurance companies	heating system trade	energy utilities	neighbours

Requirements metrics

	requirements	success metrics range			
1	*low carbon*	% of base year carbon emissions:	20	0	
2	*large technical potential*	proportion of existing semi- and detached homes:	0.1	0.5	
3	*commercialised by 2027*	TRL <7	3 increments above TRL 9 for an established commercial product with 0.5m units installed & 15 years market experience		
4	*low cost*	current costs x3	current costs x1		
5	*safe*	any incident/effect c.f. existing gas boiler safety, per home:			
		x 10	same		
		(legionnaire's risk eliminated by design in all meta-solutions, not scored)			
6	*easy to install and maintain*	plan and install:	4 months	1 month	
		vacant:	6 weeks	none	
		maintain:	4 hr bi-annual service; MTBF 2 yr	2 hr annual service; MTBF 8 yr	
7	*low use of valuable space*	inside	$1.5m^3$	distributed internally/under counter, fridge-size i.e. $0.25m^3$/in old airing cupboard	
		outside	$5m^3$	$1m^3$	
		underground	$15m^3$	$3m^3$	
8	*quiet*	not allow any of the activities listed	neighbours and home occupiers allowed undisturbed sleep, TV watching, talking (all with windows open in summer), enjoyment of garden		
9	*thermal comfort in rooms & DHW when needed*	SH response time to desired temperature:	>=1 hr	<=20 mins	
		DHW response time: basins & showers:	>=2 mins	instant	
		DHW response time: bath:	>=10 mins	<=5 mins	
		legend:	complete failure	complete success	

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Weightings for requirements: Analytical Hierarchy Results

requirements	weight	rank
safe	15%	1
low carbon	14%	2
low cost	11%	3
quiet	11%	3
warm rooms & DHW when needed	11%	3
large technical potential	10%	6
commercialised by 2026	10%	6
low use of valuable space	10%	6
easy to install & maintain	9%	9

Subsystem candidates (Function Means Analysis)

function									
	supply (all) energy	sun	wind (1)	ambient air	stale air (2)	LC electricity	biogas via gas network (3)	biogas deliveries (4)	
		hydrogen via gas network (5)	hydrogen deliveries (6)	off-site wood (7)	heat from waste DHW (8)	ground heat vertical boreholes	ground heat horizontal loops/ slinkies		
	convert energy (space heat/ DHW)	ST panels	PV panels	PV-T panels	MVHR (2)	on-site small wind turbine (1)	instant home electric heater	wood boiler (7)	
		CHP (Stirling, GT IC, fuel cell) (3,4,5,6,7)	electric-driven ASHP	electric-driven GSHP	heat-driven ASHP (3,4,5,6,7)	heat-driven GSHP (3,4,5,6,7)			
	store energy	STES	daily TES (heat i/p)	daily TES (elec i/p)	daily electrical store	fuel storage (4,6,7)			
	distribute heat/ energy	existing pipe-work	air ducting, inter-room ducts	existing cabling					
	heat rooms	existing radiators	low temperature radiators	underfloor heating (piped)	air vents	instant room electric heating	room (daily) TES (elec i/p)	ceiling panels (11)	infra-red panels (12)
	supply DHW	DHW tank with electric immersion heater	electric DHW at POU						
	remove waste products	solids manual removal (7)	solids mechanism removal (7)	pipe for liquid to drain	exhaust ducting / chimney (2,3,4,5,6,7)				

legend:

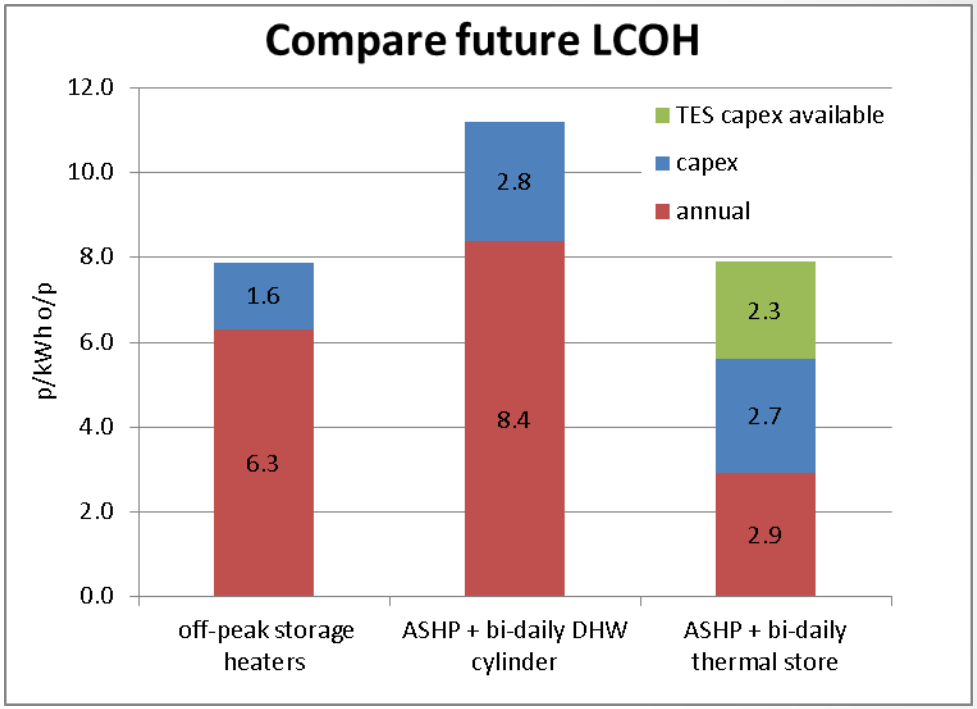
- **rejected** below acceptance range in one or more requirements.
- **redundant** due to associated rejected subsystems
- **available** for concept systems

Some sample comparisons

Selected inputs

22.5	future peak electricity cost, p/kWh
6.0	future off peak, night and mid afternoon, p/kWh
3.5	social discount rate, %
1571	yearly DHW demand, with savings, kWh
8571	yearly SH demand, semi, kWh
111	price/storage heater incl VAT, GBP
2.5	COP SH
1.25	COP DHW
1000	price/ASHP incl VAT, based on gas boiler, GBP
120	radiator cost scaled for deltaT=20 deg C

£3300 available for
35kWh TES



On-going work

- finishing ‘Requirements-driven Targeting of Retrofit Home Heating Subsystem Options to Meet the UK 2050 Carbon Target’ paper
- learning curves
- systems comparison paper, nominals, hybrids
- systems comparison paper, sensitivities