Domestic heating appliances: A critical investment appraisal

March 2022

The Energy and Utilities Alliance (EUA)

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The decision to replace a natural gas boiler with a heat pump is one way to reduce the carbon footprint of home heating. As the electricity carbon intensity reduces (aiming for Net Zero in 2035), from its current level then the carbon savings will grow (assuming the carbon content of gas remains constant[1]) . Using Ofgem's Typical Domestic Consumption Value of 12,000 kWhs of gas, this is approximately 2400 kgs of carbon emitted per year per household.

There are claims made that using a heat pump for home heating also saves consumers money. This is far from clear-cut. Few studies have examined the decision to replace a gas boiler with a heat pump purely as a financial decision, using the capital investment appraisal techniques common in the accountancy profession and by economists.

This short paper does just that, using a range of techniques it sets out to establish the financial rationale for replacing a mains gas boiler with a heat pump. It seeks to combine the financial impact of the choice between replacing a gas boiler with a heat pump, both in terms of initial capital outlay and annual cost differentials throughout the appliance's lifetime. It will use a range of techniques, from the most basic of "traditional payback" where a calculation is made on how long it takes for the outflow of cash or investment to be "paid back" by positive cash inflows over the appliance lifetime; to more sophisticated discounting techniques, recognising there is a time value for money i.e. £1 today is worth more than £1 in ten years time.

1 The study ignores the impact of hydrogen blending from 2023 and potential conversion of the gas networks from 2026 from natural gas (methane) to hydrogen.

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The paper also considers a range of sensitivities around the assumptions to test at what levels the decision outcome might change.

The following techniques will be used:-
- Traditional payback
- Discounted payback
- Net Present Value (NPV)
- Internal Rate of Return (IRR)

It will examine five decisions, based on buildings requiring no retrofit expenditure and some that require external wall cladding.

A common financial model will be applied to all the cases being considered (see Appendix One), the variation in heat pump efficiency (Seasonal Coefficient of Performance (SCOP)) is modelled against an annual gas boiler running cost of £983.75 (which is based on the average Price Cap cost set by Ofgem). Any heat pump cost that is lower than this figure is shown as a positive saving to the consumer for the annual running cost.

Indicators

Traditional and discounted payback periods – the shorter the payback period the better. Consumers will be wary of anything over three years. Industry may accept longer, depending upon their business.

Net Present Value – only a positive number is justifiable on financial grounds.

IRR – any outcome in excess of the cost of capital (3%) would be justifiable.

Assumptions:-
- Boiler replacement cost £1400[2] , lifetime 15 years (straight swap of appliance)
- Gas boiler efficiency 92% as per ErP regulations (Boiler Plus).
- Heat pump installation cost £10,855[3] , lifetime 15 years.
- External wall cladding cost £12,068[4] , lifetime 25 years.
- Unit energy prices Ofgem Price Cap April 2022.
- Average consumption Ofgem TDCV gas 12,000 kWh.
- Cost of capital 3 per cent.
- Conversion from gas cooking to electric is not part of this analysis, but impact would be additional upfront capital spending.
- Additional power requirements, such as three-phase connections, are not included in the analysis, but impact would be greater with higher upfront capital spending.
- Maintenance and servicing, insurance costs are all excluded.
- No costs have been considered for disruption/redecoration as part of any heat pump installation.

2 https://www.checkatrade.com/blog/cost-guides/new-boiler-cost/ last accessed 14.2.2022
3 Clean Homes Grant Table 1.1 - Phase 1 Measures Installed, Mean Allocated Government Funding, and Mean Total Funding by Measure Type, based on data to the end of November 2021
4 Clean Homes Grant Table 1.1. ditto

Conclusions

From a purely financial position, the decision to replace a gas boiler (on the gas network) with a heat pump is irrational, based on the assumptions outlined. Of the scenarios considered, only replacing a gas boiler at the end of its life, with a heat pump guaranteed to operate at a seasonal coefficient of 5.0 or higher and being in receipt of the Government's £5000 Boiler Upgrade subsidy passes any of the financial test associated with capital investment appraisal techniques used by the accountancy profession.

Using discounted cash flow appraisal techniques, the costs to the consumer can be quantified, with some consumers being nearly £25,000 worse off switching to a heat pump from a gas boiler.

The key findings are:-

Replacing a functioning gas boiler for a heat pump delivers a worse financial outcome than replacing a boiler, like-for-like, at the end of its life. This poses delivery challenges for system change, given that a street-by-street conversion to heat pumps requires premature replacement of appliances.

Replacing a gas boiler at the end of its life is currently not a financially rational decision, under all methods of appraisal, albeit with slightly more positive outcomes than premature switching of appliance.

Having External Wall cladding fitted, to make a home suitable for a heat pump to function effectively, rules out a heat pump switch on financial grounds. The upfront costs, over £21,000 massively outweigh any financial saving from even the highest SCOP. As a result, policymakers need to find an alternative to heat pumps for homes with solid walls. This applies even when the Boiler Upgrade subsidy is paid.

The Boiler Upgrade subsidy of £5000 upfront makes a marked improvement in the financial outcomes, with more positive results shown. That said, only with a SCOP of 5.0 or higher, does it make financial sense to replace a gas boiler with a heat pump and only in homes that do not require External Wall cladding. (The proposed minimum SCOP for the Boiler Upgrade grant is 2.8 not the 5.0 needed to be financially rational).

Further considerations

- These figures are based on the April 2022 Price Cap, following a period of record gas prices. Reducing gas prices, given the UK's current energy mix, to a more normal level will make the financial decision to swap a gas boiler for a heat pump even more difficult to justify. (see annual savings chart, Appendix One)

- Conversely, if gas prices do increase, without any impact on electricity unit costs, then the financial decision becomes more favourable for heat pumps. However, using a SCOP of 3.0, the gas unit price would need to be 14.5p kWh (more than double the current record level) to deliver positive scores using NPV and IRR measures of investment appraisal.

- If electricity unit price is lower, then all other things being equal, that has a positive impact upon the decision to replace a gas boiler with a heat pump. Again using a SCOP of 3.0, the electricity unit price needs to fall to 6.6p kWh (a fall of 77 per cent on current levels) to deliver positive scores using NPV and IRR measures of investment appraisal.

- In the same manner that higher SCOPs for a heat pump improve that technologies financial performance, lower levels of gas boiler efficiency reduce it. However, new boiler installations are governed by BoilerPlus building regulations and ErP levels of efficiency are prescribed. Any further improvement in boiler efficiency levels (above 92%) will further weaken the case for heat pumps.

- Future costs of hydrogen-ready appliances have not been considered in this analysis, but their initial purchase cost is at parity with natural gas boilers following the UK manufacturers' pledge to Government, so all the conclusions above will still apply to the initial capital outlay.

- Future hydrogen unit costs are still uncertain, but the Energy Networks Association calculated a unit cost, up to 2050, of 5.59p per kWh[5] in their 2020 study. In line with point 2. above, hydrogen unit costs could rise to 14p a kWh before a heat pump with SCOP of 3.0 becomes financially more attractive.

- If the life of a heat pump is assumed to be 25 years, with a gas boiler replaced at 15 years (and all other things being equal) for a non-subsidised installation, it requires a SCOP of over 6.0 to become financially rational. With a £5000 Boiler Upgrade subsidy, the SCOP required falls to 4.0.

- This analysis does not consider off gas grid heating with oil or LPG, or other electrical heating systems. The methodology is easily transferable, should off-gas grid heating decisions come under consideration, since they are standard capital investment appraisal techniques used.

5 https://www.energynetworks.org/industry-hub/resource-library/gas-goes-green-hydrogen-cost-to-customer-report.pdf

Appendix One

Annualised cost comparison

	Based on Ofgem 12000kWh gas usage				
	Gas	Heat Pump	Difference	COP	SCOP
Heat generated (kWhs)	11040			0.92	3
Energy used for calculation	12000	3680			
Unit rate	0.0737	0.2834			
Cost of energy usage £	884.4	1042.91			
Standing charge	£99.35	£0			
TOTAL COST £	983.75	1042.91	**-59.16**		
Carbon factor	0.20297	0.23112			
Carbon emitted (Kgs)	2436	851	**1585**		

Appendix One

Heat pump savings £s v gas boiler used throughout the paper (based on April 2022 Price Cap)

SCOP 2.5	-267.74
SCOP 3.0	-59.16
SCOP 4.0	+201.57
SCOP 5.0	+358.00
SCOP 6.0	+462.29

For reference, the Price Cap from October 2021 to March 2022 delivers the following cost savings (£s)

SCOP 2.5	-352.46
SCOP 3.0	-197.90
SCOP 4.0	-4.70
SCOP 5.0	+111.22
SCOP 6.0	+188.50

Case Study One

Replace a perfectly functioning gas boiler with an ASHP.

The upfront cost is £10,855 and using a range of SCOPs for the heat pump, we obtain annual running cost savings of:-

SCOP	Annual savings £	Traditional payback	Discounted payback	Net Present value £s	Internal Rate of Return %
SCOP 2.5	-267.74	n/a[6]	n/a	-14,051	n/a[7]
SCOP 3.0	-59.16	n/a[8]	n/a	-11,561	n/a[9]
SCOP 4.0	201.57	n/a[10]	n/a	-8,449	-12.9
SCOP 5.0	358.00	n/a[11]	n/a	-6,581	-7.7
SCOP 6.0	462.29	n/a[12]	n/a	-5,336	-5.1

On this basis, there are no measures of capital investment appraisal that support replacing a gas boiler with a heat pump. Even at a SCOP of 10.0, none of the measures supports replacing a functioning boiler with a heat pump on purely financial grounds.

6 The investment does not payback in the lifetime of the asset purchased
7 Negative present value of investment, therefore no IRR
8 The investment does not payback in the lifetime of the asset purchased
9 Negative present value of investment, therefore no IRR
10 The investment does not payback in the lifetime of the asset purchased
11 Ditto
12 Ditto

Case Study Two

Replace a gas boiler at the end of its life with an ASHP.

The upfront cost reduces to £9,455 (£10,855 - £1,400) and using a range of SCOPs for the heat pump, we obtain annual running cost savings of:-

SCOP	Annual savings £	Traditional payback	Discounted payback	Net Present value £s	Internal Rate of Return %
SCOP 2.5	-267.74	n/a[13]	n/a	-12,651	n/a[14]
SCOP 3.0	-59.16	n/a[15]	n/a	-10,161	n/a[16]
SCOP 4.0	201.57	n/a[17]	n/a	-7,049	-11.7
SCOP 5.0	358.00	n/a[18]	n/a	-5,181	-6.4
SCOP 6.0	462.29	n/a[19]	n/a	-3,936	-3.6

On this basis, there are no measures of capital investment appraisal that support replacing a gas boiler with a heat pump. Even at a SCOP of 10.0, the crude Traditional Payback method would see the investment paying for itself in the final year of its life; all other measures would be negative on financial grounds.

13 The investment does not payback in the lifetime of the asset purchased
14 Negative present value of investment, therefore no IRR
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16 Negative present value of investment, therefore no IRR
17 The investment does not payback in the lifetime of the asset purchased
18 Ditto
19 Ditto

Case Study Three

Replace a gas boiler at the end of its life with an ASHP, having had External Wall cladding fitted to deliver the necessary heat pump efficiencies.

The upfront costs not increase to £21,523 (£9455 + £12068) and using a range of SCOPs for the heat pump we obtain annual running cost savings of:-

SCOP	Annual savings £	Traditional payback	Discounted payback	Net Present value £s	Internal Rate of Return %
SCOP 2.5	-267.74	n/a[20]	n/a	-24,719	n/a[21]
SCOP 3.0	-59.16	n/a[22]	n/a	-22,229	n/a[23]
SCOP 4.0	201.57	n/a[24]	n/a	-19,117	-18.2
SCOP 5.0	358.00	n/a[25]	n/a	-17,249	-13.8
SCOP 6.0	462.29	n/a[26]	n/a	-16,004	-11.7

On this basis, there are no measures of capital investment appraisal that support replacing a gas boiler with a heat pump if External Wall cladding is also needed. Even at a SCOP of 10.0, all measures would be negative on financial grounds, suggesting the investment is not financially viable.

20 The investment does not payback in the lifetime of the asset purchased
21 Negative present value of investment, therefore no IRR
22 The investment does not payback in the lifetime of the asset purchased
23 Negative present value of investment, therefore no IRR
24 The investment does not payback in the lifetime of the asset purchased
25 Ditto
26 Ditto

Case Study Four

Replace a gas boiler at the end of its life with an ASHP, but also receive the Boiler Upgrade £5000 subsidy.

The upfront costs, accounting for the subsidy, are £4,455 (£9455 - £5000) and using a range of SCOPs for the heat pump, we obtain annual running cost savings of:-

SCOP	Annual savings £	Traditional payback	Discounted payback	Net Present value £s	Internal Rate of Return %
SCOP 2.5	-267.74	n/a[27]	n/a	-7,651	n/a[28]
SCOP 3.0	-59.16	n/a[29]	n/a	-5,161	n/a[30]
SCOP 4.0	201.57	n/a[31]	n/a	-2,049	-4.5
SCOP 5.0	358.00	12.4yrs	n/a	-181	2.4
SCOP 6.0	462.29	9.6yrs	11.5yrs[32]	1,064	6.1

On this basis, the upfront costs can become a positive capital investment decision, with a heat pump COP of just over 5.0 or higher for traditional and discounted payback as well as NPV and IRR. Using the Price Cap from October 2021 to March 2022, a SCOP of 6.0 would deliver a NPV of -£2,205; and IRR of -5.2% and would not be a financially viable option.

27 The investment does not payback in the lifetime of the asset purchased
28 Negative present value of investment, therefore no IRR
29 The investment does not payback in the lifetime of the asset purchased
30 Negative present value of investment, therefore no IRR
31 The investment does not payback in the lifetime of the asset purchased
32 The investment does not payback in the lifetime of the asset purchased

Case Study Five

Replace a gas boiler at the end of its life with an ASHP, requiring External Wall cladding but also receive the Boiler Upgrade £5000 subsidy.

The upfront costs, accounting for the subsidy, are £16,523 (£4,455 + £12,068) and using a range of SCOPs for the heat pump we obtain annual running cost savings of:-

SCOP	Annual savings £	Traditional payback	Discounted payback	Net Present value £s	Internal Rate of Return %
SCOP 2.5	-267.74	n/a[33]	n/a	-19,719	n/a[34]
SCOP 3.0	-59.16	n/a[35]	n/a	-17,229	n/a[36]
SCOP 4.0	201.57	n/a[37]	n/a	-14,117	-16.3
SCOP 5.0	358.00	n/a[38]	n/a	-12,249	-11.6
SCOP 6.0	462.29	n/a[39]	n/a	-11,004	-9.3

On this basis, there is no COP that delivers a positive decision to invest in External Wall cladding, with a heat pump (even discounted by £5000). Even a COP of 10.0 returns a negative figure on all measures.

33 The investment does not payback in the lifetime of the asset purchased
34 Negative present value of investment, therefore no IRR
35 The investment does not payback in the lifetime of the asset purchased
36 Negative present value of investment, therefore no IRR
37 The investment does not payback in the lifetime of the asset purchased
38 Ditto
39 Ditto

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