Ecuity Consulting LLP Off Grid Heat Decarbonisation Pathways

December 2020

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Study commissioned by Calor and supported with analysis from Ecuity Consulting LLP.

The report aims to provide an overview of the potential future market for heating in rural, off-grid homes in the UK and the costs associated with illustrative pathways. Data assumptions are available in the annex. Calor Gas provided the bioLPG assumptions.

Our work was completed in October 2020.

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Contents

Ecuity Building Archetype Model

Inputs

1. Building stock and heating tech data
- Over 50 building archetypes
- Heating system and fuel costs – includes heat pumps, biofuel, and fossil fuel heating systems
- Technology replacement rates

2. Household features & behaviour
- Disposable income data
- Behavioural response modelling capability (tech laggards vs early adopters)

3. Policy scenarios
- Target emission reduction levels
- Grant and support levels

Ecuity building archetype model

- Dynamically selects heating technology solutions based on levelised cost optimisation – i.e. lowest cost solution
- Income and low carbon constraints can be used to narrow the technologies available to each household – to meet carbon targets and household budgets
- Accounts for heating system efficiency, costs and building efficiency level

Outputs

- In-depth analysis of the mix of solutions needed to cost effectively decarbonise heat.
- Understanding of the likely support levels needed to encourage switching to low carbon heat, and pace of technology transition.
- Analysis of the levels of household disposable income available for the transition and to inform national/local policy.
- Can be used to evaluate the commercial impacts of the heat transition.

Off-grid heat decarbonisation report

Challenge

- **Time left before the net zero target**. Close to 7,400 working left days before 2050 to retrofit 2 million rural households, so that they use a low-emission heating system.
- **Consumer engagement**. Some consumers are unable or unwilling to pay for retrofits. Transition needs to be low cost and easy where possible.

Report methodology

- Utilised English Housing Survey to develop over 52 rural house (non-apartment) archetypes
- Modelled low-carbon heating technology options for each property type
- Costed the options in terms of capex, opex and evaluated consumer time required for installation

Report results

1. When accounting for technology costs, the size of the "hard to treat" sector is larger than BEIS' 20% estimate of properties unsuitable for low-temperature heat pumps*

   We estimate that over 56% of properties are immediately suitable for cost-effective electrification, and/or after energy efficiency retrofit. The remaining 44% are hard to treat, and a biofuel driven boiler or hybrid heat pump solution is most cost effective, based on a provided biofuel price of 9.3 p/kWh.

2. Supporting more than one technology (i.e. biomass) for hard-to-treat properties can reduce total decarbonisation costs and offer consumer choice

   For the largest and oldest rural homes, biomass boiler costs often exceed £15,000, and heat pump with retrofit costs could reach over £30,000. Other lower cost options are needed for these consumers.

* See BEIS (2020) *Future Support for Low Carbon Heat* consultation

Decarbonising a rural home – an example

- Options faced by a typical hard-to-treat off-grid household

Mrs Smith lives in a detached home, with no major renovations that was built pre-1918. She heats the home with an old oil boiler that needs replacing.

Mrs Smith's home is representative of around **16%** of homes currently heating using oil in England.

The home typically has an annual heating demand of

31,906 kWh

Mrs Smith's home is large, with a floor area of

198m²

It would cost an estimated **£31,690** to make all these improvements with a heat pump.

Which energy efficiency **improvements** could be made to this Mrs Smith's homes?

1. **Loft insulation**
2. **Solid wall insulation**
3. **Double-glazing**
4. **PVC door**

It could take up between **31-96 hours** of Mrs Smith's own time to research, prepare, oversee and clean up from these improvements.

The question – how to support effective decarbonisation in rural areas?

- Mrs Smith is a typical consumer in rural UK. She currently heats her old, detached home using an oil boiler that needs replacing. The home also has the potential for considerable fabric efficiency improvements.

What options does Mrs Smith have for replacement of her oil boiler?

Heating Technology	LPG/BioLPG Boiler	BioLPG Hybrid	Heat Pump	Deep Retrofit with Heat Pump	Biomass Boiler	Direct Electric	New Oil Boiler
A route to heat decarbonisation ?	Yes – using bioLPG	Yes – renewables need to increase and using bioLPG	Yes – renewables need to increase	Yes – renewables need to increase	Yes – although air pollution issues	Yes – renewables need to increase	No

- Mrs Smith must switch away from oil to a low carbon alternative.
- Which low carbon option offers Mrs Smith the best choice?

The below table gives the results from this example archetype - which is an old, large detached home. See annex for further analytical results

What options does Mrs Smith have for replacement of her oil boiler?

Heating Technology	Heat Pump	Deep retrofit with Heat Pump	LPG/BioLPG Boiler	BioLPG Hybrid	Biomass Boiler	Direct Electric	New Oil Boiler
A route to heat decarbonisation?	Yes – renewables need to increase	Yes – renewables need to increase	Yes – using bioLPG	Yes – renewables need to increase and using bioLPG	Yes – although air pollution issues	Yes – renewables need to increase	No
Upfront Cost	£18,270	£31,690	£2,000	£14,960	£16,574	£1,400	
Yearly Fuel Bill	£3,040	£1,166	LPG £2,777, BioLPG £3,276	£2,705	£2,325	£5,603	
Levelised Costs	£133/MWh	£159/MWh	LPG £92/MWh, **BioLPG £108/MWh**	£123/MWh	£132/MWh	£169/MWh	
Annual Emissions	2,433 $kgCO_2e$ (2020), 478 $kgCO_2e$ (2050)	933 $kgCO_2e$ (2020), 183 $kgCO_2e$ (2050)	LPG 7,438 $kgCO_2e$, BioLPG 1,689 $kgCO_2e$	3,434 $kgCO_2e$ (2020), 1,870 $kgCO_2e$ (2050)	686 $kgCO_2e$	4,484 $kgCO_2e$ (2020), 881 $kgCO_2e$ (2050)	

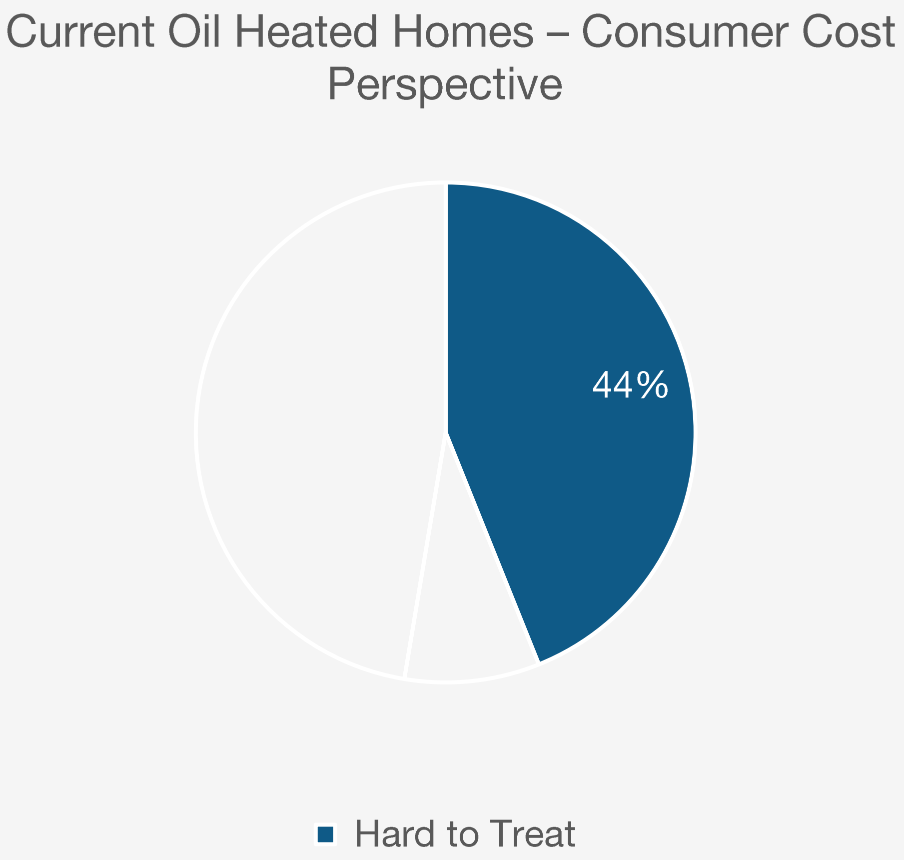
See annex for results for other archetypes

Results of the archetype analysis

- Proportion of hard-to-treat properties

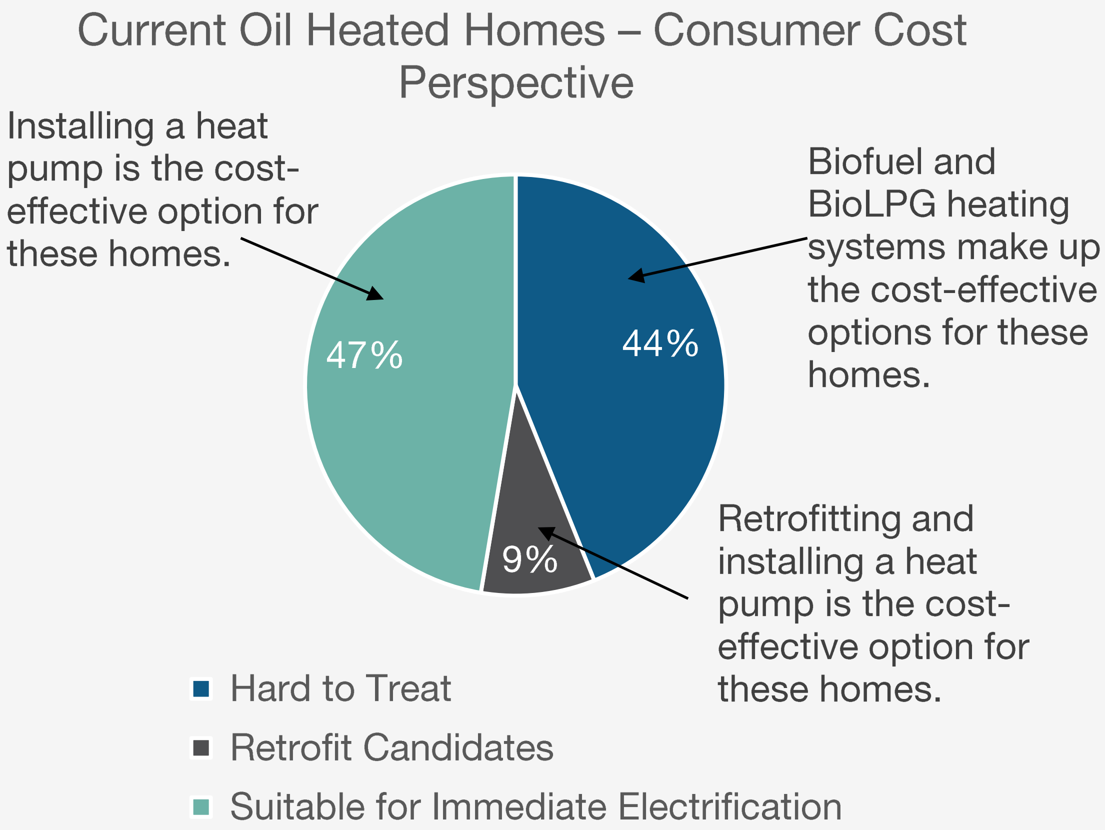
Around 44% of households currently using heating oil should be deemed as hard-to-treat from a consumer perspective.

- In 44% of homes currently heating using oil, the cost-effective low-carbon heating option is shown to require bioLPG boiler or bioLPG hybrid deployment.
- This category of homes here are defined as “Hard to Treat”.



The remaining 56% of households may be suitable for retrofits or immediate electrification.

- In 56% of homes currently heating using oil, the cost-effective option is either carry out a retrofit to allow the use of a heat pump or to immediately electrify.
- However, this route brings in wider considerations above levelised costs that may not make these properties suitable for retrofit or electrification.
- These options often require **upfront costs** that are simply unaffordable for many, there **are space and technical constraints** that may prevent the possibility of these installations, or consumers may want to avoid the **hassle and time commitment** that this route often requires.
- **This report further explores the affordability of the upfront costs of these systems through detailed household level analysis.**

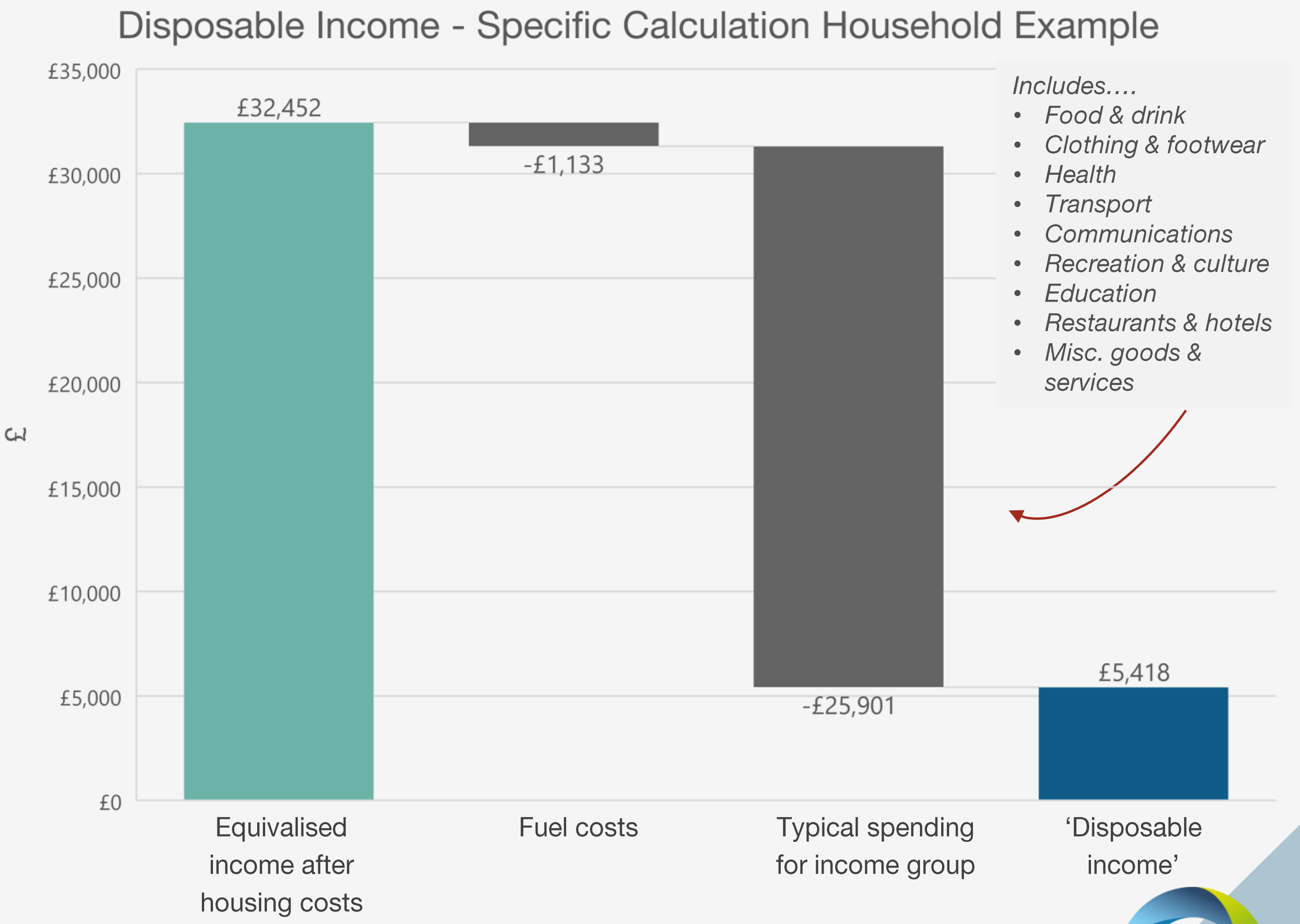


Rural income analysis

- Assessing the ability to pay for low carbon heating systems

Disposable Income

- To analyse the affordability of low carbon heating systems, a metric of 'disposable income' is used.
- The metric is designed to show the level of spending that a household could reasonably spend in additional costs on a heating system.
- Annual "disposable income" here is defined as annual equivalised household earnings after housing costs minus fuel costs, and minus typical spending on non-housing costs for that income group.
- Household earnings after housing costs (mortgage, rent) use an 'equivalised' value in line with the English Housing Survey definition, which considers the characteristics of the household and how they influence spending.

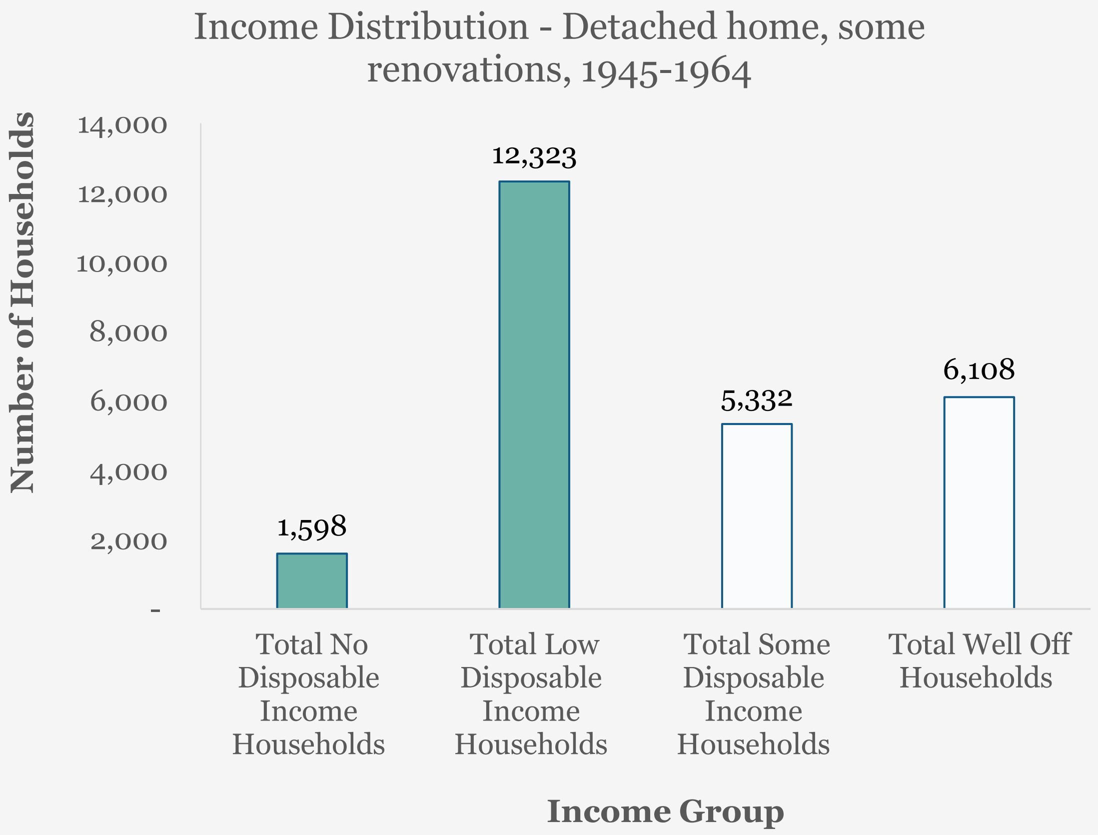


To analyse the affordability of low carbon heating systems, we've developed 4 characteristic household income groups

Household Group	**Characteristics**
No Disposable Income Households	• Household has no disposable income each year • Typically fuel poor homes • Financial assistance would be required for low carbon heating systems with higher upfront costs
Low Disposable Income Households	• If required to do so they would be able to afford a higher upfront cost low carbon heating system but would require saving 'effort' • The additional cost would require over 1 year's worth of disposable income and would often require many years of saving
Some Disposable Income Households	• Would be able to afford a higher upfront cost low carbon heating system but would require additional savings for fabric efficiency upgrades • Heating system cost only would be below 1 year's worth of disposable income, but fabric efficiency on top of this would be more
Well-off Households	• Household can afford higher upfront cost systems and energy efficiency upgrades • The additional cost would be less than a year's worth of disposable income.

Example: Detached home, some renovations, 1945-1964

This archetype is representative of around **25,400** of homes currently heating using oil in Great Britain.



Which energy efficiency **improvements** could be made to this building archetype?

1. **PVC door**

Heat pumps are the cost-effective decarbonisation option for households living in this type of home on a levelised cost basis.

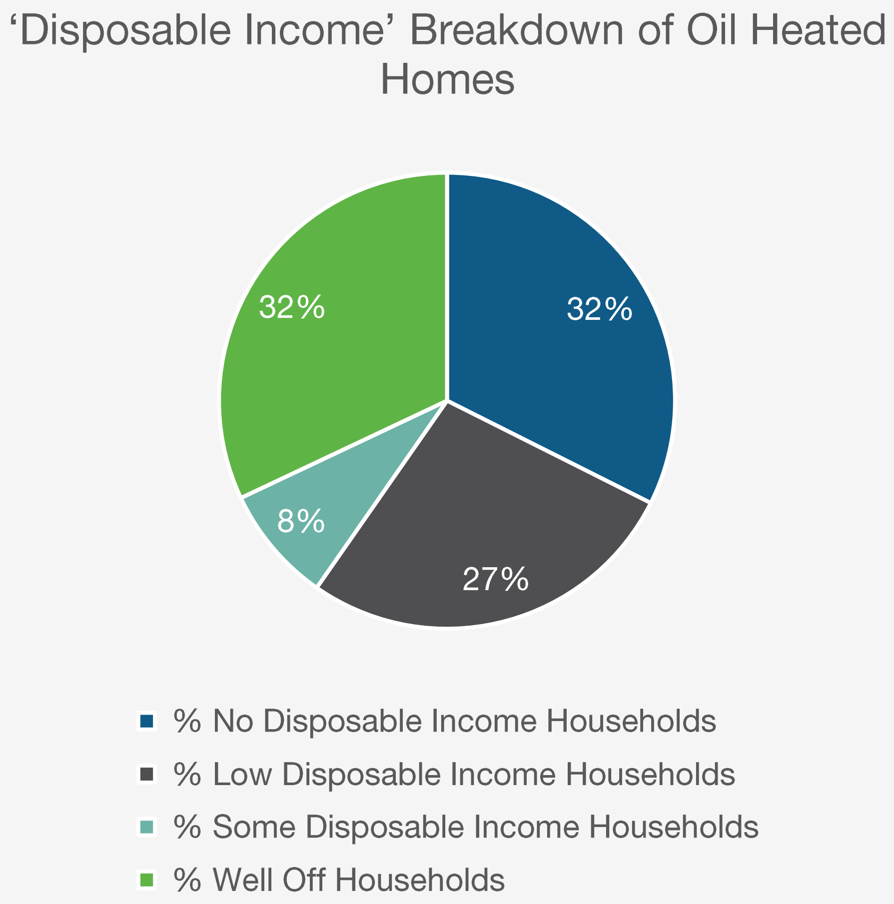
To install the **heat pump** would cost an estimated upfront

£7,290.

An estimated **55%** of households within this archetype would **not be able to afford this upfront cost.**

The picture across the total housing stock currently using oil

- The analysis conducted looked at another 51 archetypes, in addition to the previous example, to build up a picture of affordability of heat pumps across the oil heated off-grid housing sector.
- **59% of households** fall into the 'No' or 'Low' disposable income groups meaning that they would be **unlikely to be able to afford a heat pump for their property**.
- 32% of households would likely be able to afford the costs of fabric efficiency upgrades and a heat pump, falling into the 'Well Off' disposable income category.



Annex

A selection of prominent archetypes

Nine chosen to illustrate range of outcomes from over 50 separate archetypes developed

What options does Mrs Smith have for replacement of her oil boiler?

Archetype	Proportion of oil-heated homes	Fabric Efficiency Improvements	Deep Retrofit with Heat Pump Upfront Cost	Time Required for Fabric Improvements	Additional Household Time Requirement	Levelised Costs (of cheapest heating option)	Levelised Costs (of 2nd cheapest heating option)
Detached home, no major renovations, pre-1918	16%	1) Loft insulation, 2) Solid wall insulation, 3) Double-glazing, 4) PVC door	£31,000	15 ½ working days	31-96 hours	£108/MWh (BioLPG)	£113/MWh (Biomass)
Detached home, no major renovations, 1919-1944	4%	1) Loft insulation, 2) Solid wall insulation, 3) Double-glazing, 4) PVC door	£31,200	15 ½ working days	31-96 hours	£110/MWh (BioLPG)	£123/MWh (Biomass)
Detached home, no major renovations, 1945-1964	6%	1) Loft insulation, 2) Cavity wall insulation, 3) Double-glazing, 4) PVC door	£20,300	6 ½ working days	15-75 hours	£111/MWh (BioLPG)	£113/MWh (Biomass)
Detached home, major renovations, 1965-1980	7%	Improvements already carried out	£6,400	No additional time	No additional time	£97/MWh (Heat pump)	£108/MWh (BioLPG Hybrid)
Detached home, no major renovations, 1991-2003	6%	1) Double-glazing, 2) PVC door	£16,000	6 ¼ working days	9-36 hours	£104/MWh (Retrofit + Heat pump)	£108/MWh (Heat pump)
Terrace home, no major renovations, pre 1918	4%	1) Loft insulation, 2) Cavity wall insulation, 3) Double-glazing, 4) PVC door	£21,400	12 ½ working days	31-96 hours	£115/MWh (BioLPG)	£140/MWh (Biomass)
Semi-detached home, some renovations, 1919-1944	1%	1) PVC door	£6,700	½ working day	1-2 hours	£111/MWh (Heat pump)	£112/MWh (Retrofit + Heat Pump)
Terrace home, major renovations, 1965-1980	2%	Improvements already carried out	£6,200	No additional time	No additional time	£111/MWh (Heat pump)	£121/MWh (BioLPG)
Detached home, no major renovations, 2004-2009	2%	1) Double-glazing	£15,600	5 working days	4-8 hours	£101/MWh (Heat pump)	£109/MWh (BioLPG Hybrid)

* Note that proportions do not sum to 100%, this is a sample of the archetypes analysed, selected to give an illustrative cross-section of the archetypes, including those that are most common.

Annex Data Inputs – Heating Systems

Input	Amount	Units	Source
Oil Condensing Boiler Efficiency	0.89	COP	BEIS
Gas Condensing Boiler Efficiency	0.92	COP	BEIS
Biomass Boiler Efficiency	0.70	COP	BEIS
Electric storage heaters	1	COP	Assumption
Hybrid Electric Proportion of Total Load	80%		Element Energy
Hybrid LPG Proportion of Total Load	20%		Element Energy

Input	Amount	Units	Source
Oil Condensing Boiler Lifetime	15	Years	BEIS
Coal Boiler Lifetime	15	Years	BEIS
Gas Condensing Boiler Lifetime	15	Years	BEIS
Biomass Boiler Lifetime	20	Years	BEIS
Air Source Heat Pump Lifetime	18	Years	CCC
Electric Storage Heater Lifetime	15	Years	BEIS
Hybrid Lifetime	15	Years	CCC

Input	Amount	Units	Source
ASHP Capital Cost	£5,770 (3kW) - £18,270 (20 kW)	£	BEIS RHI
Oil Boiler Capital Cost	£2100 (12 kW) - £2,900 (36 kW)	£	ECO3
Oil Tank Replacement	£1250		General Internet research
Gas Boiler Capital Cost	£1,500 (12 kW) – £2,000 (28 kW)	£	ECO3
LPG Tank Rental	£65	£/year	Household Quotes
Direct Electric Capital Cost	£1,000 - £1,400	£	General Internet research
Biomass Boiler Capital Cost	£8120 (10kW) – £18100 (30kW)	£	BEIS RHI

Annex Data Inputs – Energy Inputs

Input	Amount	Units	Source
Electricity Carbon Intensity Factor	Projected Yearly	kgCO2e/kWh	HM Treasury
LPG Carbon Intensity Factor	0.2145	kgCO2e/kWh	DEFRA
BioLPG Carbon Intensity Factor	0.0487	kgCO2e/kWh	ADEME
Heating Oil Carbon Intensity Factor	0.2683	kgCO2e/kWh	DEFRA
Biomass Carbon Intensity Factor	0.0151	kgCO2e/kWh	DEFRA
B30k Carbon Intensity Factor	0.220	kgCO2e/kWh	SAP 10.1
B70k Carbon Intensity Factor*	0.1071	kgCO2e/kWh	Ecuity calculation
B100k Carbon Intensity Factor**	0.018	kgCO2e/kWh	Ecuity calculation

Input	Amount	Units	Source
Electricity Price	0.1756	£/kWh	SAP 10.1
Electricity off-peak tariff	0.1490	£/kWh	SAP 10.1
Conventional LPG price	0.0785	£/kWh	SAP 10.1
BioLPG Price Premium	0.0141	£/kWh	Calor Assumption
Oil Price	0.0435	£/kWh	SAP 10.1
Biomass Price	0.0510	£/kWh	SAP 10.1

** Calculated as 30% heating oil (DEFRA emission factor) and 70% biodiesel (SAP 10.1 emission factor) blend as per SAP 10.1 method.*

*** Calculated as 100% biodiesel blend (SAP 10.1 emission factor).*