Heat Pumps and Energy Retrofit - a Case Study with Policy Insights
Why a sample home with a C BER hasn't upgraded to a Heat Pump

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1. Introduction

Government policy is to install 400,000 heat pumps and carry out 500,000 home energy upgrades by 2030 [1] with the National Retrofit Plan assuming that by 2025 up to 88% of B2 upgrades will involve the installation of a heat pump [2].

There are clear advantages for the retrofit of old energy inefficient homes, e.g., those with a BER of F and G, where homes are made more healthy and comfortable, and heating costs are slashed following the (albeit expensive) energy retrofit. The considerable energy retrofit and heat pump grants available through SEAI are key enablers in this respect.

The installation of heat pumps in new energy efficient homes also continues apace with the Central Statistics Office (CSO) reporting that over 96% of dwellings built since 2015 have a BER of A, with the majority using electric heat pumps as the main heating system [3].

However, there is a cohort of Irish homes for which installing a heat pump may make little or no financial sense. The homeowners are akin to the awkward cousins at the wedding, where they don't really fit in either the newbuild group nor the energy inefficient group. The problem is that this cohort (exemplified as homes with a BER middle-of-the-road C rating) is large. Without eliminating the impediments to installing heat pumps for this group, the government will struggle to achieve the stated national targets.

The majority of dwellings constructed between 1978 and 2009 have a BER of C (and 35% of dwellings nationally have a BER of C). For over 40% of homes constructed during this period, the main space heating fuel deployed was mains gas [3], given its relatively low cost of installation and low running cost, with a kWh of gas being approximately 3.3 times less expensive than a kWh of electricity in Q1 2023 [4].

Heat pumps have the advantage of theoretically producing between three and four units of space heating for each unit of electricity consumed (known as the Coefficient of Performance, COP), which means that once installed, the cost of running a heat pump should be comparable with mains gas. But is it? For example the COP for heating hot water is typically only 2. Also space heating COPs can vary widely depending on many variables, including the specific heat pump, the energy efficiency of the home in which they operate, the difference between the internal and external temperatures, how well they were installed and operated, etc. Further, what is the cost of upgrading to a heat pump, and are the costs justifiable?

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The MacAirH (Monitoring and Comparing of Air Source Heat pumps) project [5] is a joint research project being run by UCD and MTU and aims to find out the answers to these questions for Irish homes in order to help inform policy.

MacAirH project is monitoring over 50 Irish HP installations and is calculating the actual amount of heat produced for each unit of electricity input and carrying out financial analyses. While monitoring is currently ongoing, the project is already producing interesting results, and the case study below illustrates the challenge faced by one of the largest cohort of homeowners (i.e. those with a BER of C) in upgrading to a heat pump.

2. A case study of a Deep Energy Retrofit that hasn't happened

2.1 Overview

John and Mary bought their new four-bedroom detached 175m^2 house in 1999. John is an engineer with a great interest in energy and within a few years of moving in had eliminated drafts, upgraded the attic insulation, pumped insulation to the walls, and added solar thermal Domestic Hot Water (DHW) heating, moving the Building Energy Rating (BER) from D3 to C3.

The house has the same (non-condensing) gas boiler since moving in, and John and Mary want to future-proof the house and upgrade the heating by installing a heat pump. Equally, having monitored the indoor air quality and found it to be wanting, they are keen to further improve the airtightness of the home and install Mechanical Heat Recovery Ventilation (MVHR) at the same time.

John got in touch with a One-Stop Shop (OSS) and had a survey carried out at a cost of €475, which would be reimbursed if the project went ahead. The highlights from the very comprehensive OSS report for the Deep Energy Retrofit (DER) are below:

- In order to obtain grant aid for the heat pump (HP), the building would need to be made more energy efficient first, with the Heat Loss Indicator (HLI) needing to be reduced from 2.4 to 2 W/°C m^2 or less.
- The total costs for the project would be €76k, less SEAI grants of €18.6k i.e. €57k net of grant, a saving of 25%.
    - €41k (net of grant) was needed to improve the performance of the fabric and ventilation to achieve the HLI of less than 2
    - The cost for the HP installation and associated works was €16.5k.
- As an integral part of installing the heat pump, the heating system needed to be adapted to the low-temperatures HPs. This required replacing 7 radiators, and the 300l solar DHW tank.
- In addition, the quotation included providing three heating zones – DHW and upstairs & downstairs heating zones, at a cost of €4.5k.

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It's important to remember that not only would the DER reduce the space heating demand by 21% (from a HLI of 2.41 to 1.91 W/°C m^2), but indoor air quality would also be improved because of the MVHR.

However, when (eco-warrior) John received the report, he sat down with (level-headed) Mary to go through the options. It was clear that the case for embarking on the HP installation was not clear. Not only would there be a disruptive three-month DER project, requiring the attic to be emptied, floors lifted, holes to be drilled in walls, plastering, wiring, and plumbing, but a full redecoration was going to be required for each of the rooms, given that walls would be plastered following installation of wiring to the HRV units in each room and new / moved pipework in some rooms. This would need to be added to the project costs also.

While the DER and HP project cost €57k (net of grants), the annual heating cost of heating with the electric heat pump would be reduced from €3,068 to €1,648 or €1,420 pa (at best), leading to a payback of over 40 years, much longer than the HP systems would last. By contrast, simply replacing the gas boiler with an efficient condensing gas boiler would reduce the annual cost by €437, with a payback of only eight years, with no disruption.

John decided to carry out an analysis on the overall capital and operating costs, and compare the two options open without the grant:

1. Installing a new, condensing gas boiler (€3.5k) or
2. Only installing new heat pump (€16.5k)

and compare it with the option of obtaining grant support and doing the DER and installing the heat pump (€57k).

In each case the total capital costs were obtained, and the operational costs were calculated, and an annualised figure for heating and depreciation determined for 15 (or 30 years).

In carrying out the analysis, the efficiency of the heat pump (also known as the Coefficient of Performance – COP) is key. COP figures are different for space heating and DHW, and a figure of 3.5 is the stated minimum efficiency for space heating for the proposed heat pump and the COP for domestic hot water is 2.0, leading to an overall COP figure of just under 3.

Previous research conducted in UCD correlated with a meta analysis of HPs carried out on a pan European basis [6] and found that the actual COPs for Air to Water HPs are typically 40% below the stated figures, and in-use Seasonal COPs of 2.59 being typical [7]. In this study, the manufacturers figures of 3.5 (SH) and 2.0 (DHW) were used.

The MacAirH project is important in that it will produce real life figures for the performance of heat pumps in practice in Ireland.

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2.2 Approach to carrying out the financial analysis

Three scenarios were analysed when considering replacing the existing non-condensing gas boiler with a condensing gas boiler or a heat pump:

Scenario 1: Without a DER (and therefore no grants).

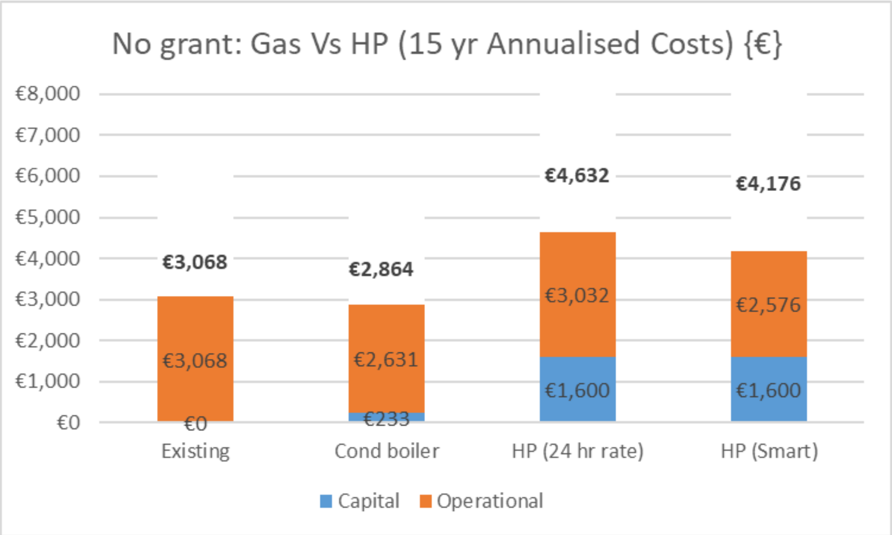
Scenario 2: Without a DER, but assuming a grant could be available to replace the HP.

Scenario 3: Carrying out the full DER assuming all grants are available.

For each of the three options, the operational and capital costs were calculated with the capital costs spread over either 15 years (for scenarios 1 & 2) or 30 years (for scenario 3, assuming the HP life is 15 years, and the insulation, HRV and windows and doors would require no further investments over 30 years). Also, the utility costs were based on those applicable to the dwelling of the time of writing (May 2023), and the smart tariffs calculated based on the hourly electricity consumption experienced in the dwelling over the previous year. All costings were based on industry quotations obtained for the case study dwelling. Detailed assumptions are listed below.

Given that the house is currently run at a constant 20°C (i.e. the same conditions recommended for a HP), the comfort levels would be very similar between HP and gas boiler but the air quality could be improved through increased ventilation rates based on the HRV installation.

Scenario 1: No Grants Are Available



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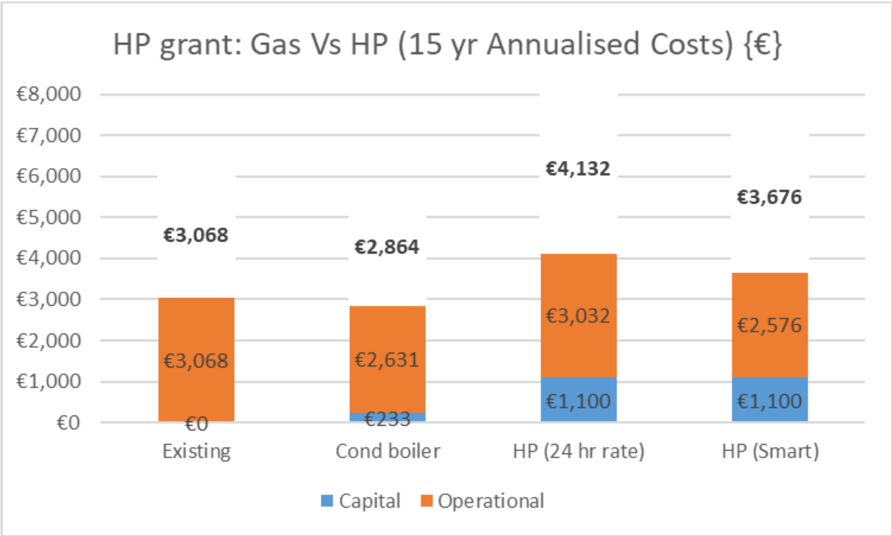
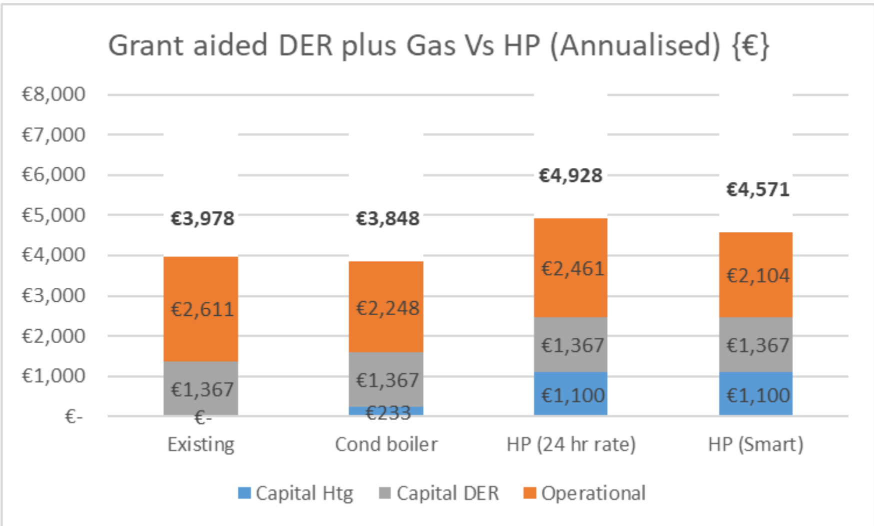
Scenario 2: If grants were available for only installing HP (without DER)



Scenario 3: DER and HP with grant aid



2.3 Results from capital and operational financial analysis

The most cost effective option is simply installing a condensing gas boiler without carrying out a DER – see bar chart for Scenario 1. Total capital cost is €3,500 (or €233 over 15 years) with running costs reduced to €2,631 pa. Overall costs are at least an extra €1,312 pa (€4,176 versus €2,864) to heat with a HP without carrying out a DER first, assuming best available smart tariffs.

Scenario one also shows that based on the standard tariffs, the annual cost of running the heat pump (€3,032) is over €400 more expensive than the annual running cost of natural gas, but by moving

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to the most advantageous smart tariffs, the HP annual running cost could be reduced to €2,576, €55pa less than the gas annual running cost.
Scenario 2 shows that even if the installation of the heat pump were grant aided at current levels (without a DER requirement), and the €152 p.a. gas standing charge therefore avoided, there would still be an extra annual cost of €812 pa (€3,676 Vs €2,864) for the HP (assuming the most advantageous smart tariffs and the manufacturers stated COP's).
Scenario 3 shows that the lowest annual running cost of all scenarios (€2,104 for the annual operational costs alone) is provided by carrying out the DER and running the HP with smart tariffs. This results in an annual operation saving of €527 compared with the condensing gas boiler in scenario 1 and 2 (€2,631 less €2,104). However, the payback of more than 31 years (given the net €16.5k HP investment) far exceeds the 15 year expected life of the HP.
Ultimately, Scenario 3 shows that DER is not financially viable, as the capital costs are an equivalent €1,367 pa, leading to an annual running cost of at least €3,848 (for the lowest cost option of a condensing gas boiler) increasing costs by almost €900 pa (€3,848 Vs €3,068) compared with the existing inefficient gas boiler without DER. Even with considerable grant funding, carrying out a DER followed by the installation of a heat pump is the most expensive option, and yields little by way of extra comfort, given the 20°C set temperature for both gas and heat pump heating systems. It should yield an improved indoor air quality given the MVHR. However, the DER expenditure of €41,000 means a 29 year payback given that the annual heating cost has reduced by €1,420 (from €3,068 to €1,648 with HP using smart tariffs).
The lowest annual operating costs of €2,104 is achieved by carrying out a deep energy retrofit with heat pump and making use of the most advantageous smart tariffs. However the additional capital cost required is €53,500 (€57,000 less €3,500) when compared with the condensing gas boiler in scenario one. The reduction in the annual operating cost of €527 (€2,631 - €2,104) results in a simple payback period of more than 100 years.
Given the influence of the HP Seasonal COP on the results, a sensitivity analysis was carried out, and in scenario two, i.e. with grant aided heat pump installation, a COP of 4.2 results in the heat pump with smart tariffs having the same TCO as the condensing gas boiler. Irrespective of the scenario, the heat pump had the highest TCO.
The official Eurostat figures (second half of 2023) for the cost of electricity for household consumers in Ireland is the third highest in Europe at €0.4199 per KWh, 48% above the EU average of €0.2840 per KWh [8]. For comparison, the cost of natural gas for households in the same period was approximately one third higher than the EU average of €0.1137 at c €0.1500 per KWh [9]. Therefore the price differential between electricity and gas was 2.5 on average in the EU and 2.8 in Ireland. This makes the financial case for HP's more difficult.

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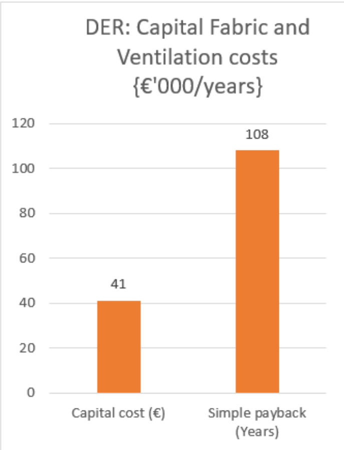
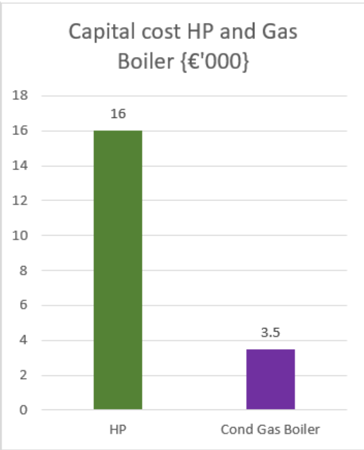
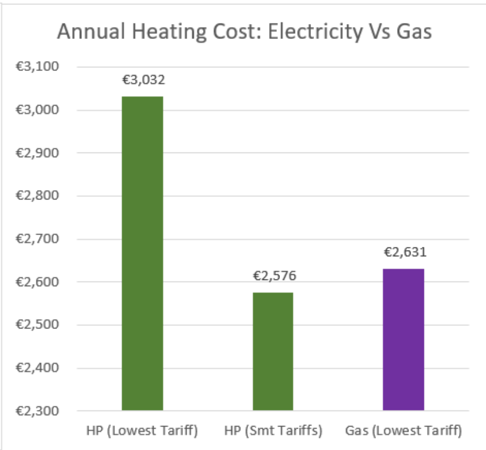
2.4 Conclusion of Case Study Total Cost of Ownership (TCO) financial analysis







- Heat pump installation is financially unattractive for the case study:

1. Overall the analysis found that the lowest Total Cost of Ownership TCO is achieved by heating with a condensing gas boiler rather than a heat pump.
2. <u>Improvements to the fabric</u> to reduce the heat loss to the required 2.0 W/°Cm^2 amounted to €41k (net of grant), yet resulted in a reduced space heating demand of only 21%, or 2,730 kWh, equivalent to an annual gas cost of €380. This gives a simple payback of over 100 years for the DER.
3. <u>The cost of the heat pump installation</u> (net of grants) amounted to €16.5k, compared with a cost of €3.5k for the installation of a condensing gas boiler.
4. <u>The annual running costs</u> for the heat pump (assuming the DER was carried out) compared with the condensing gas boiler reduced from €2,631to €2,576, or €55 annually, assuming the best case of lowest cost electric smart tariffs.

- Even if the HP installation was grant aided at current levels without requiring a deep energy retrofit, (and assuming the COP is the same with or without the DER) the additional annual costs of the heat pump compared with the condensing gas boiler are in excess of €800 per annum (assuming the most advantageous smart electricity tariffs).

In summary, the deep energy retrofit required to obtain grant funding for the heat pump was not economically justifiable, with a simple payback in excess of 100 years. Equally the cost of installing the heat pump is more than four times the cost of installing a gas condensing boiler. Once installed, the best case scenario is that the heat pump results in an annual saving of €55.

The analysis shows that specific impediments identified above need to be addressed to enable the multiple benefits of HPs to be achieved by the largest cohort of building occupants – those with moderately energy efficient buildings.

Without putting enabling supports in place, the targets for the installation of 400,000 heat pumps will be significantly impeded, with potential implications for the national strategy of decarbonising heat and improving energy security etc.

2.5 Additional (Technical) findings from the case study analysis

- The installation of low-temperature HPs requires the replacement of 9 existing high-temperature radiators and coils in a DHW cylinder. This results in high (grant aided) costs and significant additional embodied carbon. These requirements could be avoided by using a high temperature HP, which could work effectively with the existing radiators and DHW coil, obviating their replacement.
- Given the preferred operating condition for HPs is steady temperatures throughout the dwelling, the cost (and grant aiding) for the installation of a minimum of three zones could potentially be avoided.
- Similarly, the requirement for the HP to heat DHW in addition to space heating results in the requirement to replace the existing 300 L DH W tank. For dwellings where solar thermal DHW is already in place, financial and carbon benefits would accrue by simply using low carbon intensity and inexpensive night time electricity to top up the DHW as required, rather than having to replace the 300 l DHW tank with one with a high temperature coil.
- For the case study dwelling, grant aiding a high temperature HP could enable the C3 dwelling to achieve the required B2 in one step at minimal cost.
- An SEAI trial project currently underway is determining the extent to which HPs can operate effectively at Heat Loss Indicators between 2.3 and 3.0. This is important as it will determine if deep energy retrofits are essential before HPs are installed.

3. Irish Heat Pump Policy Implications

The case study illustrates the difficulty encountered for one of the 35% moderately well performing dwellings (i.e. with a BER of C) in embracing heat pump technologies in Ireland.

Key findings include:

- The current practice of requiring a DER prior to HP installation results in the overall HP and DER project being financially unattractive, as simple payback exceeds 100 years.
- The a high capital HP cost (€16,500) compares unfavourably with the alternative of a gas condensing boiler (€3,500). Further supports are required to enable the transition to heat pumps.

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- Grant aiding high-temperature heat pumps has the potential to reduce costs and increase the proportion of dwellings for which HP installation could take place obviating / reducing the need for deep energy retrofit.

- The relatively high cost of electricity results in higher total annual HP costs compared with mains gas heating based on standard tariffs. The case study indicates that operational cost parity can be achieved using currently available smart tariffs. There is potential for development of smart tariffs tailored to further enhance the financial viability of HPs.

- Annual running costs of the case study HP were hampered by the relatively high cost of electricity compared with gas (2.8 times higher). The price differential compares with the (theoretical) COP of 2.9 for the heat pump, meaning HPs have a marginal theoretical advantage.

- Research being carried out by UCD and MTU (under the MacAirH project) will determine the actual in use COP of Irish HPs, which may be lower than the theoretical the COP, indicating more favourable HP-specific smart tariffs may be required.

4. Key Assumptions in Analysis

- The existing dwelling heating set temperature of 20°C is well suited to HP operation.
- This has resulted in 21,000kWh pa of gas consumption using the existing noncondensing boiler
- If HP used, there would be a saving of €152 pa for annual gas connection.
- Smart meter tariff analysis assumes night time heating at same rate as day, despite colder nights.
- DHW is 20% of total heating consumption, given use of solar thermal panels.
- Gas and HP servicing costs assumed equal at €200 pa.
- DER costs: Ventilation, Windows & doors, Internal & attic insulation = €58k-€17k= €41k.
- Inflation not taken account of in analysis.
- Gas and electricity rates are correct at May 2023, and are based on the lowest available rates.
    - Gas: SSE Airtricity 0.1293 per kWh, SC €152pa.
    - 24 Hour Electricity: Energia 0.4359 per kWh, 266 SC.
    - Smart Meter tariff: Electric Ireland Day €0.4623, Night (11pm - 7am) €0.2155, Car Night (2-4am), SC €397.

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