Cadent
Your Gas Network

Retaining optionality in the decarbonisation of UK homes

April 2025

Content

Foreword

Home heating currently accounts for 12% of the UK’s Greenhouse Gas emissions and is often perceived as one of the most challenging parts of the economy to decarbonise. Cadent is committed to supporting a just transition to Net Zero, ensuring all domestic heat consumers have access to low-carbon heating options for their homes.

With the Department of Energy Security and Net Zero due to consult on the role of hydrogen for home heating in 2025, it is timely to provide additional economic analysis to support the decision-making process.

Whilst we agree that for many homes, electrification is the most economical solution for achieving decarbonised heating, it is not a one-size fits all solution. Low-carbon solutions are needed for all types of homes, and those that are hard or expensive to electrify also require a cost-effective and reliable solution.

We believe the chosen home energy transition pathways should consider both the whole-systems and direct costs to consumers of policy decisions, as well as providing choice to consumers.

The whole system includes all the costs that a home could incur as part of the transition including the production of energy, the delivery of the energy to the home, the management and provision of resilience and changes needed within the home.

We have carried out an analysis of hard-to-electrify homes in the UK, demonstrating that hydrogen can play a role in decarbonising domestic heat economically and practically. Our analysis for specific housing archetypes shows hydrogen to be a cost-effective and practical solution for a balanced energy system where both hydrogen and electrification play a role. On this basis hydrogen just be retained as a low carbon heating option.

Dr Tony Ballance

Chief Strategy & Regulation Officer

1 Executive Summary

This report demonstrates that it would be premature for policymakers to rule out hydrogen as an option for decarbonising hard-to-electrify homes

1

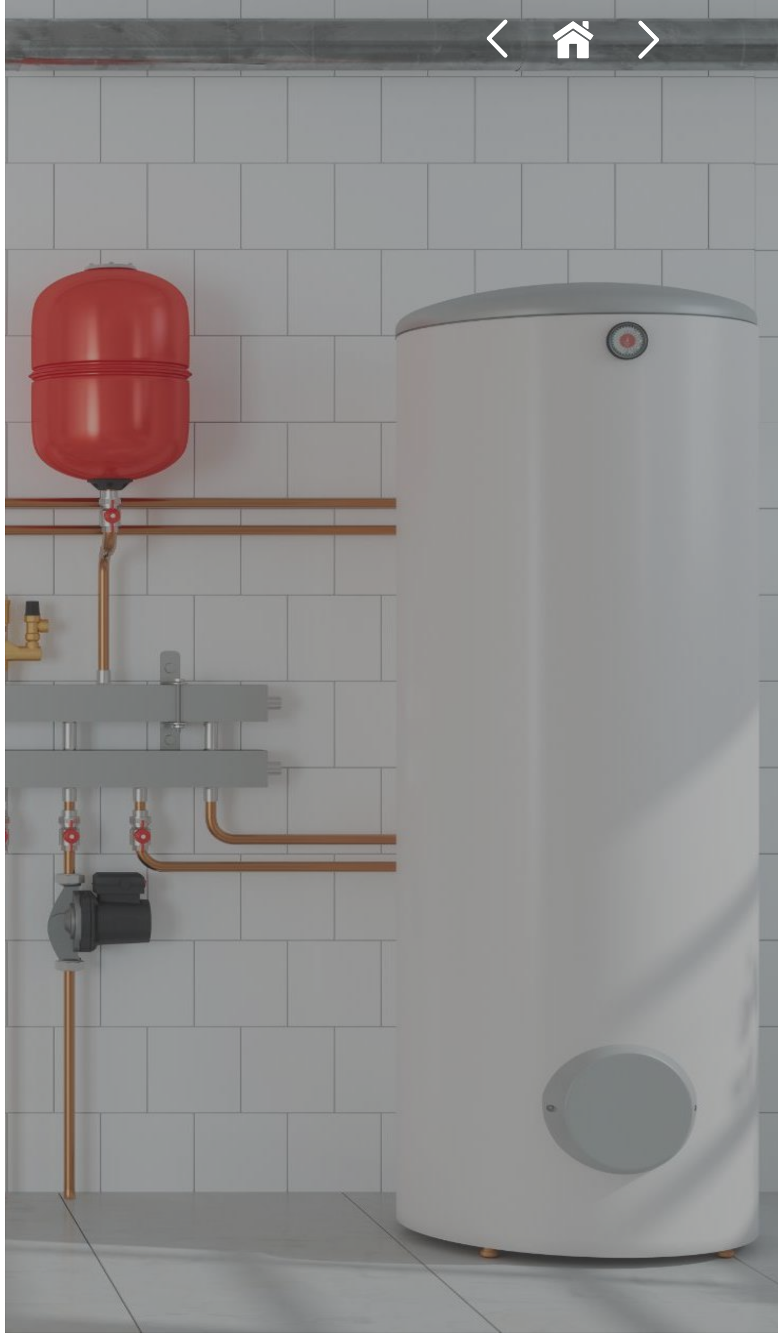
This analysis draws upon existing studies to identify the proportion of UK homes which are hard-to-electrify. We have analysed the characteristics of these properties that impact their suitability for electrification to better understand the cost/benefit of different heating solutions in these homes.

2

Three hard-to-electrify archetypes and one easy-to-electrify archetype were chosen for further analysis. To compare the economic cost of hydrogen with electrification, we have modelled the typical annual heat consumption required for each archetype.

3

We then analysed the full value chain cost to the consumer which shows hydrogen can be cheaper than heat pumps in hard-to-electrify homes. We consider both the upfront cost of the heating system alongside the cost for the energy system needed to deliver low-carbon heat to consumers.



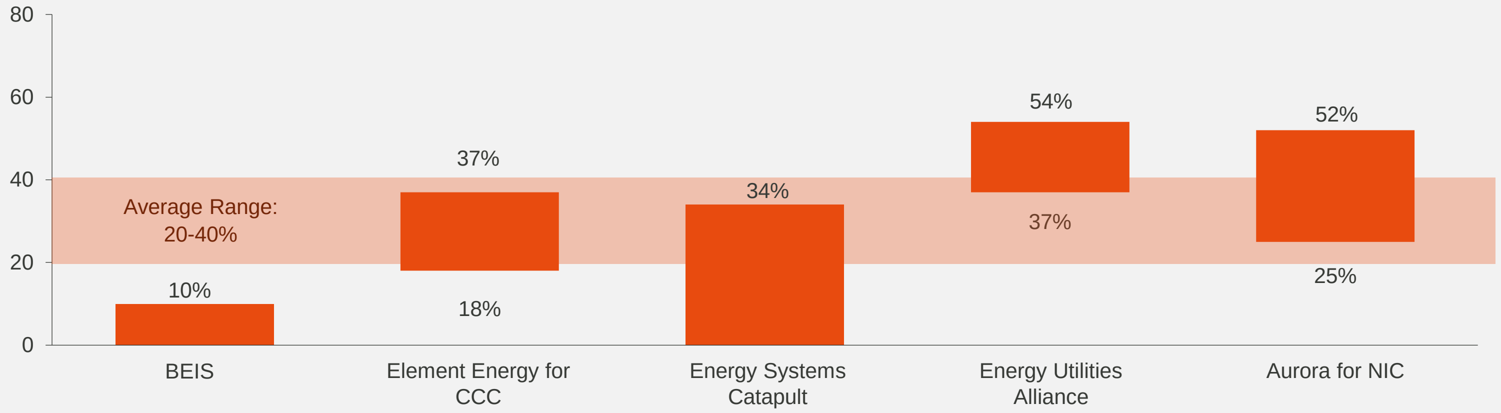
Heat pumps have an important role to play in decarbonising many British homes but should not be seen as a panacea

Several studies show that for a proportion of the housing stock heat pumps are unfeasible or uneconomic and other low-carbon options are needed

Heat pumps offer an efficient way to heat many households, especially newer buildings with adequate space and good insulation, aligning well with the UK's push towards an energy system built upon home-grown renewable energy and reduced carbon emissions.

However, there are challenges facing electrification of certain property types. For instance, homes with limited space or poor insulation may find heat pumps less effective or too costly to install.

Figure 1: Assessment of the proportion of homes that are unsuitable for a heat pump[1-5]



Key Implications

1. Between 20-40% of homes are considered hard or costly to electrify.
2. Discounting hydrogen for heat is premature whilst clear questions remain unanswered around the challenges surrounding hard-to-electrify homes.
3. Ruling out hydrogen risks significant costs falling on households which are unsuitable for heat pump installation.
4. Existing gas infrastructure can be leveraged to support hydrogen for heat delivery.
5. Our research[6] shows many consumers would prefer to have the flexibility to select their own heating solutions, rather than having them determined by government mandates.

Source: (1) BEIS 2018, (2) Element Energy, Deep Decarbonisation Pathways for UK Industry, 2020, (3) Energy Systems Catapult: All housing types are suitable for heat pumps, (4) Guidehouse, Whole System Analysis for the Energy Networks Association, (5) Aurora Energy Research, The Role of System Flexibility in Achieving Net Zero, National Infrastructure Commission, 2023, (6) Savanta - Exploring the role of choice in the heating transition

Discounting hydrogen for heat could remove a credible option for decarbonising 'hard-to-electrify homes'

We have selected four housing archetypes for further analysis made up of three 'hard-to-electrify' archetypes and one 'easy to electrify' archetype for comparison.

Collectively they represent c.6.5 million (27%) of the 24 million gas-connected UK homes.

Table 1: Characteristics of home archetypes analysed in this study[1]

		Property Age			Property Characteristics				
Property Type		**Period**	**Proportion of the Housing Stock**	**Built pre-building (thermal) standards (1965).**	**Thermal efficiency improvements needed**	**Solid Wall**	**Cavity Wall**	**Limited Outdoor Space**	**Limited Indoor Space**
Hard-to-Electrify	Mid terrace	Pre 1919	8%	✓	●	✓		✓	✓
	Semi-detached	1945-1964	10%	✓	◐		✓		
	Detached	1945-1964	7%	✓	◐		✓		
Easier to Electrify	Detached (modern)	Post 1990	3%						

● Significant thermal efficiency upgrades needed ◐ Some thermal efficiency upgrades needed

What do you have to believe for electrification to be a panacea for home heating:

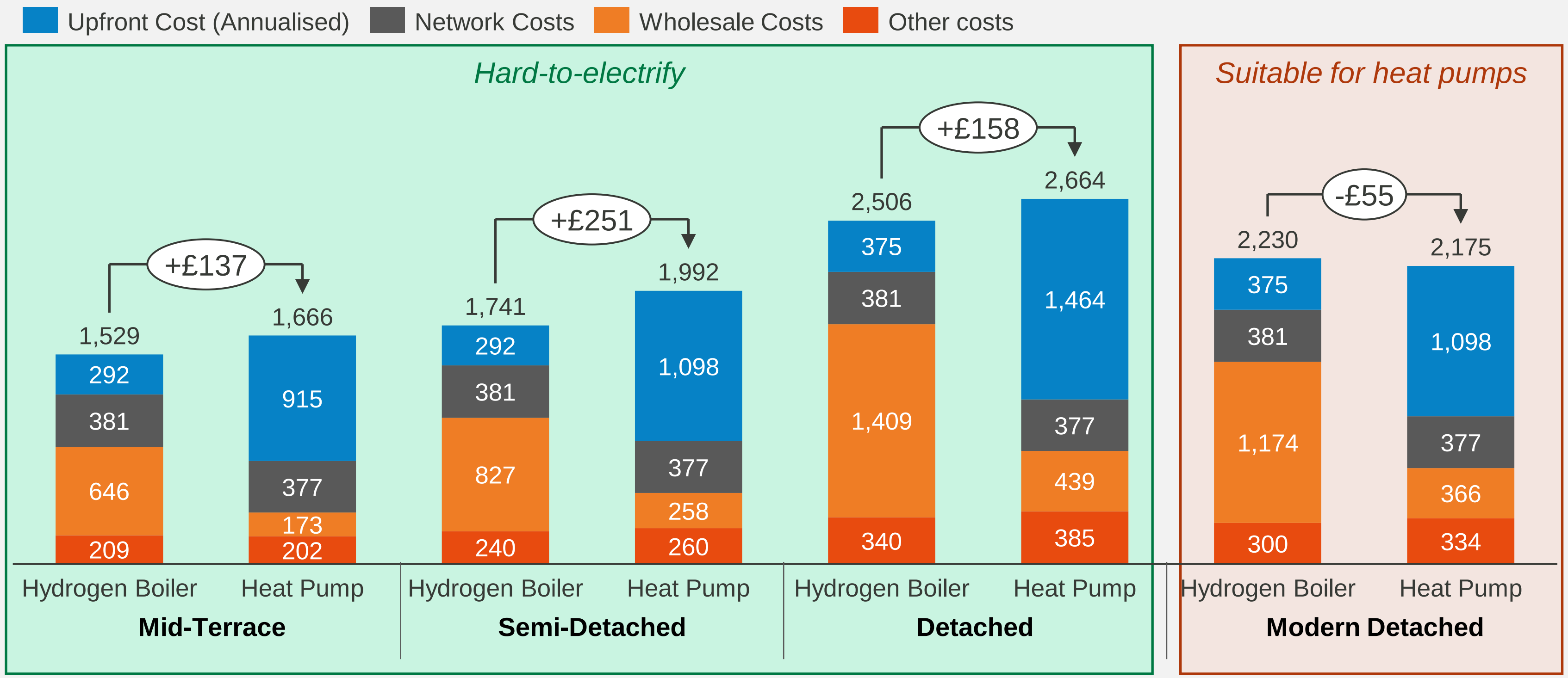
1. All UK home types are suitable for electrified heating.
2. Sufficient renewable power and system resilience will be in place to meet 1 in 20 peak demand, while also electrifying transport and industry.
3. There will be widespread consumer acceptance of the experience and costs (both upfront and ongoing) associated with heat pumps.
4. At a whole-systems level it is more economically advantageous to electrify all households than all other low-carbon options (e.g. hydrogen heating).
5. The UK has sufficient skills and supply chains to deliver a 15x increase in heat pump installation rate over 10 years.

Source: (1) Ministry of Housing, Communities and Local Government - English Housing Survey data on stock profile

A full value chain analysis of both heating systems shows hydrogen can be cheaper than heat pumps in hard-to-electrify homes

This analysis demonstrates **the annualised costs for hydrogen heating customers can be lower than that of a heat pump user** in 3 out of 4 analysed home archetypes.

Figure 2: Annualised cost to consumers in each analysed home archetype (£)



Key Point to note:

We have quantified the full value chain cost of electrification in a conservative manner to demonstrate hydrogen heating can be competitive even in unfavourable scenarios.

For example, our analysis does not include the cost of retrofit or insulation that is often recommended with home electrification (which can cost up to £48,200 according to one study[1]) to reduce the heat loss and the requirement for a larger heat pump. We have also used modest estimates for the cost of electricity network enhancements and storage required to integrate renewable energy sources to reliably deliver heat to UK homes.

Source: (1) Energy Systems Catapult - Electrification of heat demonstration project summary report

The most economic heating solution will depend on the home archetype

Key takeaways from the analysis:

H_2

The analysis shows the upfront costs of hydrogen heating to be substantially lower than heat pumps. This can be up to 70% lower in some home archetypes.

Legacy network and decommissioning costs are similar for both hydrogen and heat pump users, although the cost to consumers of upgrading the electricity grid is assumed to be marginally lower than converting the gas network to hydrogen.

On a per unit basis, wholesale hydrogen is expected to be cost competitive with electricity when considering significantly higher cost of storage and flexibility required to integrate renewable energy sources. **Despite this, heat pump users will pay less for their energy than hydrogen users due to higher efficiency and thus lower heat demand.**

Our analysis demonstrates that once the full value chain costs are considered, hydrogen heating can be cost competitive in hard-to-electrify homes, with consumers saving between £137 and £251 annually when utilising hydrogen in comparison to electricity.

2 Introduction

Decarbonising domestic heating requires affordable, practical, and reliable low-carbon solutions

Decarbonising domestic heating, unlike other parts of the energy sector, will require major changes to homes and lives. Consumer needs must therefore be kept front of mind when policy decisions are being considered

Consumer needs

Affordability: This is a critical concern for consumers as heating costs constitute a significant portion of household expenses.

Reliability: Consumers require heating systems that deliver consistent performance, ensuring comfort and security throughout the year.

Practicality: Systems should be easy to maintain and integrate seamlessly into existing home infrastructure, providing peace of mind to homeowners.

Known options for low carbon heat

- **Heat pumps** - A heat pump is rather like a refrigerator or air conditioner in reverse - drawing heat from the ground or outside air, even when it is cold, and transferring the heat into the building.[1]
- **Hydrogen boilers** - Hydrogen boilers have been designed as a straight swap for a gas boiler, at much the same price. The boiler is the same size and shape as conventional combination boilers and therefore provides easy integration and familiarity for the consumer. Boiler manufacturers have developed hydrogen-ready boilers that run on natural gas and hydrogen so that conversion to hydrogen - which would be managed on a street-by-street basis has minimal impact for the consumer.
- **Resistive Heaters** - Electric resistance heat can be supplied by centralised forced-air electric furnaces or by heaters in each room. These appliances run on electricity and are 100% efficient in the sense that all the incoming electric energy is converted to heat.[2]
- **Heat Networks** - A distribution system of insulated pipes that take heat from a central source and deliver it to a variety of different customers such as: public sector buildings, shops and offices, sport facilities, universities and homes.[3]

Source: (1) Energy and Climate Intelligence Unit, (2) US Department of Energy, (3) BEIS – Heat Network Investment Project

Hydrogen heating presents a compelling alternative low carbon heating solution in hard-to-electrify homes

Consumer Needs	**Affordability**	**Reliability**	**Practicality**
Benefits of hydrogen for Heat	Hydrogen boilers have been designed to integrate into existing systems, minimising capital cost. Gas networks will be utilised to distribute hydrogen and biomethane to industry and power generation and therefore large parts will be able to be repurposed for hydrogen, avoiding significant decommissioning costs.	Hydrogen heating systems are designed to function in a similar way to today's gas boilers, with performance consistent with that of gas, in terms of heating capacity and efficiency. By establishing a local supply chain to produce and store home-grown hydrogen, distributing it where and when it is needed in heating, industry and power generation, we can increase resilience and support energy security.	Conversion to hydrogen will need to happen on a street-by-street basis. The impact on households of the conversion process is minimised due to the development of hydrogen-ready boilers. Homes are likely to need new meters, a hydrogen monitor and an additional excess flow valve as part of the conversion. Hydrogen systems are designed to be easy to maintain, reducing the complexity and cost of ongoing maintenance.

3 Decarbonising a diverse housing stock

The UK housing stock is diverse and predominantly dependent on gas for heating – this presents some complexity when it comes to decarbonisation

Many UK homes lack the insulation and modern heating systems needed to keep energy bills low and reduce carbon emissions

Much of the UK's housing was built long before energy efficiency standards became a priority. In fact, the Institute for Government found that the UK's housing stock is among the least energy-efficient in Europe.[1]

12%

Of UK Greenhouse Gas emissions come from domestic heating[2]

85%

Homes connected to gas supply[3]

35%

of homes were built pre-1945[4]

64%

of homes rated D-G in energy efficiency[5]

98,468

Heat pumps installed in the last year[6]

1.5M

Annual heat pump roll out required by 2035 to achieve electrified heating[2]

Source: (1) Institute for Government – Tackling the UK's Energy Efficiency Problem, (2) Climate Change Committee – 7th Carbon Budget, (3) Gas Goes Green - Answering your questions about Gas Goes Green, (4) Uswitch Research, (5) Ministry of Housing, Communities and Local Government - English Housing Survey data on stock profile, (6) Heat pump association – Statistics

Decarbonising heat is a major challenge for achieving Net Zero by 2050 and requires targeted action to address

When it comes to decarbonising UK homes, electrification is often seen as the frontrunner, but the diversity in the housing stock provides a strong justification for maintaining optionality in heating technologies

Electrified heating offers an efficient way to heat many homes, especially newer builds with good insulation. It aligns well with the UK's push towards moving to an energy system built upon home-grown renewable energy and reduced carbon emissions.

However, the diversity of the UK's housing stock presents challenges to electrification. For instance, properties with limited space or poor insulation may find heat pumps less effective or too costly to install.

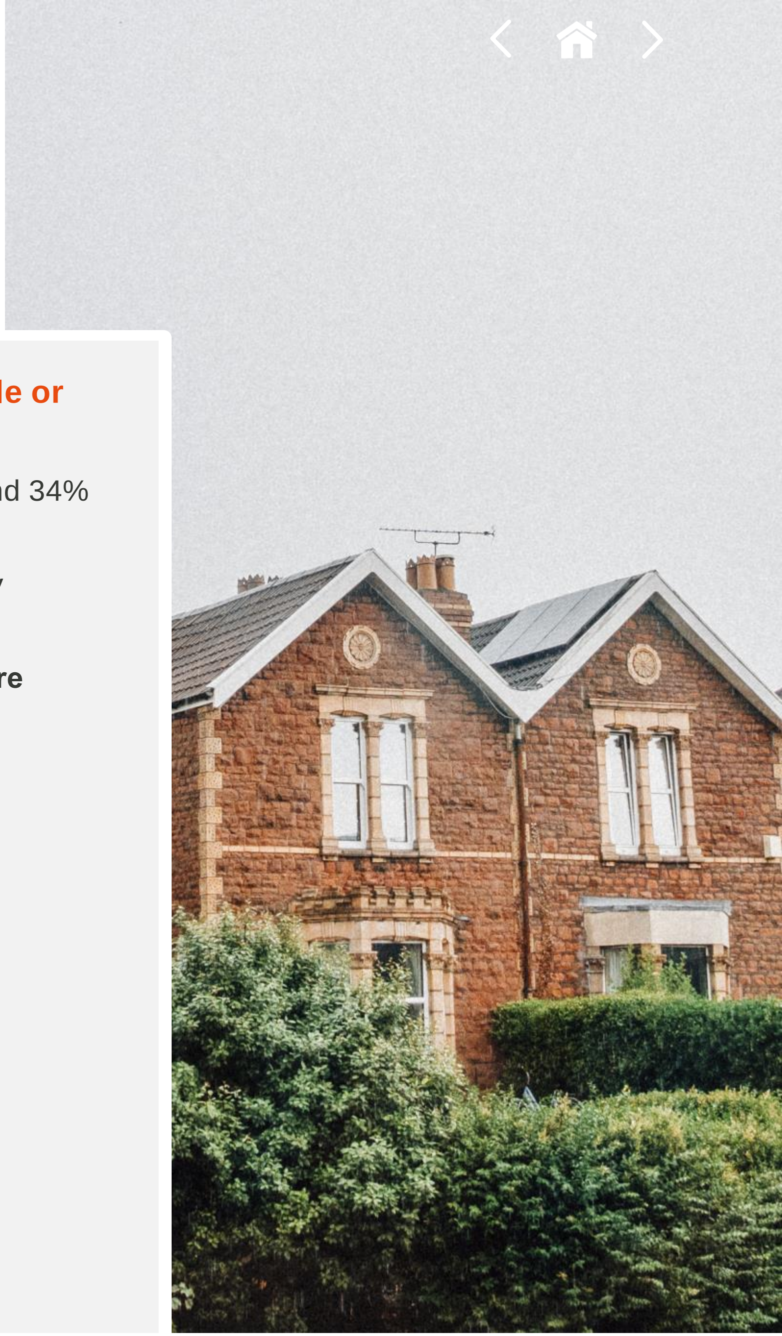
For homes that are hard to electrify, the availability of a range of other domestic heating systems options will be an important pillar of supporting home decarbonisation.

Policymakers should therefore consider retaining optionality to ensure the most economic and viable route to low-carbon heating

What do you have to believe for electrification to be a panacea for home heating:

1. All UK home types are suitable for electrified heating.
2. Sufficient renewable power and system resilience will be in place to meet 1 in 20 peak demand, while also electrifying transport and industry.
3. There will be widespread consumer acceptance of the experience and costs (both upfront and ongoing) associated with heat pumps.
4. At a whole-systems level it is more economically advantageous to electrify all households than all other low-carbon options (e.g. hydrogen heating).
5. The UK has sufficient skills and supply chains to deliver a 15x increase in heat pump installation rate over 10 years.

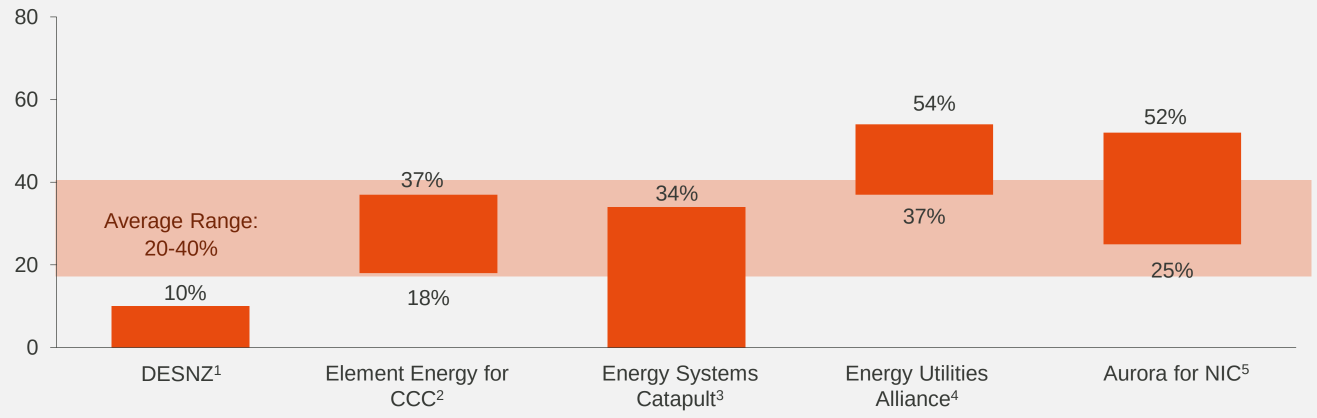
It is estimated that electrifying 20 - 40% of homes may be unfeasible or uneconomic



Several studies agree that for a proportion of the housing stock heat pumps are unfeasible or uneconomic

- **Energy Systems Catapult:** details that 12% of heat pump installations were technically unfeasible and 34% were not recommended.[3]
- **The Energy Utilities Alliance** evaluated feasibility based on space constraints and calculated a likely challenge in 37% to 54% of homes – identifying terraced houses and flats as likely challenges.[4]
- A similar range of 25% to 52% was highlighted in **Aurora's evaluation for the National Infrastructure Commission.[5]**

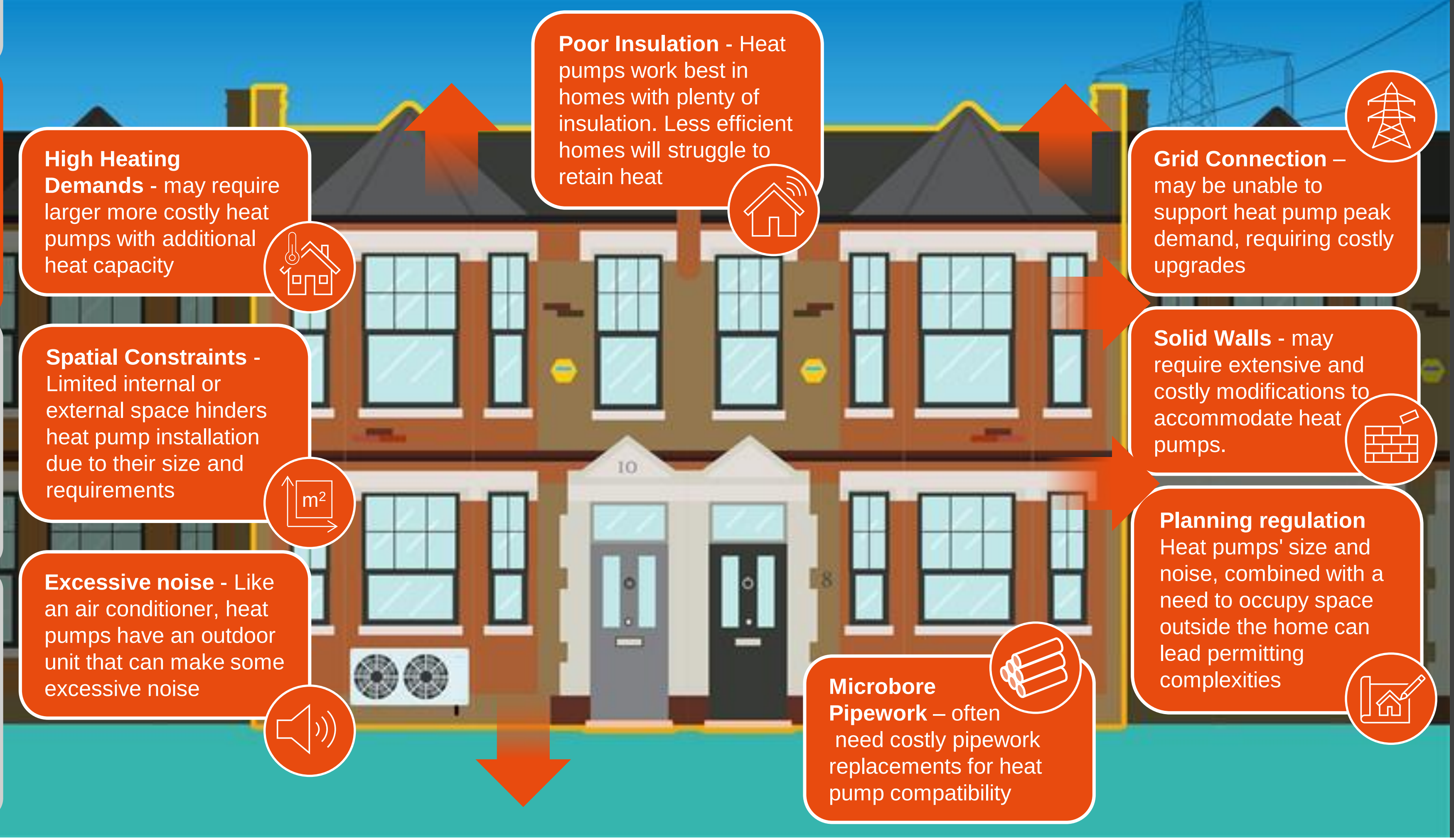
Figure 3: Assessment of the proportion of homes that are unsuitable for a heat pump[1-5]



Source: (1) BEIS 2018, (2) Element Energy, Deep Decarbonisation Pathways for UK Industry, 2020, (3) Energy Systems Catapult: All housing types are suitable for heat pumps, finds Electrification of Heat project, (4) Guidehouse, Whole System Analysis for the Energy Networks Association, (5) Aurora Energy Research, The Role of System Flexibility in Achieving Net Zero, National Infrastructure Commission, 2023,

Reasons some homes may not be suitable for heat pumps

For these homes, the availability of other domestic heating systems options will be crucial to supporting the UK's Net Zero goals and ensuring that no home is left behind in the energy transition



High Heating Demands - may require larger more costly heat pumps with additional heat capacity

Spatial Constraints - Limited internal or external space hinders heat pump installation due to their size and requirements

Excessive noise - Like an air conditioner, heat pumps have an outdoor unit that can make some excessive noise

Poor Insulation - Heat pumps work best in homes with plenty of insulation. Less efficient homes will struggle to retain heat

Microbore Pipework – often need costly pipework replacements for heat pump compatibility

Grid Connection – may be unable to support heat pump peak demand, requiring costly upgrades

Solid Walls - may require extensive and costly modifications to accommodate heat pumps.

Planning regulation Heat pumps' size and noise, combined with a need to occupy space outside the home can lead permitting complexities

Figure 4: Reasons Heat Pumps were not recommended – Energy System Catapult[1]:

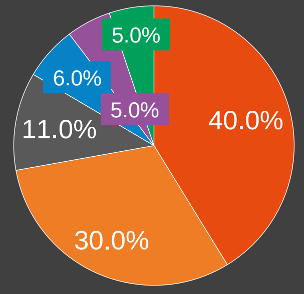


Table 2: Barriers to heat pump suitability[1]

Category	Example Barriers
Practical	• Insufficient external/internal space • Excessive noise • Disruptive works • Routing issues • Fabric incompatibility • Reinforcement required
Technical	• Size incompatibility • Impedes comfort
Economic	• Excessive installation costs • Cost of energy efficiency measures • Excessive running costs

Source: (1) Energy Systems Catapult: All housing types are suitable for heat pumps, finds Electrification of Heat project,

Discounting hydrogen for heat prematurely may remove a compelling option for decarbonising "hard-to-electrify" homes

To demonstrate this, we have conducted a full value chain cost analysis of three typical hard-to-electrify UK housing archetypes representing 24% of the housing stock

For comparison we have also included a home archetype where heat pumps are most likely to be the best option (representing 3% of the housing stock). These archetypes, collectively represent around 6.5 million (27%) of the 24 million gas-connected UK homes.

Table 3: Characteristics of home archetypes analysed in this study[1]

		Property Age			Property Characteristics				
Property Type		**Period**	**Proportion of the Housing Stock**	**Built pre-building (thermal) standards (1965).**	**Thermal efficiency improvements needed**	**Solid Wall**	**Cavity Wall**	**Limited Outdoor Space**	**Limited Indoor Space**
Hard-to-Electrify	Mid terrace	Pre 1919	8%	✓	●	✓		✓	✓
	Semi-detached	1945-1964	10%	✓	◐		✓		
	Detached	1945-1964	7%	✓	◐		✓		
Easier to Electrify	Detached (modern)	Post 1990	3%						

● Significant thermal efficiency upgrades needed ◐ Some thermal efficiency upgrades needed

Hard-to-electrify housing archetypes

We have selected three housing architypes that are "hard-to-electrify". These make up the majority of the 20-40% of homes that could be suitable for hydrogen heating. Our archetypes are defined in more detail overleaf. To summarise these are:

- **Mid-terrace:** Built 1919-1945; these homes can have space constrained gardens and rooms, impacting the installation of heat pumps, water tanks, insultation and radiators.
- **Semi-detached:** The homes specified in this report were built post-war (1945-1964) typically having cavity walls.
- **Detached:** These older properties (also 1945-1964) from the mid-20th century that can have very poor thermal efficiency with harder-to-insulate solid walls.

Source: (1) Ministry of Housing, Communities and Local Government - English Housing Survey data on stock profile

To enable assessment of the economics of hydrogen heating compared with electrified heating, the analysis considers annual heat consumption of each home

Table 4: Data assumptions utilised for each archetype

	Hard-to-electrify			*Suitable for heat pumps*
	Mid-terrace	**Semi-detached**	**Detached (post-war)**	**Detached (modern)**
				
	EPC Rating: F	**EPC Rating: E**	**EPC Rating: E**	**EPC Rating: B**
Key Characteristics	Solid wall, lack of exterior space, low thermal fabric	Uninsulated cavity walls Only 50mm of loft insulation	Uninsulated cavity walls Only 50mm of loft insulation	Filled cavity walls
Heat and hot water demand (kWh)	8,050	10,304	17,549	14,624
Hydrogen Boiler Capacity (kW) 87% Efficiency	24	24	32	32
Air Source Heat Pump Capacity (kW) 300% Efficiency	8	10	12	10

4 Full value chain cost assessment

Taking a full value chain approach to economic analysis allows for a comprehensive assessment of the costs to consumers

The system costs of hydrogen heating across a range of home types should be a critical component of future policy decisions on its role

1

To understand the economics of hydrogen heating, we categorised the housing stock into archetypes based on their architectural characteristics, construction periods and considered typical insulation levels, energy efficiency and potential required interventions for electrification.

2

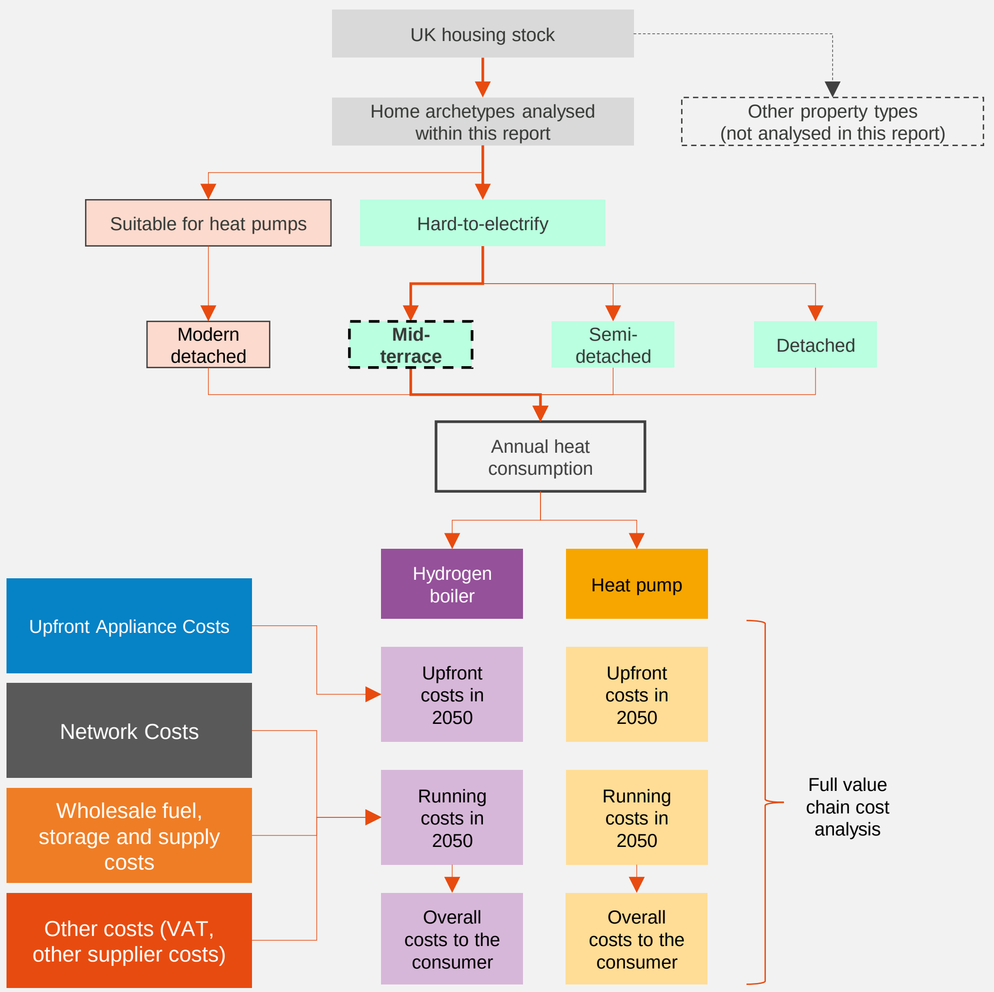
This identified a specific set of four home archetypes for detailed analysis, with the mid-terrace house chosen as the key comparator archetype as it the hardest to electrify archetype, accounting for 8%[1] of the housing stock.

3

Our analysis evaluates the costs to consumers in 2050, by which point both systems must be widespread to reach Net Zero. We consider the entire value chain, including appliance costs, system costs, and fuel costs, which are reflected in consumers' energy bills.

4

This full value chain cost analysis approach allows for the financial impacts of heat pump uptake to consumers in hard-to-electrify homes to be fully understood and evaluated against a hydrogen alternative.

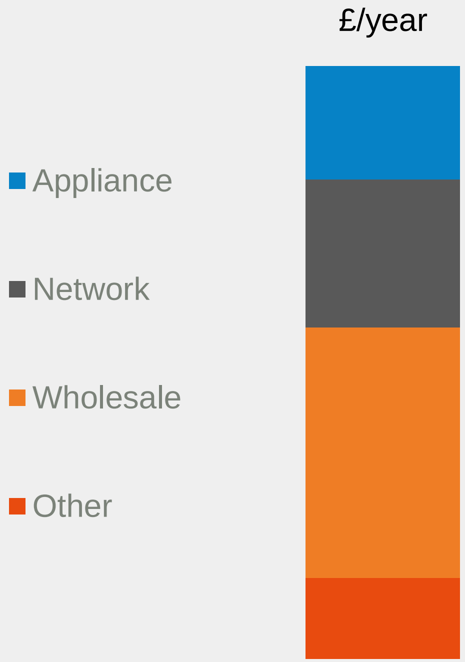


Source: (1) Ministry of Housing, Communities and Local Government - English Housing Survey data on stock profile

Our analysis consists of a direct comparison of the costs that consumers will face in 2050 for both electric and hydrogen heating options.

Our examination of heating system economics starts with the costs related to home installation and setup as well as the costs of the energy system (i.e. the infrastructure required to produce, transport and integrate energy) and fuel required to deliver both heating options.

Illustrative annual cost stack for homes



1. **Upfront Costs:** The annualised cost of a fully installed heating appliance, including retrofit work necessary within the home
2. **Network:** The cost of building and running a network capable of meeting demand in a Net Zero system
3. **Wholesale energy:** The cost of producing electricity or hydrogen and the associated flexibility and integration
4. **Other:** Supplier costs, margin and VAT, plus other Govt imposed costs such as the Warm Homes Discount (WHD) and the Energy Company Obligation (ECO)

For the purposes of this analysis 'Other Costs' are assumed to remain consistent and socialised among billpayers in similar proportions to those observed at the time of writing between gas and electricity consumers. Therefore, our analysis focuses on items 1 to 3.

The following slides provide a worked example, using a mid-terrace home, to demonstrate hydrogen can be economical in hard-to-electrify home archetypes

1 **Upfront Costs**

2 **Running Network Costs**

3 **Running Wholesale Energy Costs**

For this worked example we analyse and compare the annualised costs to consumers using a heat pump versus a hydrogen boiler in a mid-terrace home with no additional energy efficiency costs included.

This enables a like-for-like comparison of both heating options, utilising a commonly occurring archetype within the UK housing stock without, introducing the complexity of the interaction insulation measures would have on heating demand and appliance efficiency.

The analysis is structured as follows:

1. **Analysis of the property type and appliance costs:** We start by identifying the property type and its typical thermal properties. Based on these characteristics, we calculate the heat demand. This helps us determine the size of the appliance required, whether it be a hydrogen boiler or an air source heat pump and compare their annualised upfront costs.
2. **Network Costs:** Next, we consider the key elements of consumer bills for both heat pump and hydrogen boiler users, the first of which is the cost of the electricity and hydrogen networks required to deliver the energy required for heating the homes. We then demonstrate how those costs are recovered and apportioned through consumer bills.
3. **Wholesale Energy Costs**: We then compare the cost of producing the energy needed, considering the unit cost of producing the hydrogen and electricity, as well as the cost of the flexibility and storage required to deliver heating requirements. Finally, considering both homes' heating demand we calculate the respective impact on consumer bills.

Home archetype:
Mid-terrace house

H_2 Hydrogen heating	Electrified heating
Annual heating demand: **9,253 kWh**	Annual heating demand: **2,300 kWh**
Hydrogen boiler cost 87% efficiency	**Heat pump cost** 3.0 performance coefficient

1 **No additional insulation costs**

2 **Legacy network & gas decommissioning costs** distributed across all consumers

Hydrogen heating	Electrified heating
Cost of converting gas network to hydrogen	Cost of grid enhancements to support heat demand

3

Hydrogen heating	Electrified heating
Cost of hydrogen production	Cost of generating renewable electricity
Cost of hydrogen storage	Cost of storage and flexibility to integrate renewables

Introduction

Decarbonising A Diverse Housing Stock

Cost Assessment

Conclusions

1. Upfront appliance costs: The upfront costs of retrofitting homes for hydrogen boilers is expected to be significantly less than for electrification through heat pumps

1

Upfront Costs

2

Running Network Costs

3

Running Wholesale Energy Costs

Our analysis of annualised costs of hydrogen boilers against heat pumps in a mid-terrace home demonstrates a saving of up to 70%

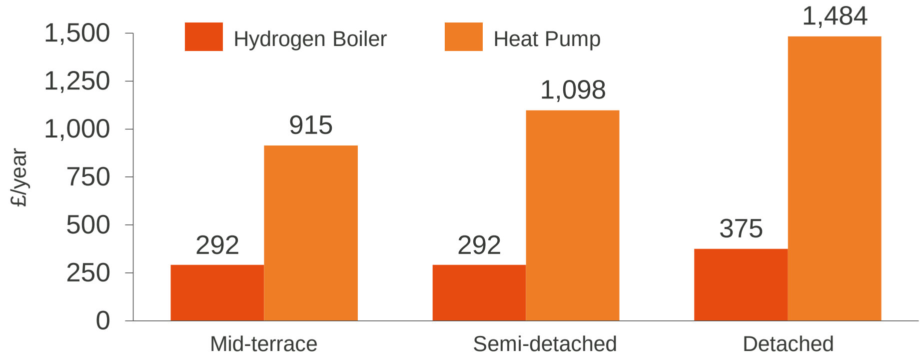
Upfront costs of heat pumps vary significantly within archetypes. In the 7th Carbon Budget, the CCC has shown the cost of heat pumps to be increasing historically[1], but forecasts it to decrease rapidly from 2030 to around £8,000 by 2050. It does not provide a rationale for this decrease and states it is likely to be an underestimate.

We have therefore assumed a heat pump to cost of £10,500 in 2050, which annualises to £915/yr over a 15-year useful life. This is derived from the typical heat pump installations which average around £13,000 under the Government Boiler Upgrade Scheme (BUS) as well as expected cost efficiencies of around 20% from UK Government and industry participants, like Octopus Energy.

Hydrogen boilers are expected to cost no more than existing gas boilers. We have assumed installation to cost around £3,000 including additional necessary pipework costs. This annualises to £292/yr.

Removing alternative heating options to electrification will force consumers to spend a large amount of upfront money on heat pumps, at a time when **reducing consumers energy bills whilst delivering decarbonisation should be government's top priority.**

Figure 5: Upfront annualised appliance costs by 2050



For simplicity, this analysis considers the cost of both heating systems in a typical mid-terrace home with consistent levels of insulation. This analysis therefore does not include additional upfront costs of energy efficiency measures that are often required for a heat pump systems to operate efficiently.

The ESC study demonstrate that **heat pump installation including energy efficiency upgrades can cost up to £48,200 to install, which would further increase the upfront cost discrepancy**.[2]

Upfront annualised costs in 2050 for mid-terrace houses	
Annualised hydrogen boiler cost **£292/yr**	Annualised heat pump cost **£915/yr**

Source: (1) CCC – 7th Carbon budget, (2) Energy Systems Catapult - Electrification of heat demonstration project summary report

2. Network costs: Transitioning to Net Zero heating will require significant costs to transform both gas and electricity networks, regardless of the energy mix

1 Upfront Appliance Costs

2 Running Network Costs

3 Running Wholesale Energy Costs

The way we transport energy to homes will undergo changes to support the transition, this cost will be recovered through consumers bills

To understand the cost implications of these changes, we have broken down and estimated the network costs required to operate both electrified and hydrogen-based heating. These costs are recovered from consumers as part of their energy bills. These costs include:

- **Legacy Gas & Electricity Networks**: This represents the costs to consumers for operating the portions of gas and electricity networks which exist today which will still be online in 2050.
- **Decommissioning Costs:** It is expected that with the drive for electrification, some decommissioning of the gas network will be required. There are costs associated with decommissioning and maintaining a safe system during the disconnection of customers.
- **Transition Costs:** Investments needed to prepare future gas and electricity networks for Net Zero, including in-home changes specific to each heating solution.

In table 5, we outline the assumptions made about how these costs will be distributed across the population.

Table 5: Basis of network cost calculation

Cost Item	Treatment	Assumed Network Cost (£bn/yr)	
		Hydrogen	Electricity
Estimated Number of homes in 2025[1]		9.6 Million	32.4 Million
Legacy Costs	Borne by all consumers	10.1[2-3]	
Gas	Borne by all consumers	6.0[2-3]	
Electricity	Borne by all consumers	4.1[2-3]	
Decommissioning Costs	Borne by all consumers	0.7[4]	
Transition Costs	Apportioned to relevant consumers	1.5[5]	1.4[5]
Total cost to the consumer		**£382/yr**	**£377/yr**

Source: (1) NESO – Future Energy Scenarios, (2) Smart Meters Statistics, (3) Ofgem - Q2-24 Default Tariff Cap (4) ARUP for the NIC: Future of Great Britain's gas network, (5) Cadent Analysis

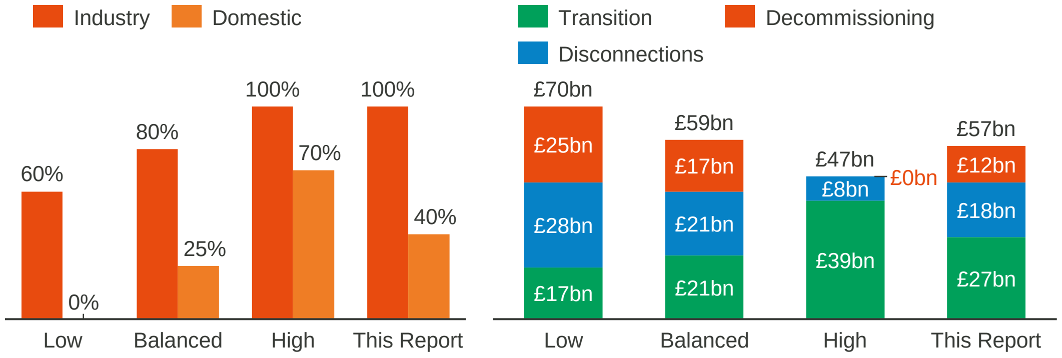
2. Hydrogen network costs: hydrogen for heat enables a pathway to utilise existing gas infrastructure and avoid costly decommissioning of the network

Converting the gas grid to hydrogen for heating, although expensive, avoids significant decommissioning costs

The transition to Net Zero leads to unavoidable costs regardless of whether we convert to hydrogen or decommission parts of the gas network. Analysis[1] conducted by ARUP for the NIC found that converting the gas network to hydrogen would save £24bn compared to decommissioning a significant portion of the network. Figure 6 illustrates the costs of converting the gas network to hydrogen and decommissioning costs for a set of scenarios that ARUP developed.

We have extrapolated ARUP's analysis to achieve an assumed cost of £57bn associated with converting 40% of homes to hydrogen. This includes conversion, disconnections and decommissioning of the unutilised network. Bottom-up analysis is recommended to obtain a more accurate figure as the location of these homes will impact the network size and cost.

Figure 6: Hydrogen conversion and transition costs



Costs paid by All Consumers

Consumers
32.4 Million

Cost Item	Network Cost (£bn/yr)	Consumer Bill cost (£/yr)
Legacy Costs	**10.1**	**311**
Decommissioning Costs	0.7	22

Costs paid by Hydrogen Boiler Users

Consumers
9.6 Million

Cost Item	Network Cost (£bn/yr)	Consumer Bill cost (£/yr)
Transition Costs	**1.5**	**£48**

Network costs per year in 2050 for mid-terrace houses	Hydrogen Network: **£382/yr**

Source: (1) ARUP for the NIC: Future of Great Britain's gas network. Note for legacy costs, please see technical annex

2. Electricity network costs: significant grid upgrades will be required to electrify domestic heating demand, while also electrifying transport and industry.

1 Upfront Appliance Costs

2 Running Network Costs

3 Running Wholesale Energy Costs

£10bn p.a is expected to be required until 2050[1] for electricity network upgrades to support heat pump uptake

The integration of additional renewable energy capacity required to power heat pumps will pose several grid challenges, such as peak demand mismatches and the need for more system resilience. These upgrades will increase electricity network costs and require significant investments in the infrastructure needed to transport electricity from distant renewable energy sources, over and above what would already require due to electric vehicle proliferation.

According to Aurora[1], £180bn of investment in grid upgrades will be needed to support increased home electricity demand. In the Electricity Networks Strategic Framework[2] Government estimates the cost of the network to be up to £240bn. Socialising the former, as the more conservative assumption, across future heat pump users we arrive at a cost of £44/yr. When accounting for legacy network costs and gas network decommissioning, this results in a total £377/yr of cost to the average mid-terrace house heat pump bill payer.

A more aggressive electrification scenario would lead to a significantly higher electricity network cost to consumers – e.g. in the same government framework up to £350bn of investment may be needed to deliver sufficient electricity network capacity for Net Zero. **This would virtually double the annualised grid upgrade costs to consumers.**

Costs paid by All Consumers

Consumers
32.4 Million

Cost Item	Network Cost (£bn/yr)	Consumer Bill cost (£/yr)
Legacy Costs	**10.1**	**311**
Decommissioning Costs	0.7	22

Costs paid by heat pump Users

Consumers
22.8 Million

Cost Item	Network Cost (£bn/yr)	Consumer Bill cost (£/yr)
Transition Costs	**1.4**	**£44**

Network costs per year in 2050 for mid-terrace houses

Electricity Network:
£377/yr

Source: (1) Aurora Project C: The impact of decarbonising heating on the power sector, (2) DESNZ: electricity-networks-strategic-framework-appendix-1-electricity-networks-modelling.

3. Wholesale production costs: although the wholesale cost of hydrogen is expected to decline by 2050, wholesale electricity will remain cheaper

1 Upfront Appliance Costs

2 Running Network Costs

3 Running Wholesale Energy Costs

The wholesale price of hydrogen is expected to drop significantly by 2050 as it becomes more established as a low-carbon energy source

The cost of producing hydrogen could make up a large portion of consumers overall energy costs. Its unit price is expected to decline as technology matures and scales, converging in the range of 5-6 p/kWh by 2050.

This analysis has used a weighted average cost of 6.5p/kWh of blue and green hydrogen production based on BNEF and UK Government forecasts for 2050. Supportive government policy for hydrogen is likely to lower energy prices and bills – this will be crucial to further enhance its cost-competitiveness.

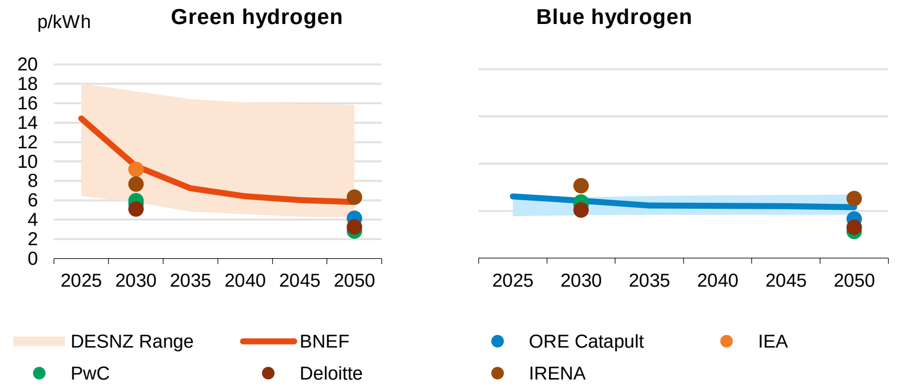
Estimated heating demand for a typical mid-terrace house using a hydrogen boiler is 9,253kWh/yr. The resulting impact of wholesale energy for hydrogen users is therefore £601/yr

However, the wholesale price of electricity is expected to continue to be lower than hydrogen at 4.5p/kWh

The Levelised Cost of Electricity (LCOE), the cost of producing electricity, is expected to decline to 4.5p/kWh as low marginal cost renewable electricity sources such offshore wind expand and become the primary source of generation.

Due to their higher efficiency, heating demand for heat pumps in a mid-terrace home is lower, at 2300kWh/yr, with a resulting bill impact of £104/yr.

Figure 7: UK forecast hydrogen production cost ranges[1]



2050 energy production cost comparison – Mid-terrace house

Cost item	Hydrogen boiler user	Heat pump user
LCOE (p/kWh)	6.5	4.5
Heating Demand (kWh/yr)	9,253	2,300

Hydrogen Fuel Cost: **£601/yr**

Electricity Cost: **£104/yr**

Sources: (1) DESNZ: Hydrogen Production Costs, BNEF: Levelised Cost of Hydrogen, ORE Catapult. Offshore Wind And Hydrogen: Solving The Integration Challenge, Hydrogen Council. Hydrogen Insights 2023, IEA. Global Hydrogen Review 2023, BNEF. Green Hydrogen to Undercut Gray Sibling by End of Decade CRU. Energy from green hydrogen will be expensive, even in 2050, PwC. Green Hydrogen Cost, Deloitte. Green hydrogen: Energizing the path to net zero, IRENA. Making the Breakthrough: Green Hydrogen Policies and Technology Costs, Element Energy. Hydrogen supply chain evidence base.

3. Wholesale storage and flex costs: the analysis shows that integrating and storing the energy demand through hydrogen would be cheaper than electricity

1
Upfront Appliance Costs

2
Running Network Costs

3
Running Wholesale Energy Costs

Hydrogen: Provision of storage is expected to add £0.5p/kWh to the cost of wholesale hydrogen, adding £46/yr to hydrogen user bills

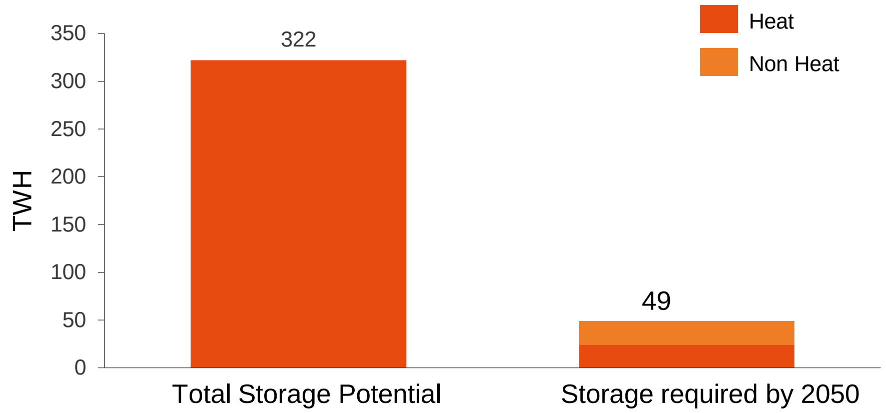
A key component of wholesale energy is the provision of storage. Sufficient energy must be produced and distributed to match demand in both volume and timing. This becomes more complex when variable and seasonal heat demand is added to the typically flatter industrial demand. Hydrogen's storability is a significant advantage over electricity, as it allows for long-term storage in salt caverns or depleted gas fields, abundant in the UK.[1]

Our previous analysis[2] suggests storing 28% of variable annual heat demand would balance daily fluctuations, requiring up to 28 TWh of storage if 40% of homes convert to hydrogen heating. Analysis from Gafney-Cline[3] shows that using salt bed storage to meet this need only adds 0.5p/kWh to supply costs per unit of energy stored for consumers, amounting to only an additional £46/yr for a typical mid-terrace house.

Electricity: In contrast the Climate Change Committee estimates the costs of integrating 75-90% renewables would add 3p/kWh to supply costs[4], adding £69/yr to heat pump user bills

Electricity can be integrated through a variety of flexibility assets such as interconnectors or storage technologies ranging from short durations (8 hours or less) such as Battery Energy Storage Systems to longer duration technologies including hydrogen. All of these technologies add to system costs required to deliver electrified home heating.

Figure 8: UK potential hydrogen storage capacity vs forecast requirement (TWh)[1]



2050 Storage and flexibility cost comparison – Mid-terrace house

Cost item	Hydrogen boiler user	Heat pump user
Unit flexibility cost (p/kWh)	0.5	3
Heating Demand (kWh/yr)	9,253	2300

Hydrogen storage cost:
£46/yr

Cost of integrating renewable electricity:
£69/yr

Sources: (1) Element Energy. Hydrogen supply chain evidence base, (2) Converting Wind into Hydrogen for Heating Homes, Cadent Gas, (3) Gafney-Cline. Underground Hydrogen Storage, (4) CCC: Net Zero – Technical Annex: Integrating variable renewables into the UK electricity system

3. Total wholesale energy costs: when considering generation and flexibility, hydrogen heating costs are competitive with heat pumps on a per unit basis

1 Upfront Appliance Costs
2 Running Network Costs
3 Running Wholesale Energy Costs

Due to higher efficiency, heat pumps retain a cost advantage on annual running costs over hydrogen boilers as less energy is needed overall

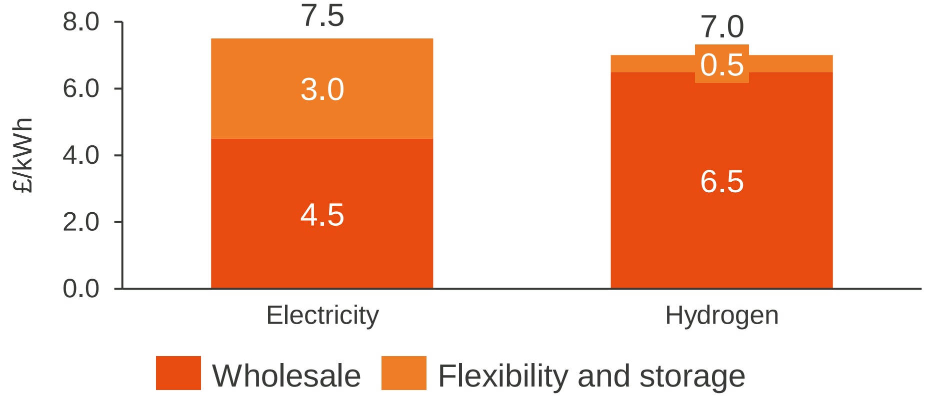
While electricity production costs are currently lower on a per unit of energy basis, hydrogen becomes cost-competitive for hard-to-electrify homes in 2050 when storage and flexibility costs are factored in.

However, across a year of consumption, the difference in efficiency between hydrogen boilers (~98%) and heat pumps (~300%) in 2050 leads to higher annual running costs for hydrogen users, as they require more units of energy to run.

We recognise that energy efficiency will be a key pillar of decarbonising homes in either scenario and believe more should be done to enable widespread upgrades of UK homes. A wide-scale rollout of energy efficiency measures such as insulation will particularly benefit hydrogen users as it will reduce their annual consumption.

Whilst this has a relatively small effect on the upfront cost of systems it leads to much lower running costs, which impacts hydrogen users' bills much more, and further supports the case for hydrogen for heat to compliment home energy efficiency measures being pursued by the UK Government to lower consumers bills.

Figure 9: Electricity and hydrogen supply and flexibility costs in 2050



2050 total wholesale cost comparison – Mid-terrace house

Cost item	Hydrogen boiler user	Heat pump user
Heating Demand (kWh/yr)	9,253	2300
Generation (£/yr)	601	104
Storage and Flex (£/yr)	46	68

Total wholesale hydrogen cost
£646/yr

Total wholesale electricity cost
£176/yr

Our analysis demonstrates that by 2050, heating a typical mid-terrace home with hydrogen could be more economical than electrification

For a mid-terrace home, hydrogen heating is estimated to be around £127 per year cheaper than electrification, representing an annual saving of approximately 9%

- **One key area where hydrogen holds an advantage is in upfront appliance costs**. A hydrogen boiler has significantly lower capital costs—up to 70% cheaper—resulting in an annualised cost of £292 per year, compared to £915 per year for a heat pump.
- **Network costs, largely made up of legacy network and decommissioning costs, are similar for both hydrogen and electrification**. The marginal differences arise due to slightly lower transition costs in the electrification scenario compared to hydrogen.
- **However, electrification benefits significantly from lower wholesale energy costs**. While energy prices per unit are broadly competitive, the heat pump's higher efficiency results in significantly lower heat demand—2,300kWh per year versus 9.253 kWh for a hydrogen boiler. This leads to a lower wholesale energy cost to the consumer, at £173 per year for electricity compared to £646 per year for hydrogen.
- Other costs, such as supplier charges, VAT, and additional charges, are also factored into the analysis (see page 18). **Our analysis assumes these costs will continue to be apportioned across electrified and hydrogen heating homes in the same proportions observed today with electricity and gas heated homes respectively.** This results in a minor cost difference in this worked example, £209 per year for hydrogen homes versus £202 per year for electrified homes, it does not materially impact the overall cost comparison.

H_2 **Figure 10: Annualised costs of heating a mid-terrace home with a hydrogen boiler**

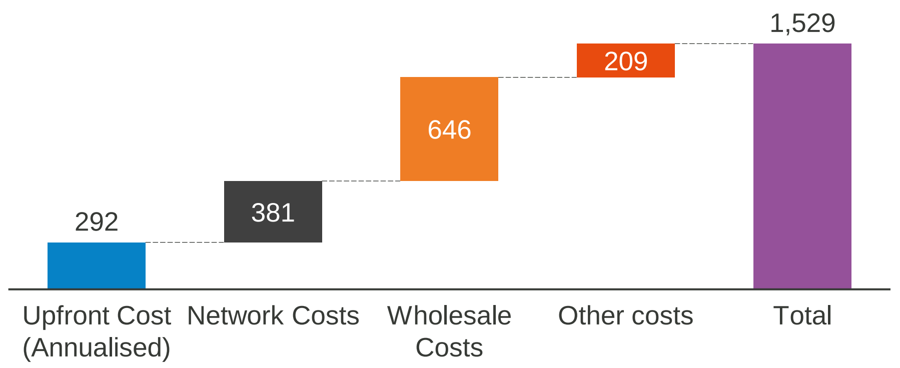
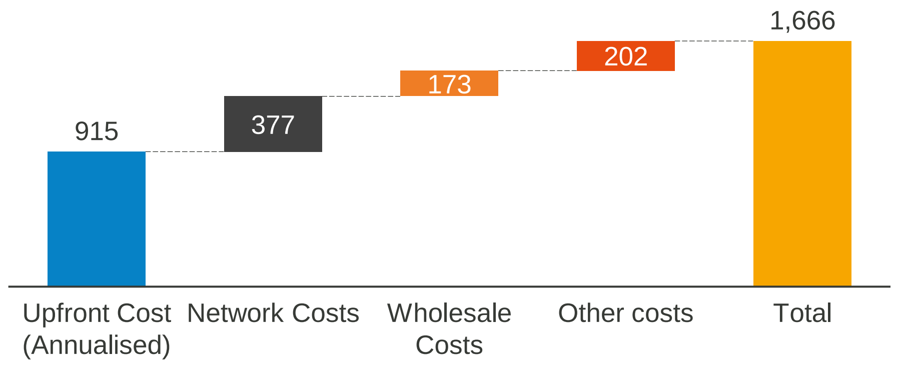


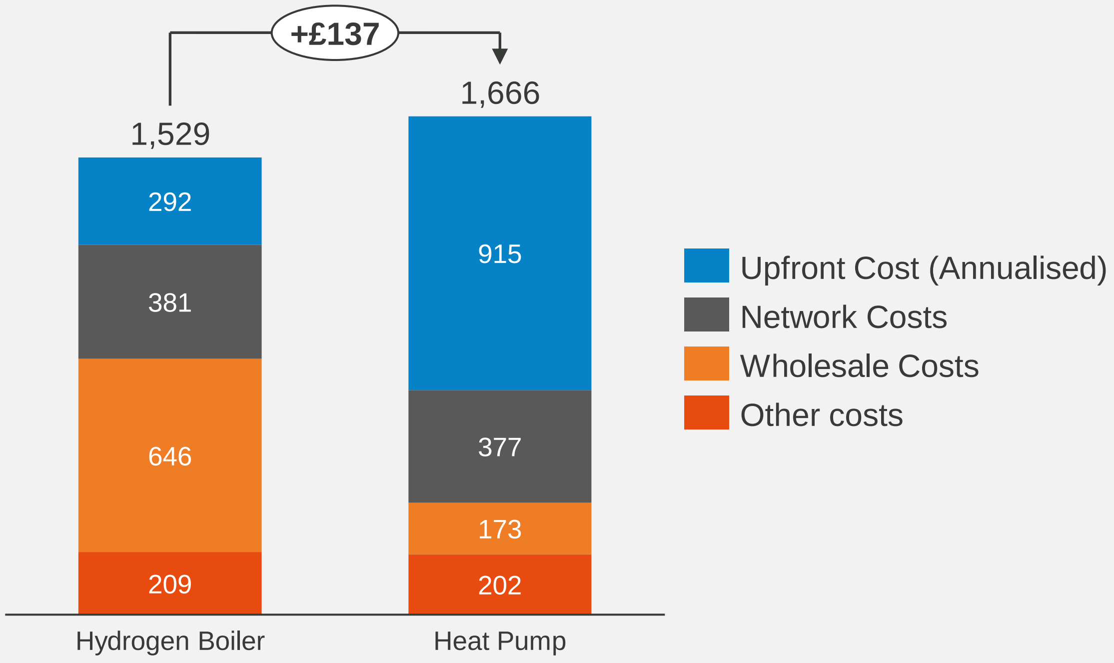
Figure 11: Annualised costs of heating a mid-terrace home with a heat pump



5 Conclusions

A full value chain analysis of both heating systems shows hydrogen can be cheaper than heat pumps in hard-to-electrify homes

Figure 12: Annualised cost to consumers in typical mid-terrace home (£)



This analysis demonstrates that by 2050, **across a 15-year equipment life the annualised costs of hydrogen heating customer are expected to be lower than that of a heat pump user** in a mid-terrace house (*for more archetypes see overleaf).*

This is driven by substantially lower upfront costs for hydrogen heating when compared with heat pumps but higher annual bills, driven by lower efficiency and higher fuel costs**.**

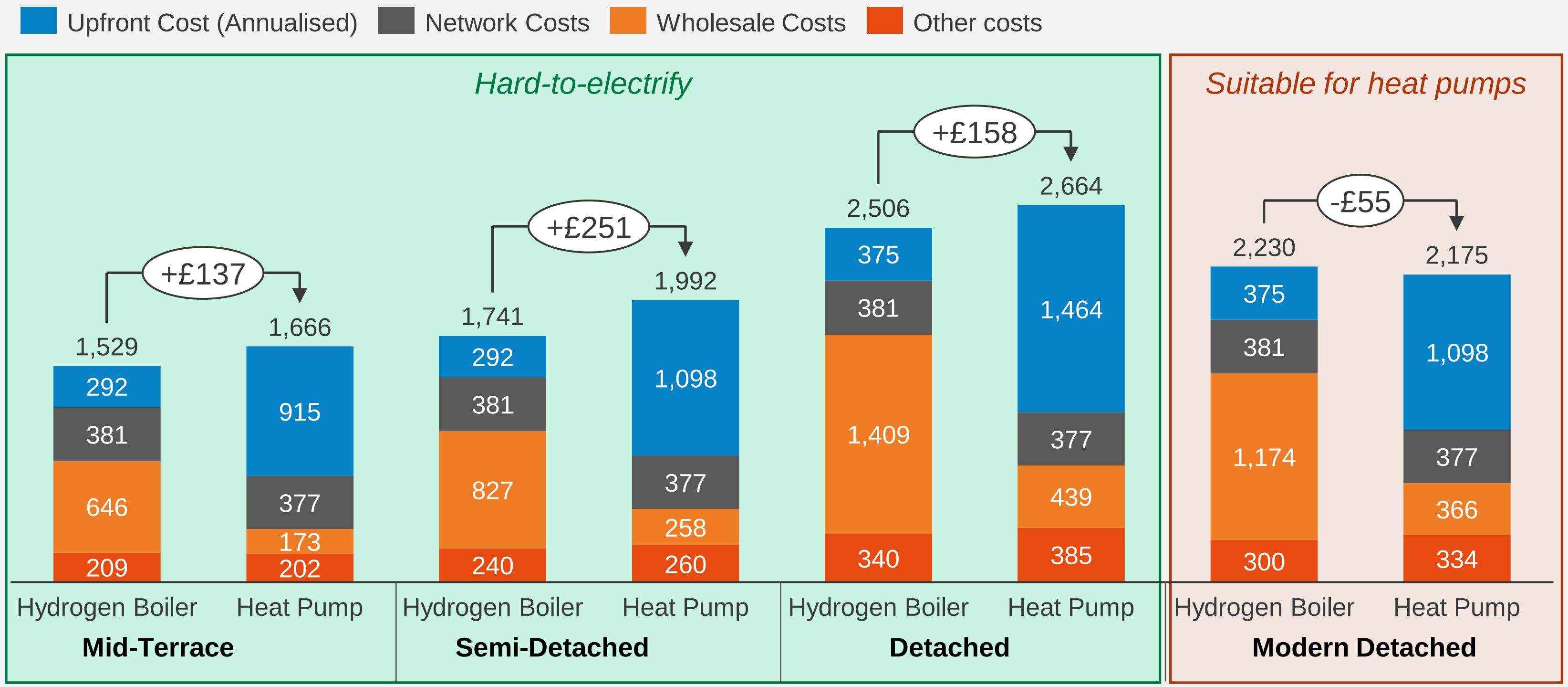
This evaluation **demonstrates that there is not a one-size fits all solution for home heating, with hydrogen offering a potential solution** for those 20 to 40% of homes that are harder and more costly to electrify.

Furthermore, a future heating system where gas continues to have a role will bring other benefits, such as repurposing the existing gas network: added system resilience from diversified fuels (e.g. hydrogen and biomethane), and providing optionality for hybrid heating systems

The most economic heating solution will depend on the home archetype

The analysis also demonstrated that for 3 out of the 4 analysed archetypes, **hydrogen was at least cost-competitive with electrification. Hard-to-electrify homes can save between £137 and £252 annually when utilising hydrogen** in comparison to electricity.

Figure 13: Annualised cost to consumers in each analysed home archetype (£)



Discounting hydrogen for heat risks removal of a viable and cost-effective option, increasing costs for consumers

The UK Government has outlined plans for hydrogen as a key component of its Net Zero strategy. Investing in hydrogen heating aligns with these policies.

Based on a review of published literature, there are between 20 to 40% of homes that are considered hard or costly to electrify. This is the equivalent to between 4 and 8 million homes out of the 24 million currently connected to the gas network.

Existing gas infrastructure and supply can be leveraged to support hydrogen for heat delivery, from repurposing gas networks to re-skilling technicians to install and service equipment in the home.

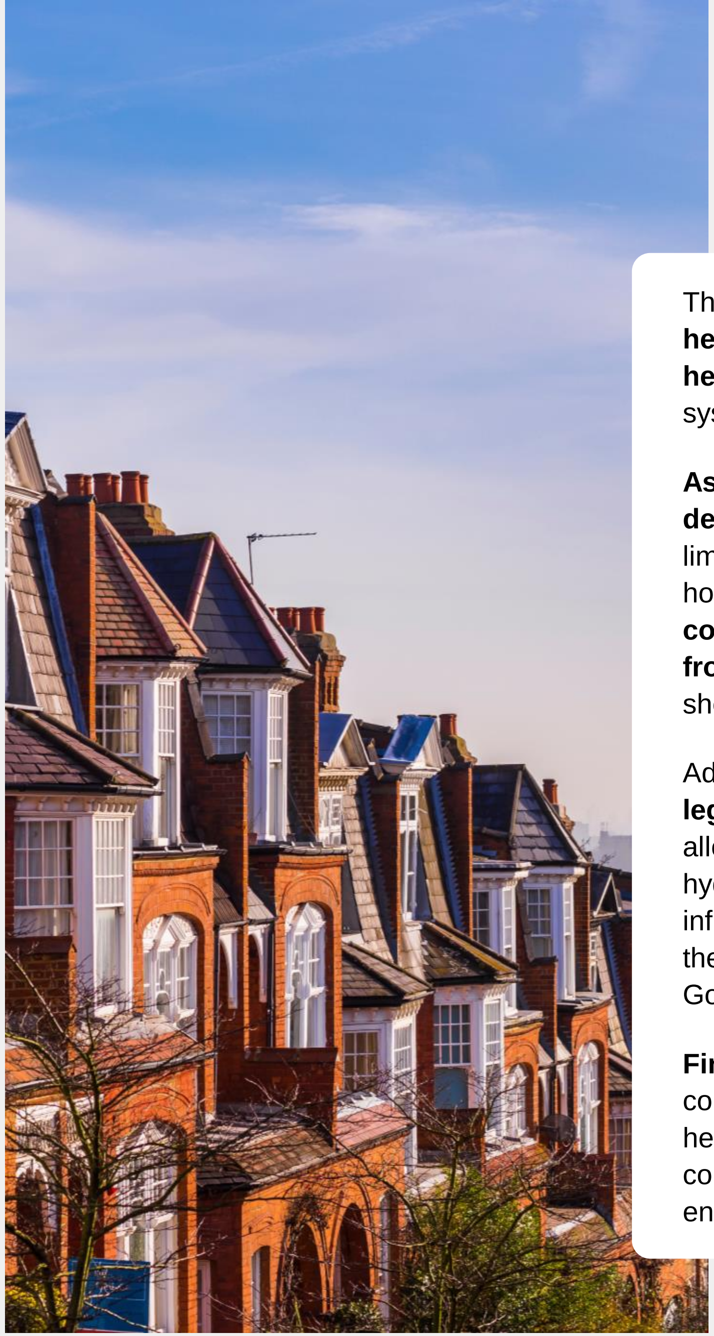
Discounting hydrogen for heat altogether runs the risk of significant additional costs for homes which are unsuitable for heat pump installation. A bottom-up full cost benefit analysis of a balanced approach between hydrogen and electrification should be evaluated to ensure an informed heat decision in 2026.

The wholesale costs to supply hydrogen and electricity are broadly similar by 2050 when the costs of flexibility management for electricity and hydrogen storage are considered.

Consumer choice should be considered. Consumers want to be empowered to choose their own heating solutions, and to not "foot the bill" for a government mandated decision. Ensuring people's trust in decisions is essential for any change to occur and a successful Net Zero transition.

Cadent
Your Gas Network

Appendix



Acknowledgements and Limitations of this analysis

This analysis seeks to take a **conservative yet balanced approach in assessing the potential value chain costs of hydrogen heating versus heat pump heating**. It does so within a **balanced energy system scenario, where both hydrogen and electrified heating contribute to decarbonising home heating**. It is important to emphasise that this is not a comparison of an all-hydrogen system versus an all-electrification system. Instead, it evaluates a scenario in which both technologies play a role.

As a top-down analysis, findings rely on forecasts, benchmarks and studies from reputable industry sources rather than a detailed, bottom-up dispatch model that accounts for costs across the entire energy system. As a result, there are inherent limitations in how costs are allocated, particularly when distinguishing between those that specifically apply to heating (when we know home electricity demand may increase for a variety of reasons, such as greater EV uptake). **The report demonstrates cost competitiveness across a significant proportion of the UK housing stock, but we would welcome a full cost benefit analysis from UK Government analysing the bottom-up whole-systems impact and affordability of a range of different scenarios.** This should be used to inform the final policy decision on hydrogen for heat in 2026.

Additionally, because this analysis frames costs through the lens of consumer energy bills, **assumptions have been made about how legacy network costs should be socialised across the economy.** This report does not attempt to define the “optimal” or “fair” way to allocate these costs. Instead, a balanced approach has been taken, in which legacy transition costs are spread equally between hydrogen and electrified heating users. However, new costs—such as investments in hydrogen networks or upgrades to electricity infrastructure to support increased electrified heating—are allocated to their respective user groups. Ultimately the decision on how these costs are socialised across consumer groups goes beyond the scope of this project and should remain a decision for UK Government and Ofgem.

Finally, it is important to recognise that the analysis is highly sensitive to fuel costs, which are the primary drivers of cost competitiveness between hydrogen and electrified heating. In a scenario where hydrogen remains prohibitively expensive, hydrogen heating would become a less attractive option. Therefore, government support is crucial in ensuring that hydrogen can become cost-competitive. A positive decision to consider hydrogen for heat as a viable option would help create the necessary policy and investment environment to achieve this.

Please get in touch with us at:

Cadent Gas Limited

@CadentGasLtd

@Cadent

0800 389 3000

insights@cadentgas.com

cadentgas.com

Cadent

Your Gas Network