ecuity

Turning energy policy insights into commercial results

LGUK – Wales Archetype Analysis

12th August 2021

Executive summary

This analysis compares the relative suitability of various heating methods for two Welsh archetype properties.

The methods of heating considered include: oil boilers, coal boilers, LPG boilers, bioLPG boilers, ASHPs, LPG-ASHP hybrid systems and biomass boilers.

The suitability will depend on three factors:

1. The cost to the consumer
2. The consumer income
3. The ease of the transition

Introduction

As the UK works towards a net-zero greenhouse gas emissions by 2050 target, the residential heating sector is required to phase out high-carbon forms of heating and replace with low-carbon heating technologies. Homes not connected to the gas grid, often use more carbon intensive forms of heating, primarily oil boilers. The imminent replacement of these systems therefore represents the fastest route to heat decarbonisation. Approximately 18% of Welsh homes are not connected to the gas grid, representing over 240,000 homes.[1,2]

Low-carbon alternatives however, often come at a high capital cost and low-income households are prohibited in their ability to transition to an expensive low-carbon alternative such as a heat pump. LPG is a fossil fuel, but with a lower carbon intensity to oil and gas. BioLPG, being produced from more sustainable feedstocks, provides an even lower carbon alternative. BioLPG boilers can therefore be offered as an attractive compromise; being a low-carbon heating source and available at low capital costs, they provide a more financially feasible low-carbon heating source for many households, particularly low-income households.

The following report outlines analysis which compares the capital, operational and levelized costs of various low-carbon heating systems to determine which is the most financially attractive to households. The analysis compares two archetype properties and assesses the relative suitability of each heating system. It also considers the 'consumer journey', addressing how the hassle of transitioning to a new heating system is also within consumer interest.

Results

Archetype 1:

- Detached house
- 1945 - 1964
- (Representative of approximately 24,700 Welsh homes)[1,4]
- Floor area: 134 m^2
- No major renovations (assume cavity walls – uninsulated, uninsulated pitched roof)
- Energy needed for heating: 145 kWh/m^2*year (19,430 kWh/year)[3]

Cost Breakdown:

Heating System	CapEx (£)	OpEx (£/yr) [2020]	Levelized Cost (£/MWh) [2020]	Carbon Emissions (kgCO2e/yr) [2020]
Oil Boiler	4,150	1,272	74	7,211
Coal Boiler	6,269	1,284	83	10,079
LPG Boiler	1,900	1,926	95	5,112
BioLPG Boiler	**1,900**	2,272	**111**	1,161
ASHP	11,730	2,131	138	1,705
ASHP (+R) *	19,640	**976**	144	781
Hybrid	12,350	2,012	141	1,596
Hybrid (+R) *	20,720	1,046	160	782
Biomass Boiler	18,100	1,598	131	**472**

Table 1: This table displays the upfront capital expenditure (CapEx), ongoing operational expenditure (OpEx) and the resulting levelized cost for ten different heating system scenarios. The final column on the right displays the annual carbon-equivalent emissions for each of the heating systems. The first three in the table are highlighted in orange indicating them as 'high carbon' systems, the remaining seven scenarios are deemed to be 'low-carbon' heating systems. The (+R) next to the ASHP and Hybrid options represents a scenario where the archetype undergoes renovations.

Renovations: *loft insulation (£3,100), cavity wall insulation (£950), double glazing (£8,300) – total additional CapEx: (£12,350).*

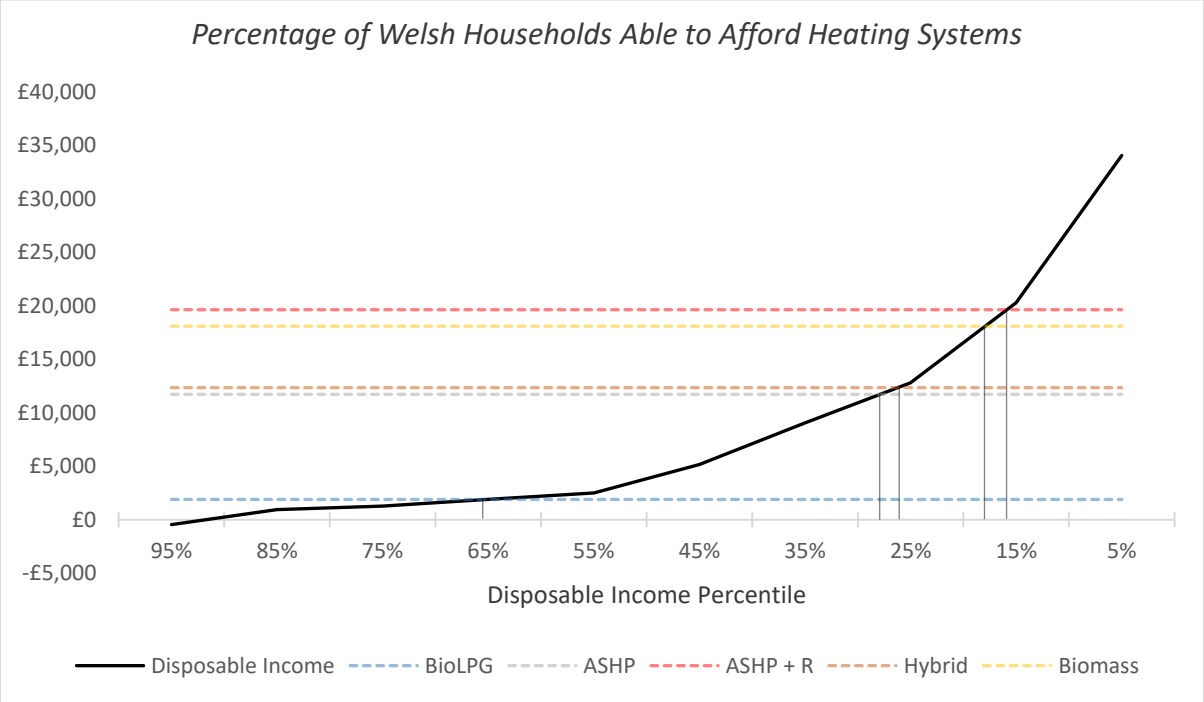
New cost of ASHP (+R) = £7,290.

New cost of hybrid system (+R) = £8,370.

Analysis:

- The lowest capital cost (low-carbon) heating system is a bioLPG boiler. All other low-carbon heating systems require a substantially higher upfront cost, with the next lowest cost system (ASHP), being over six times more expensive than a bioLPG boiler.
- The heating system with the lowest operational cost is an ASHP + R (with renovations), followed closely by a hybrid system + R. However, the upfront cost of these systems, with expensive renovation costs, are highly prohibitive.
- As well as having the lowest capital cost, bioLPG boilers also have the lowest levelized cost of any low-carbon heating system. This means that not only are bioLPG boilers the most financially accessible from an upfront cost point of view but are also the most cost-effective heating systems over the course of their lifetimes.
- Due to the high cost of renovation, the levelized costs for the ASHP / hybrid + R are higher than without renovations.
- BioLPG boilers also have the fourth lowest carbon intensity of any of the low-carbon heating systems, with significantly lower emissions than any of the high carbon heating systems.

Deriving heating system affordability via household disposable income:



Graph 1: The line graph in black shows the percentage of Welsh households existing within a certain annual disposable income range. The dashed lines are constants representing the upfront cost of each heating system. The point at which the dashed lines intersect the solid black line indicates how affordable each heating option is, with the percentage of households able to afford the system displayed along the x-axis.

Heating System (CapEx)	Percentage of households who can afford the capital cost:
BioLPG Boiler (£1,900)	**65%**
ASHP (£11,730)	28%
Hybrid (£12,350)	26%
Biomass (£18,100)	18%
ASHP + R (£19,640)	16%

Table 2: Displays the approximate percentage of Welsh households that have an annual disposable income greater than the capital cost of each of the low-carbon heating systems.

Consumer Journey:

Consumer journey measures the amount of time required throughout all stages of the installation process of a new system, indicating the amount of hassle associated with each option.

Heating System	Research, Search and Contact (hours)	Pre-Installation (hours)	Installation (Days)	Post-Installation (hours)	Ongoing (hours per year)	Approximate Total Time:
BioLPG:	4-8	3.5-8	0.5	6-16	1-2	**3.5 – 7.5 days**
Biomass:	10-18	3.5-8	1	7-17	1-3.5	**5.5 – 10.5 days**
ASHP:	10-18	3.5-14	2-5	7-20	1-3.5	**6.5 – 19 days**
ASHP + R:	10-18	3.5-14	5-8	7-20	1-3.5	**9.5 - 22 days**
Hybrid:	10-18	3.5-14	2-5	7-20	1-3.5	**6.5 – 19 days**
Hybrid + R:	10-18	3.5-14	5-8	7-20	1-3.5	**9.5 - 22 days**

Table 3: Displays the consumer journey of each heating system for the archetype.[5]

Renovation time:
Loft insulation (1 day), cavity wall insulation (1 day), double glazing installation (1 day) – total renovation time – 3 days.

Archetype 2:

- Detached rural house
- Pre-1945
- (Representative of approximately 10,700 Welsh homes)[1]
- Floor area: 198 m^2
- No major renovations (solid walls – uninsulated, uninsulated roof)
- Energy needed for heating: 142.2 kWh/m^2*year (28,156 kWh/year)[3]

Cost Breakdown:

Heating System	CapEx (£)	OpEx (£/yr) [2020]	Levelized Cost (£/MWh) [2020]	Carbon Emissions (kgCO2e/yr) [2020]
Oil Boiler	4,150	1,851	69	10,493
Coal Boiler	6,090	1,868	75	14,665
LPG Boiler	2,000	2,777	92	7,438
BioLPG Boiler	**2,000**	3,276	**108**	1,689
ASHP	18,270	3,039	139	2,433
ASHP (+R) *	31,690	**1,217**	167	974
Hybrid	14,960	2,886	131	2,284
Hybrid (+R) *	28,380	1,336	164	988
Biomass Boiler	16,574	2,325	109	**686**

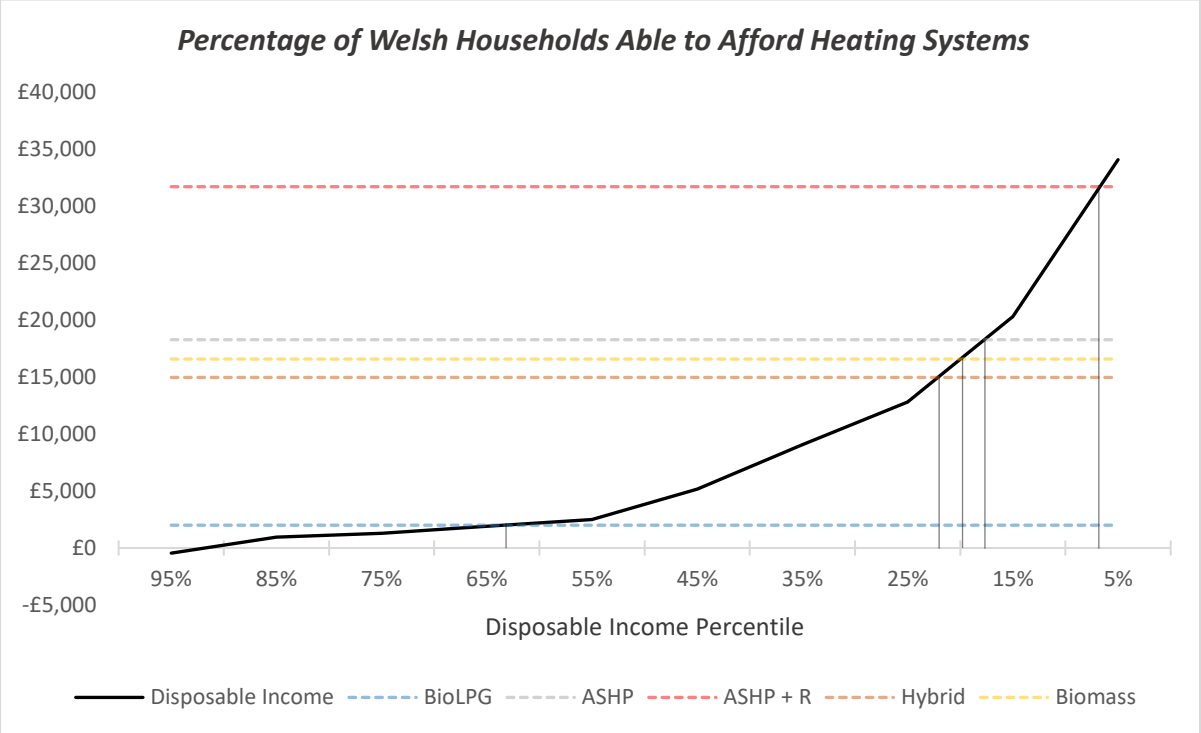
Table 4: This table displays the upfront capital expenditure (CapEx), ongoing operational expenditure (OpEx) and the resulting levelized cost for nine different heating system scenarios. The final column on the right displays the annual carbon-equivalent emissions for each of the heating systems. The first three in the table are highlighted in orange indicating them as 'high carbon' systems, the remaining seven scenarios are deemed to be 'low-carbon' heating systems. The (+R) next to the ASHP and Hybrid options represents a scenario where the archetype undergoes renovations.

Renovations: *total additional CapEx: (£13,420).*

Analysis:

- The lowest capital cost (low-carbon) heating system is a bioLPG boiler. All other low-carbon heating systems require a substantially higher upfront cost, with the next lowest cost system (hybrid system), being over seven times more expensive than a bioLPG boiler.
- The heating system with the lowest operational cost is an ASHP + R (with renovations), followed closely by a hybrid system + R. However, the upfront cost of these systems, with expensive renovation costs, are highly prohibitive.
- As well as having the lowest capital cost, bioLPG boilers also have the lowest levelized cost of any low-carbon heating system. This means that not only are bioLPG boilers the most financially accessible from an upfront cost point of view but are also the most cost-effective heating systems over the course of their lifetimes.
- Due to the high cost of renovation, the levelized costs for the ASHP / hybrid + R are higher than without renovations.
- BioLPG boilers also have the fourth lowest carbon intensity of any of the low-carbon heating systems, with significantly lower emissions than any of the high carbon heating systems.

Deriving heating system affordability via household disposable income:



Graph 2: The line graph in black shows the percentage of Welsh households existing within a certain annual disposable income range. The dashed lines are constants representing the upfront cost of each heating system. The point at which the dashed lines intersect the solid black line indicates how affordable each heating option is, with the percentage of households able to afford the system displayed along the x-axis.

Heating System (CapEx)	Percentage of households who can afford the capital cost:
BioLPG Boiler (£2,000)	**64%**
ASHP (£18,270)	17%
Hybrid (£14,960)	22%
Biomass (£16,574)	20%
ASHP + R (£31,690)	7%

Table 5: Displays the approximate percentage of Welsh households that have an annual disposable income greater than the capital cost of each of the low-carbon heating systems.

Consumer Journey:

Consumer journey measures the amount of time required throughout all stages of the installation process of a new system, indicating the amount of hassle associated with each option.

Heating System	Research, Search and Contact (hours)	Pre-Installation (hours)	Installation (Days)	Post-Installation (hours)	Ongoing (hours per year)	Approximate Total Time:
BioLPG:	4-8	3.5-8	0.5	6-16	1-2	**3.5 – 7.5 days**
Biomass:	10-18	3.5-8	1	7-17	1-3.5	**5.5 – 10.5 days**
ASHP:	10-18	3.5-14	2-5	7-20	1-3.5	**6.5 – 19 days**
ASHP + R:	10-18	3.5-14	9-12	7-20	1-3.5	**13.5 - 26 days**
Hybrid:	10-18	3.5-14	2-5	7-20	1-3.5	**6.5 – 19 days**
Hybrid + R:	10-18	3.5-14	9-12	7-20	1-3.5	**13.5 - 26 days**

Table 6: Displays the consumer journey of each heating system for the archetype.[5]

Renovation time:
Loft insulation (1 day), solid wall insulation (5 days), double glazing installation (1 day) – total renovation time – 7 days.

Discussion of Results

Heating system cost:

From a consumer perspective, the cost of a heating system is usually the primary consideration when determining the choice of heating system.

This cost includes both the upfront capital cost of the heating system and the ongoing operational costs. Consumers will pay a higher upfront cost if it results in lower ongoing costs and they are able to break-even on their higher initial investment within a sufficiently short time-period.

The levelized cost of the heating system encompasses both the capital and operational cost and indicates the total amount of money the consumer will pay over the system's lifetime. It is therefore a useful measure of the financial attractiveness of the system, with the lower levelized costs being of greater appeal.

This analysis has found the annualised capital expenditure, the operational expenditure and the resulting levelized cost of various heating systems for two Welsh archetypes that together are representative of approximately 35,000 Welsh, off-grid homes.[4]

The heating system types can be divided into 'carbon intensive' forms of heating and 'low-carbon' forms of heating. The carbon intensive forms of heating can prove to be more financially attractive than the low carbon alternatives, however, in line with the UK's net-zero targets, a gradual phase out of these high carbon systems is underway.

For these archetypes, bioLPG boilers prove to be the cheapest option when defined by both capital cost and levelized cost. This makes them not only the most affordable heating option from an upfront cost perspective, but also means that they are the most cost-effective heating system over the boiler's lifetime.

Renovating a property to improve its thermal efficiency, alongside the installation of an air-source heat pump is usually advised. This is to allow them to operate more efficiently and provide lower operational costs. The same is true for a hybrid heating system. These renovation options were therefore included in the model. However, for the two archetypes considered here, despite reducing the operational expenditure, the levelized cost increases due to the high upfront cost of the renovations.

Heating system affordability via household disposable income:

The option of paying a higher capital cost for a lower operational cost system and long-term financial gain, beyond the breakeven point, is considered differently depending on a household's level of disposable income. Whilst one heating system may provide a lower levelized cost and greater financial gain over the system's lifetime, the capital cost may be prohibitive to lower income households. Capital cost is therefore an important metric to analyse and determine the heating system's short term financial accessibility. This was done here by comparing the capital cost with household disposable income.

The household disposable income was derived from the household gross income using the following formula:

Household Disposable Income = *Household Gross Income* – *Household Costs* – *Typical Spending*

UK gross household income data from 2020 was taken from the Office for National Statistics and used to derive 'income deciles'.[6] These income deciles were then weighted for Wales by multiplying by the ratio of average UK household income to the average household income in Wales, in an attempt to create an income profile more representative of the Welsh population.[7] With the average household income in Wales being below the national average, all heating systems are in general less affordable to households in the rest of the UK.

For each gross income decile, an expected 'household cost' was derived, consisting of housing (rent/mortgage payments), as well as fuel and power costs, and this was then subtracted from the corresponding gross income decile. The additional 'typical spending' of each income decile was also predicted and subtracted from the gross income, resulting in a final 'household disposable income' value.

The affordability of the heating system was then defined. This affordability measure relies on two assumptions:

1. The household income of this archetype can be represented by the average household income in Wales.
2. If the capital cost of a heating system exceeds the annual disposable income of a household it is deemed 'not affordable'.

The results of the analysis show that bioLPG boilers are a more affordable option to a significantly higher proportion of Welsh households, than any other low-carbon heating system.

BioLPG boilers were found to be affordable to 64% to 65% of households in Wales, compared to the next most affordable heating system option only being affordable to 22% to 28% of households, (across the two archetypes).

Consumer Journey:

The other important consideration from a consumer point of view is the 'consumer journey'. This is here defined by the amount of time required to organise the replacement of the old system, the time required for the installation/renovation process and the ongoing maintenance requirements over the system's lifetime. Effectively, the consumer journey measures the convenience of the overall operation, which can also impact on the consumer's choice of heating system.

The amount of time for each stage of the process was estimated for each heating system and for each archetype, based off estimated ranges made in a previous study that considered the consumer journey in detail.[5]

For the heating systems which include renovations (ASHP + R and Hybrid + R), these renovation times were also included, adding a total of three days to the installation process.

BioLPG boilers prove to have the shortest amount of time required by the consumer throughout the installation process at between 3.5-7.5 days. The operational lifetime of a bioLPG boiler, at 15 years, is slightly less than a biomass system, at 20 years, and an ASHP system, at 18 years, meaning over a 60-year period it may need replacing one more time. However, such long time periods are of less concern to consumers.

Overall, bioLPG boilers provide an attractive consumer journey compared with other low-carbon heating system options, with low-labour requirements required over the course of the installation process and system's lifetime.

Additional Consideration - costs of electrical supply and network upgrades:

Additional to the direct consumer cost of installing a new heating system, it is important to consider the consumer and network costs associated with upgrading electricity supply. Single phase electricity supply is more prominent in UK homes. This poses a challenge for the installation of certain larger heat pumps, and needs addressing to prevent malfunctions of other electrical appliances.[8]

Not all installations require connection upgrades, but typically in properties with a large peak heat demand (100-150 W/m^2 and higher), which require a larger heat pump, upgrades to three phase supply are a realistic requirement. This adds to the upfront capex for the consumer, with upgrades varying in price but typically costing more than £3,000 per job.[9] Additionally, DNOs are facing local network costs associated with the integrating of electric vehicles and heat systems. Whilst disruption is less of a challenge and cost in rural areas, analysis suggests that DNOs will need to upgrade over 130,000 km of underground or overground cable – a greater length of network than DNOs serving urban areas.[10]

Summary of Results

1. Cost Breakdown:

BioLPG boilers demonstrated to have the lowest capital cost of any low-carbon heating system, making them the most accessible low-carbon heating option with the majority of households from both archetypes being able to afford the capital.

Despite having higher operational costs, bioLPG boilers also have the lowest levelized cost of any low-carbon heating system, making them the most affordable option over the system's lifetime.

2. Sustainability:

BioLPG boilers have carbon emissions over four times lower than any of the high-carbon heating systems (oil, coal and LPG boilers). With the present-day carbon intensity of electricity supply, they also result in less carbon equivalent emissions than both ASHP and hybrid systems. Despite not having as low a carbon intensity as biomass boilers, bioLPG is a much cleaner burning fuel with far fewer air pollutant emissions.

3. Consumer Journey:

BioLPG boilers also prove to have the most appealing 'consumer journey' with less time required over the total installation process than any other low-carbon heating system option.

References:

[1]: ONS – Statistical Bulletin (2019) https://gov.wales/sites/default/files/statistics-and-research/2019-10/welsh-housing-conditions-survey-energy-efficiency-dwellings-april-2017-march-2018-795.pdf

[2]: ONS – Household Estimates: mid-2019 (2020) https://gov.wales/household-estimates-mid-2019

[3]: TABULA Web Tool: TABULA WebTool (building-typology.eu)

[4]: Green, E., Lannon, S., Patterson, J., Variale, F. and Iorwerth, H. (2020). Decarbonising the Welsh housing stock: from practice to policy. *Building & Cities.*

[5]: Holdaway, E., Samuel, B., Greenleaf, J., Briden, A. and Gardiner, A. (2009) "The Hidden costs and benefits of domestic energy efficiency and carbon saving measures" *ECOFYS*.

[6]: Average household income, UK: financial year 2020, the Office for National Statistics: https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/bulletins/householddisposableincomeandinequality/financialyear2020

[7]: Household incomes by region (2018). House of Commons Library. https://researchbriefings.files.parliament.uk/documents/CBP-8191/CBP-8191.pdf

[8] Kensa Heat Pumps (2015) *Heat Pumps and Single-Phase Power.*

[9] UK Power Networks (2021) *Upgrade electricity: Time and cost*

[10] Vivid Economics and Imperial College (2018) *Accelerated electrification and the GB electricity system.*

Appendix:

[11]: BEIS (2018) Energy Company Obligation – Eco3: 2018-2022, Final Stage Impact Assessment.

[12]: European Commission (2017) https://ec.europa.eu/energy/studies/mapping-and-analyses-current-and-future-2020-2030-heatingcooling-fuel-deployment_en?redir=1

[13]: LPG Gas Boiler & Central Heating Costs 2021 Price Comparison (householdquotes.co.uk)

[14]: BEIS (2018) Non-Domestic RHI and Domestic RHI monthly deployment data.

[15]: Element Energy (2017) Hybrid Heat Pump, report for BEIS.

[16]: SAP 10.0 (2018) The Government's Standard Assessment Procedure for Energy Rating of Dwellings.

[17]: The Consumer Council Home Heating Oil | Consumer Council

[18]: CCC (2019) Net Zero Technical Report.

[19]: DEFRA (2018) UK Government GHG Conversion Factors for Company Reporting.

Appendix:

Capital Costs:

Heating System:	Cost:
Oil Condensing Boiler 13-24 kW	£2,700[11]
Oil Tank	£1,250
Coal Boiler <25 kW	£251 /kW [12]
Gas Condensing Boiler 19-24kW	£1,900[11]
LPG Tank Rental	*£65 / year*[13]
Biomass Boiler 21-25kW	£13,650[14]
Hybrid Heat Pump <5kW	£1,285 / kW[15]
Hybrid Heat pump 5-11kW	£625 / kW[15]
Hybrid Boiler	£1,000[15]
Hybrid Installation Cost	£2,600[15]
ASHP 13kW (ASHP)	£11,890[14]
ASHP 5kW (ASHP+R)	£6,890[14]
ASHP 10kW (Hybrid)	£10,830[14]
ASHP 4kW (Hybrid+R)	£6,870[14]

Fuel Price:

Heating Fuel:	Fuel Price:
Electricity standard tariff with VAT	0.1784 £/kWh [16]
Electricity – off-peak tariff	0.1514 £/kWh [16]
Conventional LPG	0.0785 £/kWh [16]
LPG (bioLPG premium included)	0.0926 £/kWh [16]
BioLPG Cylinder Fuel (Hybrid System)	0.1187 £/kWh [16]
BioLPG Premium	*0.0141 £/kWh* [16]
Heating Oil	0.0410 £/kWh [17]
Coal	0.0418 £/kWh [16]
Biomass	0.0510 £/kWh [16]

Heating Lifetimes:

Heating System:	**Heating Lifetimes:** [11, 18]
Oil Condensing Boiler	15 years
Coal Boiler	15 years
Gas Condensing Boiler	15 years
Biomass Boiler	20 years
ASHP	18 years
Hybrid	15 years

Carbon Intensity Factors:

Heating Fuel:	**Carbon Intensity:** [19]
Electricity	0.2831 kgCO2e/kWh
LPG	0.2145 kgCO2e/kWh
BioLPG	0.0487 kgCO2e/kWh
Coal	0.3447 kgCO2e/kWh
Heating Oil	0.2467 kgCO2e/kWh
Biomass	0.0151 kgCO2e/kWh