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LGUK – Northern Ireland Archetype Analysis

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Executive summary

This analysis compares the relative suitability of various heating methods for a typical Northern Irish archetype property.

The methods of heating considered include: oil boiler, coal boiler, LPG boiler, bioLPG boiler, ASHP, LPG-ASHP hybrid system and biomass boiler.

The suitability will depend on three factors:

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

Introduction

Northern Ireland is committed to helping the UK meet its target of net-zero emissions by 2050. This demands a decarbonisation of all sectors, including the residential heating sector which currently accounts for 14% of Northern Irelands total emissions.[1] Northern Ireland has a very limited gas network with only 24% of homes connected to gas, compared with the UK average of 87%.[1] This means that many homes currently use oil boilers for heating which have carbon emission factors far higher than that of gas.[2] Replacing these carbon intensive heating systems with low-carbon heating systems is necessary for a rapid decarbonisation and should therefore be a priority in Northern Ireland's attempt to reach its net zero targets. However, many of the low-carbon alternatives come at a high cost and low-income households are limited 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. 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 lower costs, bioLPG boilers present 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 uses an archetype typical of the Northern Irish housing stock 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

Northern Irish Archetype[3]:

- Detached house
- Pre-1900
- (Representative of up to 36% of N. Ireland housing stock)[4]
- Floor area: 106 m
- No major renovations (assume solid walled – uninsulated, some room-in roof loft insulation)
- Energy needed for heating: 161 kWh/m^2*year (17,066 kWh/year)

Cost Breakdown:

Heating System	CapEx (£)	OpEx (£/yr) [2020]	Levelized Cost (£/MWh) [2020]	Carbon Emissions (kgCO2e/yr) [2020]
Oil Boiler	3,950	1,041	73	6,262
Coal Boiler	5,962	1,115	86	8,752
LPG Boiler	1,900	1,680	97	4,439
BioLPG Boiler	1,900	1,982	**113**	1,008
ASHP	11,890	1,992	152	1,570
ASHP (+R) *	19,390	**942**	156	742
Hybrid	12,430	1,844	154	1,457
Hybrid (+R) *	20,870	983	174	735
Biomass Boiler	13,650	1,387	123	**286**

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 (£2,300), solid wall insulation (£10,200), – total additional CapEx: (£12,500).*

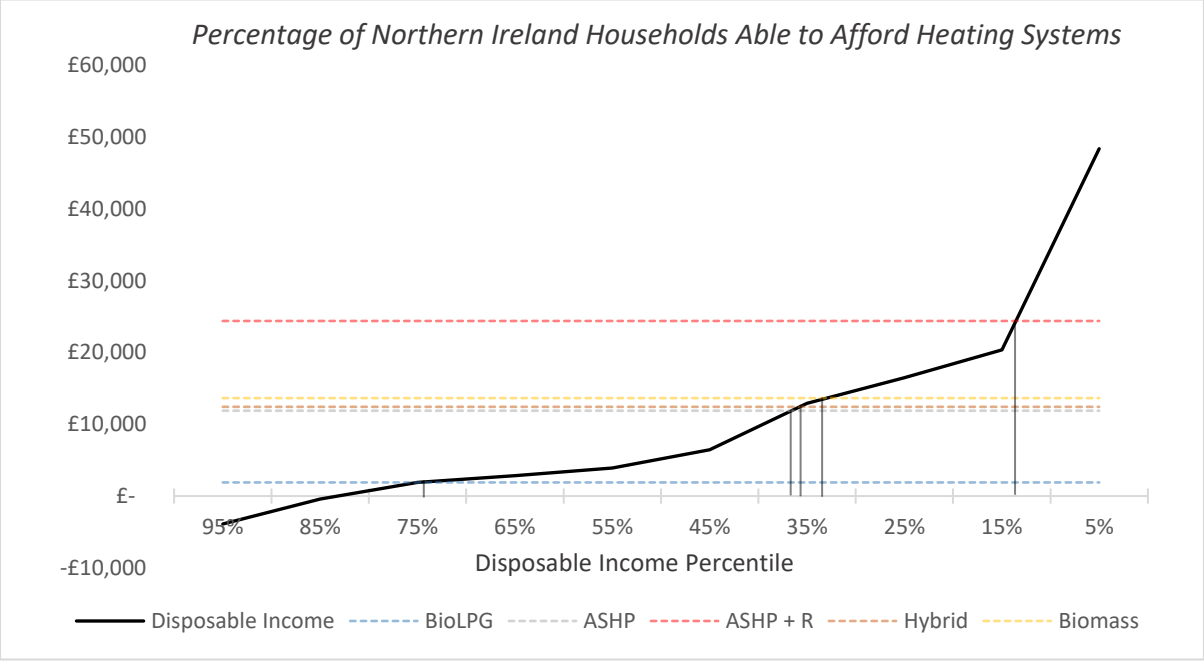
New cost of ASHP (+R) = £6,890.

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

Analysis:

- The lowest capital cost (low-carbon) heating system is a bioLPG boilers. 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 Northern Irish 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)	**74%**
ASHP (£11,890)	37%
Hybrid (£12,430)	35%
Biomass (£13,650)	33%
ASHP + R (£19,390)	14%

Table 2: Displays the approximate percentage of Northern Irish households that have an annual disposable income greater than the capital cost of each of the low-carbon heating systems, for the archetype 1 property.

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	**2.5 – 4.5 days**
Biomass:	10-18	3.5-8	1	7-17	1-3.5	3.5 – 6 days
ASHP:	10-18	3.5-14	2-5	7-80	1-3.5	4.5 – 6 days
ASHP + R:	10-18	3.5-14	6.25-9.25	7-80	1-3.5	11 - 15 days
Hybrid:	10-18	3.5-14	2-5	7-80	1-3.5	4.5 – 6 days
Hybrid + R:	10-18	3.5-14	6.25-9.25	7-80	1-3.5	11 - 15 days

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

Renovation time:
Loft insulation (0.25 days), solid wall insulation (4 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 a Northern Irish Archetype that is representative of up to 35.6% of the total housing stock.

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 Northern Ireland's net-zero targets, a gradual phase out of these high carbon systems is underway.

For this archetype property, bioLPG boilers are 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 this archetype, despite reducing the operational expenditure, the levelized cost increases due to the very high upfront cost of the renovations. This is largely a result of the property being old; it does not have wall cavities and so cheap cavity wall insulation is not possible, leaving the more expensive solid wall insulation alongside loft insulation as the most logical first steps to improving the thermal efficiency of the property.

Heating system affordability via household disposable income:

The option of paying a higher capital cost for lower operational costs 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's disposable income.

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

Data for Northern Irish specific household gross income was not available and so UK income data was used, taken from the Office for National Statistics (UK) 2020 household survey.[6] These income data, expressed in 'income deciles', were then multiplied by the ratio of average UK income to average Northern Ireland income, in an attempt to create an income profile more representative of the population.[7]

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 national income average.
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 Northern Irish households, than any other low-carbon heating system.

BioLPG boilers were found to be affordable to **74%** of households in Northern Ireland, compared to the next most affordable heating system option, ASHP, only being affordable to 37% of households.

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 4.25 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 2.5-4.5 days, considerably less than the 11-15 days required for the installation of the ASHP+R or hybrid+R heating systems. The

operational lifetime of a bioLPG boiler, at 15 years, is slightly less than a biomass system, at 20 years, and a ASHP (+R) 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.

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 3 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 each archetype being able to afford the capital.

Despite having above average 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:

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

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Appendix:

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[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.

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

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

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

[20]: 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 [17]
LPG (bioLPG premium included)	0.0926 £/kWh [17]
BioLPG Cylinder Fuel (Hybrid System)	0.1187 £/kWh [17]
BioLPG Premium	*0.0141 £/kWh* [17]
Heating Oil	0.0410 £/kWh [18]
Coal	0.0418 £/kWh [17]
Biomass	0.0510 £/kWh [17]

Heating Lifetimes:

Heating System:	**Heating Lifetimes:** [11, 19]
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:** [20]
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