

Optimal residential heating decarbonisation: Comparing the cost of biomethane and heat pumps from the household perspective

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Abstract

Residential heating is a substantial contributor to global greenhouse gas emissions. To decarbonise this sector, heat pumps may compete with faster drop-in solutions, such as biomethane, in existing buildings. Heat pumps require high upfront investments by households, both in the heat pump and for improvements in dwelling insulation, but they have low running costs. Biomethane requires no changes to the household heating system but has high running costs. We develop a microsimulation model to compare the direct costs of the two options for households with existing gas central heating over a 15-year period, using the Irish Household Budget Survey from 2015/16. We find that, without subsidies, 59.8% of households benefit financially from heat pumps, while the remainder would benefit financially from adopting biomethane. Using the example of the Irish government grants for heat pumps and home retrofits, we find that 77.6% of households would benefit from heat pumps over biomethane if heat pump grants are available, leaving 22.4% of households for whom biomethane remains the less costly option. The main factor determining which of the heating options was financially advantageous was a households' current fossil gas consumption, with higher-consuming households significantly more likely to benefit from a heat pump. Our findings highlight that most households would benefit financially from a heat pump over biomethane, driven by the high estimated biomethane price and to a lesser extent by government grants supporting heat pump adoption. However, even with the grants, for some households with low gas consumption paying the higher biomethane price is more advantageous than facing the high upfront costs of a heat pump and retrofit. Our analysis is limited to direct household costs and does not account for the wider benefits and costs associated in particular with building retrofitting, which would be an interesting avenue for further research.

1 Introduction

Emissions from residential buildings accounted for 12.5% of global greenhouse gas emissions in 2021, representing the largest contribution from a single end use (Ge et al., 2024). Heating is one of the primary sources of these emissions, with about 50% of global energy use in buildings going towards space and water heating (IEA, 2023). Decarbonising residential heating is, therefore, an important factor in reaching global climate targets.

Past research on biomethane in residential heating as a strategy to decarbonise the residential sector is scarce, possibly due to priority being given to use in hard-to-abate sectors, which have no other abatement options (see e.g., SEAI, 2022a). The research that does exist looks at policy frameworks around biomethane (Herbes et al., 2021), providers' pricing strategies (Herbes et al., 2016), and consumers' perceptions and factors influencing their decisions to adopt biomethane (Rilling and Herbes, 2022). Despite the important role clearly accorded to cost, there has, however, been no direct cost comparison with the main heating alternative, namely heat pumps. This is the gap we address in this research to see whether, from a household cost perspective, biomethane presents a more attractive option than heat pump installation for households that already have a gas boiler and would therefore not be required to make any changes in the case of a switch to biomethane.

A widely favoured decarbonisation option is heat pumps, which are several times more efficient than other heating systems since they do not create heat but rather move existing heat from outside to inside a home to heat it (IEA, 2023). While the heat pump market grew substantially between 2019 and 2022, 2023 saw a drop due to less favourable economic and political conditions (IEA, 2024a). Most countries saw a strengthening again around the first half of 2024, except the European Union (EU), which saw an astounding drop of almost 50% (IEA, 2024b). The recent decrease can be attributed to a range of factors (IEA, 2024a,b) but past research has shown that economic factors, in particular upfront costs, are one of the main barriers to heat pump adoption (Karytsas and Choropanitis, 2017; Meles and Ryan, 2022). In addition to the cost of the heat pump itself, installing heat pumps in existing buildings faces challenges due to the lower temperature heat provided by heat pumps (Lämmle et al., 2023), so that frequently prior retrofitting of these buildings is required to ensure an efficient use of the heat pump. This adds further, often substantial, upfront costs (SEAI, 2025d).

Given the need to decarbonise residential heating quickly and the barrier upfront costs represent for heat pump adoption, comparing heat pumps with drop-in renewable alternatives, such as biofuels, can provide additional insights on transition pathways. In our analysis, we focus on the EU, where heat pump adoption has recently plummeted. We compare heat pumps to biomethane, which is produced from organic feedstocks and can directly replace fossil gas, the primary household space heating fuel in the EU (ODYSSEE-MURE, 2025). Using biomethane avoids up-front costs for consumers, but it does come with high running costs due to high biomethane prices¹.

As evidenced by many studies, household decisions on heating systems are not made on price alone and many other considerations such as comfort, house ownership, other people’s experiences, and positive and negative associations with an energy source all factor into the final decision as well as the ability to make a change in the first place (Middlemiss and Gillard, 2015; Rilling and Herbes, 2022; Meles and Ryan, 2022). These elements are not covered in our analysis which only assesses which option is preferable financially for a given household.

Since dwelling types and associated costs, household energy consumption, and household income vary widely, the cost profile will be unique to each household. Consequently, we chose a microsimulation approach to understand the impacts on a wide range of different households. Many governments have put in place grants to support the roll-out of heat pumps. In altering upfront costs, such grants have the potential to strongly impact households’ heat pump adoption (Karytsas and Choropanitis, 2017; Meles and Ryan, 2022). To take this policy environment into consideration, we conduct our simulation exercise in the context of a case study of Ireland, which makes extensive heat pump support grants available to households, and apply these grants to households’ costs.

The article is split into six sections. Section 2 covers the data used as well as the process of imputing the Building Energy Rating (BER) from the BER dataset onto the Irish Household Budget Survey to enable the calculation of retrofit costs. Section 3 covers the microsimulation model. This includes the status quo scenario of using fossil gas for heating, the heat pump scenario, consisting of retrofit and heat pump costs, and the biomethane scenario which replaces fossil gas with biomethane. Additionally, the comparisons are rerun under consideration of the home upgrade grants provided by the government. Section 4 presents the results of the analysis. We outline both the number of households benefitting under each scenario, and the characteristics of these heat pump vs the biomethane households. Finally, we discuss the results and conclude in sections 5 and 6.

2 Data

2.1 Household Budget Survey

Our main microdataset is the Irish Household Budget Survey (HBS) from 2015/16, accessed through the Irish Social Science Data Archive. The HBS represents a randomly selected sample of private households in Ireland, and household and expenditure data are collected through a questionnaire and expenditure diary, respectively. The 2015/16 survey contained a sample of 6,839 households, of which, after data cleaning, we identified 2,383 as households that have full gas-powered central heating.

Table 1 gives an overview of our sample. A little under half of the households in our sample have dependent children, most live in semi-detached or terraced houses, with about half of the dwellings

¹As of 18/08/2025, the German wholesale year-ahead biomethane price was around 8 €/cent/kWh (agriportance, 2025) and the wholesale fossil gas futures price around 3 €/cent/kWh (Trading Economics, 2025).

built before 1980. Almost 60% of households in our sample are located in Dublin, and nearly all households are based in urban areas, likely linked to greater access to the gas network in those areas. Average weekly income is around 1,000€, and average weekly expenditure on gas is around 18€.

Table 1: Descriptive household statistics

	Summary
N	2,383
Weekly income	1,084 (1,194)
Dependent children	
No	1,352 (57%)
Yes	1,031 (43%)
Dwelling type	
Detached house	319 (13%)
Semi-detached or terraced house	1,786 (75%)
Apartment	268 (11%)
Other	10 (0%)
Accommodation age	
1980 or older	1,154 (48%)
1980 - 2000	503 (21%)
2001 or newer	726 (30%)
Region	
Border, Midland and West	170 (7%)
South West, South East, Mid West, Mid East	813 (34%)
Dublin	1,400 (59%)
Urban/rural	
Urban	2,352 (99%)
Rural	31 (1%)
Weekly expenditure on gas	18 (15)

Note: For continuous variables, the mean is displayed with the standard deviation shown in brackets. For factor variables, the frequency is shown with the percentage in brackets.

2.2 Building Energy Rating dataset

The HBS does not include variables detailing buildings’ energy efficiencies, which are, however, necessary to calculate home upgrade costs as well as post-upgrade energy costs. As a result, we complemented the HBS with data from the Sustainable Energy Authority of Ireland’s (SEAI) Building Energy Rating (BER) dataset. This dataset contains microdata on all dwellings in Ireland which have a BER certificate; it had roughly 1.3 million entries at the time of download. A BER certificate is required for all new dwellings and for existing dwellings that are either being sold or rented, as well as to apply for specific home upgrade grants. The dataset details building characteristics, including the building energy rating, which is the expected primary energy use for the dwelling in kWh/m²/year, and is divided according to a 15-point A to G scale (see [CSO, 2025a](#)). Following [Curtis et al. \(2015\)](#) and [Tovar Reaños \(2021\)](#), we use variables included in both the BER and the HBS dataset, namely the age of dwellings, the type of heating system, and the dwelling type, to predict the BER for households in the HBS based on coefficients obtained from the BER dataset.

3 Microsimulation model

3.1 Status quo: Fossil gas heating

To determine the starting point of our scenarios, we calculated the current levels of households’ gas consumption for heat. This was achieved by dividing the data on gas prices by consumption bands ([Eurostat, 2025b](#)), using the expenditure data provided for each household. Additionally, the 2015/16 expenditure values were adjusted for inflation to represent 2024 prices using the Harmonised Index of Consumer Prices (HICP) for Ireland ([Eurostat, 2025c](#)).

As an additional expense, we included the cost of a gas boiler upgrade in this scenario since gas boilers have an approximate maximum lifespan of 15 years (Bord Gáis Energy, 2025a) and therefore would need to be replaced at least once during the 15-year period we are looking at. A new gas boiler costs about 3000€ (Selectra, 2025; Bord Gáis Energy Local Heroes, 2025). We assume that households would pay for this upfront, and therefore, no interest accrues on top of the initial cost. As a result, the annual cost over the 15 years is 200€.

3.2 Scenario 1: Household retrofit and heat pump installation

3.2.1 Retrofit and heat pump installation costs

In line with Irish government policy, which targets the retrofitting of homes to a B2 standard, we identify those households as heat-pump-ready that have a B2 or better BER rating, or where dwellings have been built recently². All other households are assumed to require retrofit works for a heat pump to be installed.

For households that require a retrofit, we use the estimated average retrofit costs associated with a retrofit to a B-level BER rating as calculated by Kren et al. (2024, p. 41, fig. 4.3. (3) Quadratic fit³). These are broken down by starting BER rating but not by dwelling type. To account for dwelling types, we used the median cost of retrofit by dwelling type provided by the SEAI (SEAI, 2025d, p. 13). Since the median dwelling type in terms of retrofit cost is terraced and semi-detached houses, we adjusted costs downward for apartments and upward for detached houses. To determine the adjustment factor, we took the percentage change in median cost of work between terraced/semi-detached houses and the other two dwelling types respectively. Since this percentage differed between private homes and dwellings owned by Approved Housing Bodies, we took the average between the two percentages. Our cost estimates are likely on the higher end of what would be required to achieve a B2 rating, as most observations included in the paper by Kren et al. (2024) involved an upgrade to B1.

For the installation of a heat pump, all households were assigned a cost equal to the median cost paid for a heat pump under the government’s Better Energy Homes scheme (SEAI, 2025d)⁴. This was added to the cost of retrofit, where dwellings were not yet heat pump-ready.

These costs for each household were then annualised over the course of a heat pump’s lifespan, approximately 15 years (Bord Gáis Energy, 2025b) following Meles and Ryan (2022). However, with different values for lifespan and heat pump cost and with the lowest available annual percentage rate (APR) offered by banks (SBCI, 2025) instead of the interest rate, to more accurately reflect household cost. The equation for the annualised retrofit (+ heat pump) cost is the following:

$$AUC = \frac{(\text{Retrofit cost}_{BER} + \text{heat pump cost}) * ARP * (1 + ARP)^L}{(1 + ARP)^L - 1} \quad (1)$$

where AUC is the annualised upgrade cost; the retrofit cost varies according to starting BER; and L is the lifespan of a heat pump.

3.2.2 Fuel cost changes

To determine the reduction in fuel consumption post-retrofit, we then used the SEAI’s archetype data on average fuel consumption and energy demand by dwelling type, BER rating, and primary heating source (SEAI, 2022b, supporting data). We calculated the percentage change between the average fuel used for space and water heating for a gas-heated dwelling, at each given BER rating⁵, and the average fuel use of a B2-or-above rated dwelling with electric heating. Instead of using the direct fuel use information from the archetype data for the latter, we used energy demand divided by 4 to represent the Coefficient of Performance (COP) of a heat pump (Dimchev et al., 2024). We chose this

²Homes built from 2007 onwards are assumed to experience sufficiently low heat loss as to not require additional retrofit works (SEAI, 2025b). Due to constraints in the granularity of our data, we only included houses built after 2010 in our model.

³The quadratic fit was chosen as it had high predictive power and had costs increasing less for the C1 range, compared to worse BERs, than the cubic fit.

⁴The only scheme which provides grants for individual measures and therefore has a breakdown of cost by measure. Eligibility for this scheme is very broad (owner occupiers, landlords, registered charities, etc.), so the cost should be reflective of wider heat pump costs.

⁵The archetype data distinguishes between seven different categories: A1-B2, B3-C1, C2-C3, D1-D2, E1-E2, F, and G.

approach because some households in this category may use alternative forms of electric heating, such as heat pumps, which could make the average fuel use value an unreliable estimate for a dwelling with a heat pump.

This percentage change was then applied to each individual household’s initial gas consumption to identify the post-retrofit fuel consumption. In this way, we hoped to preserve the wide distribution in energy consumption behaviours between households, which is related to a range of factors unconnected to the characteristics covered by our analysis (Bae et al., 2023).

Finally, based on the predicted post-retrofit electricity demand, households are assigned an electricity price in line with their consumption band (Eurostat, 2025a) and their new fuel costs calculated accordingly.

3.2.3 Total annual savings/costs

To determine whether, and how much, households are saving, or their costs are increasing compared to the status quo, we add the annualised retrofit costs to the annual electricity costs and subtract the current expenditure on fossil gas:

$$ACS = (C_E * P_{E,2024} - Exp_{G,2024}) - AUC + ABC \quad (2)$$

Where ACS is annual costs or savings from retrofit and heat pump installation; C_E is the electricity consumption post-upgrade; $P_{E,2024}$ is the price of electricity in 2024, which varies by consumption band; $Exp_{G,2024}$ is the gas expenditure of households at the 2024 gas price level; and ABC is the annualised gas boiler cost.

3.3 Scenario 2: Biomethane

The second scenario we investigate involves using biomethane as an alternative to retrofitting and installing heat pumps. As there is not yet an established biomethane market in Ireland, we rely on cost estimates. Studies estimating the cost of domestic Irish biomethane almost exclusively calculate production costs and minimum wholesale sales prices (see, e.g., Murphy and Power, 2009; Vo et al., 2017; SEAI, 2022a; Bose et al., 2022; Wu et al., 2023; Padi et al., 2023), from which we then extrapolate the residential retail price. Most of the production cost estimates fall between 3 and 13 €cents/kWh, and we use the official government estimate of 10.5 €cents/kWh (SEAI, 2022a) for our analysis. We then divide this by the fossil gas wholesale price, which we calculate as the 12-month-average for 2024 (based on Utilityfair, 2025). We then use the so derived ‘biomethane multiplier’ to multiply household expenditure values, thereby estimating a household’s expenditure on biomethane instead of fossil gas. On the one hand, this is an overestimation because fixed cost charges do not increase in line with volatile costs, and we do not account for behavioural changes resulting from higher prices. On the other hand, purchasing biomethane as a certified renewable gas through biomethane certificates will likely come with a higher price tag, which is not yet included in the cost estimate.

3.4 Impact of home upgrade subsidies

The Irish government runs three subsidy schemes to incentivize the uptake of home upgrades. The Warmer Homes Scheme is the most comprehensive of the three, covering the full upgrade costs to households which receive certain welfare payments (e.g., Fuel Allowance, Job Seeker Allowance) if they own and live in a dwelling that was built before 2006⁶. These requirements were approximated as best as possible, given the available data (for a full description, see the supplemental material), and the cost of the home upgrade was reduced by 100% for households that met the criteria.

The other two schemes, the National Home Energy Upgrade Scheme (also known as the One Stop Shop scheme) and the Better Energy Homes Schemes provide similar grant amounts and differ mainly in the administration⁷, so we grouped them in our analysis. To be eligible for funding under these schemes, the dwelling in question must have been built and occupied before 2011, or before 2021 if only seeking financing for heat pumps. To calculate the support likely to be received under these programmes, the average grant amount was calculated as a percentage of the average cost of works, by

⁶For the full conditions, see SEAI (2025e)

⁷For the full conditions, see SEAI (2025c,a).

dwelling type, with numbers taken from [SEAI \(2025d\)](#). The retrofit cost for each household was then reduced by a respective percentage, according to their dwelling type. For heat pump ready buildings, the standard subsidy for a heat pump system under both schemes (€6,500 for houses, €4,500 for apartments) was subtracted from the heat pump cost.

The annualised retrofit and heat pump cost above is adjusted as follows to account for the subsidy schemes:

$$AUC = \frac{(\text{Retrofit cost}_{BER} + \text{heat pump cost} - \text{subsidies}) * ARP * (1 + ARP)^L}{(1 + ARP)^L - 1} \quad (3)$$

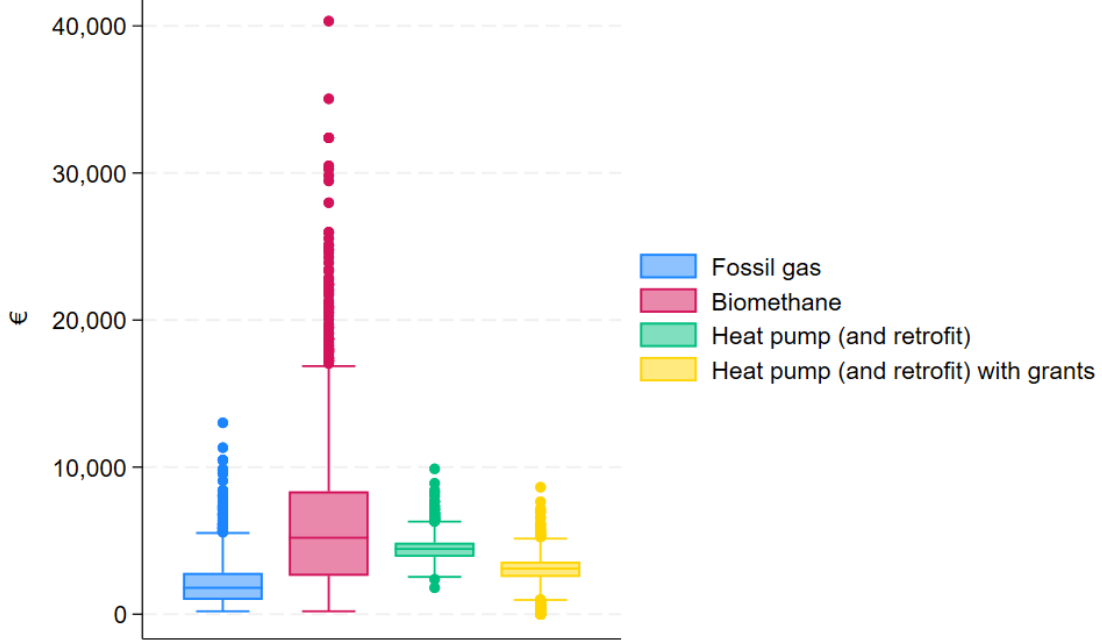
and the annual costs or savings from retrofit and heat pump installations are recalculated.

4 Results

4.1 Percentage of households benefitting financially from the heat pump vs the biomethane option

Figure 1 shows the annual fuel costs faced by households depending on the different sources of heat. For the heat pump scenarios, this included the annualised cost of retrofit. In the status quo, i.e., fossil gas, households face the lowest average annual costs at roughly 2,000€. Of the two renewable alternatives, biomethane is the most expensive at an average yearly cost of over 6,000€. This scenario also displays by far the widest spread in costs, with high maximum costs reaching up to several tens of thousands of euros annually. For both heat pump scenarios, the range is more compressed. The average annual cost of a heat pump, including retrofit, was around 4,500€ without grants, but this decreased to less than 3,000€ with grants.

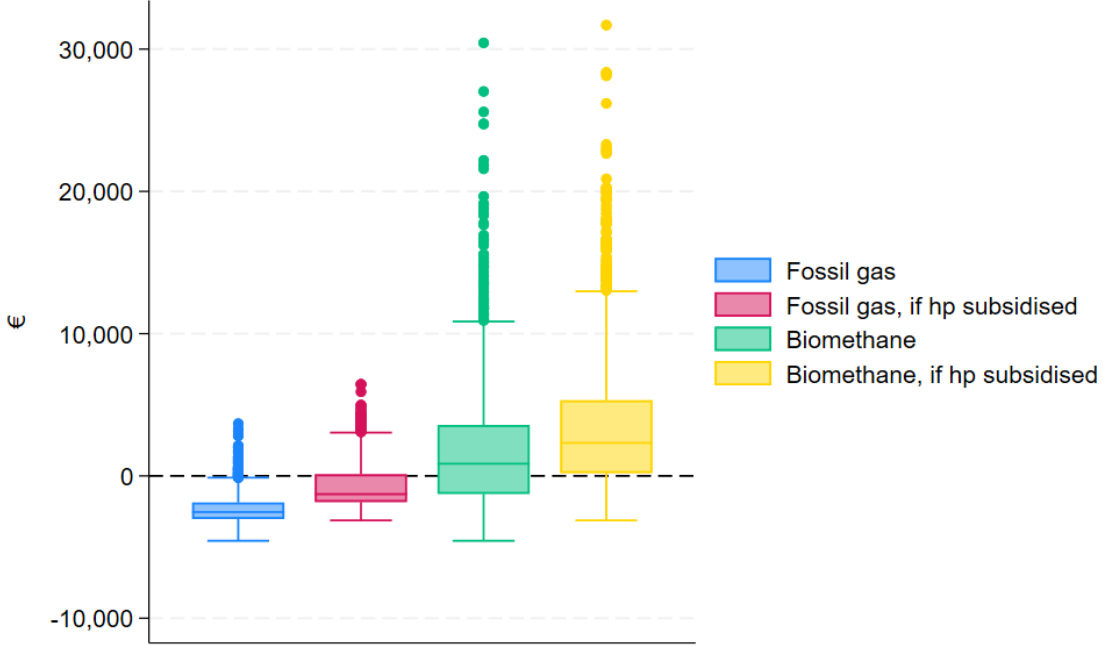
Figure 1: Annual fuel (and retrofitting) costs by heating type



However, while the average cost for biomethane was higher, it is nonetheless the cheaper option for some households. Figure 2 displays the household savings from heat pumps (including retrofit) compared to fossil gas and biomethane, both with and without government retrofit and heat pump grants. At current fossil gas prices, most households pay more for the heat pump scenarios over the 15-year period than for the fossil gas option. However, when comparing the heat pump scenario to

biomethane, 59.8% of households benefit from the heat pump scenario even without grants, and this increases to 77.6% once the grants are added. This leaves 22.4% of households for whom biomethane is the less costly option over this time frame.

Figure 2: Annual savings from a heat pump (+ retrofit) by comparison fuel



Note: Each box represents the annual savings from a heat pump (+ retrofit) compared to the respective alternative heating options. *hp subsidised* variants compare the alternative heating option to the heat pump (hp) if grants are provided for heat pump installation (including cost of retrofit).

4.2 Characteristics of households benefitting from the heat pump vs the biomethane option

The biggest factor determining if households are likely to benefit from a heat pump is their current annual expenditure on gas (see Table 2). While this does not have the largest coefficient, it has the most substantial impact when considering the fluctuation in the expenditure variable, which has a standard deviation of approx. 1,600€. The impact of this can be seen in Table 3 with the average annual gas expenditure for households where biomethane is the lower cost option (biomethane households) is 328€ and the annual gas expenditure for households where heat pumps are the lower cost option (heat pump households) is 2,339€.

In terms of household characteristics, higher income households are less likely to benefit from a heat pump, all else equal, as are people who rent and to a lesser extent those who are paying off a mortgage or otherwise have restricted ownership compared to households who own their dwellings outright (see Table 2). While the latter is reflected in higher percentages of heat pump households owning their homes outright (33.4%) compared to biomethane households (19.3%), the same does not hold true for income. In fact, a lower percentage of households in the bottom income quartile is represented among the heat pump households (23.4%) than the biomethane households (30.7%). This is likely the result of the impact of annual gas expenditure which is higher for higher income households. The reason higher income households are less likely to benefit from a heat pump if we control for gas expenditure is probably the availability of more substantial home upgrade grants for lower income households. The same mechanism is likely behind the higher number of renters for whom heat pumps are a financially beneficial option. In our model, we do not differentiate between renters and home owners in terms of loan accessibility. However, in reality, renters are not able to access loans and instead depend on their landlords for changes to heating systems, who in turn may not be eligible for the same extensive grant

supports.

No other household characteristics such as the household reference person’s age, gender, or education or the presence of dependent children was significantly linked to benefitting from a heat pump over biomethane.

In terms of dwelling characteristics, heat pump households are significantly more likely to live in apartments rather than detached houses and dwellings are significantly more likely to be older and have a lower starting BER. In percentage terms, 49.3% of heat pump households are in buildings from 1980 or older and only 29.2% in structures built after 2000, whereas the numbers for biomethane households are 45.5% and 35% respectively. However, only 10.3% of heat pump households live in apartments compared to 14.6% of biomethane households. This reverse trend is likely again connected to the impact of gas expenditures, with apartments having much lower expenditure on gas than houses. The starting BER for heat pump and biomethane households is almost the same at approx. 6.8 out of a 13-point scale (where a higher number represents a worse energy rating).

4.3 Impact by income decile

Table 4 shows the savings compared to biomethane and with grants by income decile. A Kruskal-Wallis Test did indicate a significant difference in savings between two or more income deciles ($\chi^2 = 28.16$, $p = 0.0009$), however there is no discernible trend across deciles. The lowest median value was found for the third decile at 1,707€ and the highest at the tenth decile at 3,348€, with the remaining deciles fluctuating between these two values in no particular order.

4.4 Demand for electricity and biomethane

As described above, heat pump households and biomethane households differ in their energy use for heating, with heat pump households having substantially higher initial expenditures on gas. As a result, even post-retrofit and with a heat pump, the energy demand for heat pump households is roughly equal but still higher than for non-retrofitted biomethane households. Heat pump households have an average electricity consumption of 2,201 kWh electricity per year, whereas biomethane households require an average of 2,053 kWh of biomethane. This low number for biomethane households is largely due to the large number of households with no initial expenditure on gas, despite identifying as having gas central heating in the survey. These households often display expenditures on other fuels, indicating that biomethane in these cases may not simply be a drop-in solution, but require some behavioural changes as well.

We conduct a quick back-of-the-envelope calculation of total new electricity and biomethane demand if all current fossil gas households switch to their lower cost renewable option. In 2022, there were 601,339 households with fossil gas central heating (CSO, 2025b). Assuming 77.6% of these households (roughly 466,639 households) switched to heat pumps with an average electricity consumption of 2,201 kWh per year, then they would represent a total electricity demand of 1,027 GWh. For biomethane households, 22.4%, i.e., roughly 134,700 households, at an average demand of 2,053 kWh of biomethane would equal a demand of 277 GWh of biomethane.

5 Discussion

However, our research is limited to a comparison on the basis of energy and home upgrade costs. Other factors are likely to factor into households’ decisions as well. For example, broader studies consistently highlight that home upgrades have benefits beyond direct changes in energy costs (see e.g., Hassan et al., 2024; Künn and Palacios, 2024; Ruiz-Valero et al., 2025), although some disadvantages were identified as well (Fisk et al., 2020; Hassan et al., 2024). The most commonly cited benefits are increased thermal comfort (Hassan et al., 2024; Ruiz-Valero et al., 2025) and improved health outcomes (Fisk et al., 2020; Avanzini et al., 2022; Künn and Palacios, 2024), whereas insufficient installation of ventilation leading to higher levels of some air pollutants in the home was the main risk (Fisk et al., 2020; Hassan et al., 2024). On the whole, Kamal et al. (2019) argue that a focus on purely monetary benefits is likely to undervalue home upgrades compared to other energy solutions.

Another consideration from a household perspective is feasibility. For example, households renting their homes are less likely to have control over the type of home heating system installed as well as the

Table 2: Likelihood of heat pumps (+ retrofit) being preferable to biomethane

VARIABLES	(1) Heat pump household
Household income quartile = 2, Second income quartile	-0.598** (0.276)
Household income quartile = 3, Third income quartile	-1.159*** (0.293)
Household income quartile = 4, Fourth income quartile	-1.268*** (0.336)
HRP age = 2, 35 - 54 years	-0.0619 (0.232)
HRP age = 3, over 54 years	0.430 (0.295)
Education = 2, Third level degree	-0.0987 (0.217)
Education = 3, Master's or doctorate	-0.319 (0.306)
Woman	-0.0435 (0.193)
Dependent children	-0.278 (0.226)
Tenure = 2, Own otherwise (mainly mortgage)	-0.903*** (0.325)
Tenure = 3, Rent	-2.031*** (0.325)
Dwelling type = 2, Semi-detached or terraced house	0.253 (0.322)
Dwelling type = 3, Apartment	1.272*** (0.418)
Dwelling type = 4, omitted	-
Accommodation age = 2, 1980 - 2000	-1.130*** (0.402)
Accommodation age = 3, 2001 or newer	-2.112*** (0.559)
Starting BER (on 13-point scale)	-0.329*** (0.101)
Annual gas expenditure (in 100€)	0.563*** (0.0304)
Dublin county	0.321 (0.208)
Constant	0.822 (1.035)
Observations	2,373

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Descriptive household statistics of biomethane and heat pump households

	Household heating type	
	Biomethane household	Heat pump household
N	534 (22.4%)	1,849 (77.6%)
Household income quartile		
First income quartile	164 (30.7%)	433 (23.4%)
Second income quartile	118 (22.1%)	477 (25.8%)
Third income quartile	133 (24.9%)	463 (25.0%)
Fourth income quartile	119 (22.3%)	476 (25.7%)
Weekly income	983.327 (1,130.873)	1,112.560 (1,210.656)
HRP age		
under 35 years	235 (44.0%)	637 (34.5%)
35 - 54 years	163 (30.5%)	508 (27.5%)
over 54 years	136 (25.5%)	704 (38.1%)
household.age	4.552 (1.397)	5.075 (1.605)
Education		
Primary or secondary school	251 (47.0%)	816 (44.1%)
Third level degree	210 (39.3%)	803 (43.4%)
Master's or doctorate	73 (13.7%)	230 (12.4%)
Dependent children		
No	284 (53.2%)	1,068 (57.8%)
Yes	250 (46.8%)	781 (42.2%)
Tenure		
Own outright	103 (19.3%)	618 (33.4%)
Own otherwise (mainly mortgage)	185 (34.6%)	680 (36.8%)
Rent	246 (46.1%)	551 (29.8%)
Dwelling type		
Detached house	60 (11.2%)	259 (14.0%)
Semi-detached or terraced house	396 (74.2%)	1,390 (75.2%)
Apartment	78 (14.6%)	190 (10.3%)
Other	0 (0.0%)	10 (0.5%)
Accommodation age		
1980 or older	243 (45.5%)	911 (49.3%)
1980 - 2000	104 (19.5%)	399 (21.6%)
2001 or newer	187 (35.0%)	539 (29.2%)
Dublin county		
No	243 (45.5%)	740 (40.0%)
Yes	291 (54.5%)	1,109 (60.0%)
Starting BER (on 13-point scale)	6.766 (2.315)	6.829 (2.208)
Annual gas expenditure (in 100€)	3.275 (3.131)	23.390 (15.029)

implementation of retrofits, while their landlords have a lower incentive to implement such changes as they are not the ones paying the energy bills (so-called 'split incentives') (Camprubí et al., 2016). Additionally, even where changes would be possible, renters are less likely to invest in a building that they may only live in for a short period of time (Camprubí et al., 2016). As our analysis shows that, while households renting their accommodation were generally less likely to benefit from a heat pump, renters nevertheless made up almost 30% of total heat pump households, this barrier requires some attention.

An additional barrier, in particular where larger retrofits are required, is the disruption experienced as a result of the work on the dwelling (Curtis et al., 2024). With nearly 50% of heat pump households located in housing built in or before 1980, this may affect a large proportion of the households for whom heat pumps would otherwise be a desirable choice. This barrier is further more pronounced for households where individuals spend extended time at home as is often the case for elderly, sick, or disabled household members, which are at the same time more likely to belong to a lower income bracket (Camprubí et al., 2016).

Table 4: Annual household savings from a heat pump compared to biomethane, by income decile

	Median	Standard deviation
10 quantiles of income		
1	2,007	4,417
2	2,175	4,820
3	1,707	4,478
4	2,998	4,596
5	2,643	4,391
6	2,387	4,640
7	2,006	4,314
8	2,318	4,470
9	2,189	4,419
10	3,349	4,476
Total	2,318	4,512

Note: Includes cost of retrofit as well as home upgrade grants.

For biomethane, households may face other barriers. For one, households are dependent upon biomethane being supplied through the gas network. If biomethane is prioritised for use in hard-to-abate sectors, or if gas networks are decommissioned or transition to transporting hydrogen, biomethane could simply not be an option for households. However, as long as biomethane is made available through the gas grid, households that already rely on gas central heating face few other barriers. The only significant barrier is that of cost, with biomethane estimated to cost between 3 and 13€/cents/kWh on the wholesale market (Murphy and Power, 2009; Vo et al., 2017; SEAI, 2022a; Bose et al., 2022; Wu et al., 2023; Padi et al., 2023), whereas the 12-month average wholesale fossil gas price in 2024 was just over 3€/cents/kWh (Utilityfair, 2025). This is likely to disproportionately affect low-income households, which make up more than 30% of biomethane households in our analysis.

6 Conclusion

In our research we find that while heat pumps on average have difficulty competing with fossil gas on a cost basis over a 15-year period due to high home upgrade costs, they outperform biomethane for the majority of households. This is strongly driven by the high estimated cost of biomethane, although the grants provided by the Irish government both for home retrofit and for the installation of heat pumps likewise contributed substantially to the relative attractiveness of heat pumps. The importance of the biomethane price also indicates that if fossil gas prices were to rise again, to the extent that they did at the time of the energy crisis, heat pumps would similarly outperform fossil gas, and, in turn, if biomethane prices were to fall, the majority of households might have a financial incentive to take up biomethane rather than upgrading their home and switching to a heat pump.

The defining characteristic of households for whom biomethane was identified as the lower cost option was a low annual consumption of gas. Additionally, higher income households, home owners, and households living in houses and newer buildings were more likely to benefit financially from biomethane over heat pumps, although this was not fully reflected in the final composition of biomethane households, likely due to the larger impact of annual gas consumption.

We estimate roughly 1 TWh of electricity and 277 GWh of biomethane to be required to provide all households which currently have gas central heating in Ireland with the more cost efficient of the two energy sources.

Our research faces several limitations. For one, there was no micro-dataset available which included all the necessary dwelling characteristics, BER, household characteristics, and retrofit costs. Consequently, our analysis relies on some assumptions, such as estimating the BER and using estimated average retrofit costs by dwelling type and starting BER. A more robust analysis would be possible if more detailed micro-data were available.

Secondly, biomethane is not yet available on the residential heating market in Ireland and therefore we assumed the ratio between biomethane production cost estimates and the wholesale price of fossil gas to be reflective of the ratio of the costs of the two products at retail level. This is unlikely to be completely accurate as the retail cost includes standing charges which depend on the cost of maintaining the gas network and not the product transported. On the other hand, some changes to the gas network will be required to accommodate for the decentralised nature of biomethane, such as, for example, reverse compression. As such we believe our assumption to be realistic, if likely not completely accurate.

Third, consideration should be given to behavioural responses. Our consumption estimates do not include possible rebound effects, i.e., increases in energy consumption as a result of cheaper running costs after home upgrades (A. Greening et al., 2000; Azevedo, 2014), nor decreases in energy consumption as a result of higher costs (Burke and Yang, 2016), as could be the case for biomethane. These responses would not only affect our consumption estimates but also environmental benefits and households' health and thermal comfort.

Finally, as outlined in the discussion section, our analysis is only one element to be considered in identifying the best residential heating option. Further research could expand on our work by comparing biomethane and heat pumps, as well as other residential heating options, along a broader set of criteria, possibly through methods such as multi-criteria analysis.

Nevertheless, under the existing data constraints, our research gives the best possible insights into the cost benefits to gas households of adopting heat pumps vs biomethane, and therefore can help inform policymakers' decisions on residential heating. It is also a step towards understanding the wider complexity of providing long-term sustainable residential heating solutions, but should not be considered in isolation.

References

- Lorna A. Greening, David L. Greene, and Carmen Difiglio. Energy efficiency and consumption — the rebound effect — a survey. *Energy Policy*, 28(6):389–401, June 2000. ISSN 0301-4215. doi: 10.1016/S0301-4215(00)00021-5. URL <https://www.sciencedirect.com/science/article/pii/S0301421500000215>.
- agriportance. Biomethane prices year ahead, August 2025. URL <https://agriportance.com/en/tools/biomethane-development-prices/biomethan-preise-year-ahead/>.
- Marcello Avanzini, Manuel Duarte Pinheiro, Ricardo Gomes, and Catarina Rolim. Energy retrofit as an answer to public health costs of fuel poverty in Lisbon social housing. *Energy Policy*, 160: 112658, January 2022. ISSN 0301-4215. doi: 10.1016/j.enpol.2021.112658. URL <https://www.sciencedirect.com/science/article/pii/S0301421521005231>.
- Inês M. L. Azevedo. Consumer End-Use Energy Efficiency and Rebound Effects. *Annual Review of Environment and Resources*, 39(Volume 39, 2014):393–418, October 2014. ISSN 1543-5938, 1545-2050. doi: 10.1146/annurev-environ-021913-153558. URL <https://www.annualreviews.org/content/journals/10.1146/annurev-environ-021913-153558>. Publisher: Annual Reviews.
- Chihye Bae, Jae Yong Lee, Dongwoo Kim, and Chungyoon Chun. A study on the impact of residents’ energy usage behavior on heating energy consumption based on smart meter data and surveys. *Energy and Buildings*, 300:113634, December 2023. ISSN 0378-7788. doi: 10.1016/j.enbuild.2023.113634. URL <https://www.sciencedirect.com/science/article/pii/S0378778823008642>.
- Bord Gáis Energy. Gas Boiler Replacement & Installation, September 2025a. URL <https://www.bordgaisenergy.ie/home/services/boiler-replacement-and-installation>.
- Bord Gáis Energy. Heat pumps - What they are and why you need one, March 2025b. URL <https://www.bordgaisenergy.ie/home/heat-pump-guide>.
- Bord Gáis Energy Local Heroes. Boiler Installation & Supply Services | Local Heroes, August 2025. URL <https://www.localheroes.ie/boilers>.
- Archishman Bose, Richard O’Shea, Richen Lin, Aoife Long, Karthik Rajendran, David Wall, Sudipta De, and Jerry D. Murphy. The marginal abatement cost of co-producing biomethane, food and biofertiliser in a circular economy system. *Renewable and Sustainable Energy Reviews*, 169:112946, November 2022. ISSN 1364-0321. doi: 10.1016/j.rser.2022.112946. URL <https://www.sciencedirect.com/science/article/pii/S1364032122008279>.
- Paul J. Burke and Hewen Yang. The price and income elasticities of natural gas demand: International evidence. *Energy Economics*, 59:466–474, September 2016. ISSN 0140-9883. doi: 10.1016/j.eneco.2016.08.025. URL <https://www.sciencedirect.com/science/article/pii/S0140988316302420>.
- Lluís Camprubí, Davide Malmusi, Roshanak Mehdipanah, Laia Palència, Agnes Molnar, Carles Muntaner, and Carme Borrell. Façade insulation retrofitting policy implementation process and its effects on health equity determinants: A realist review. *Energy Policy*, 91:304–314, April 2016. ISSN 0301-4215. doi: 10.1016/j.enpol.2016.01.016. URL <https://www.sciencedirect.com/science/article/pii/S0301421516300179>.
- CSO. Background Notes Domestic Building Energy Ratings Quarter 2 2025, July 2025a. URL <https://www.cso.ie/en/releasesandpublications/ep/p-dber/domesticbuildingenergyratingsquarter22025/backgroundnotes/>. Publisher: CSO.
- CSO. G0701 - SDG 7.1.2 Type of central heating fuel in occupied private households, July 2025b. URL <https://data.cso.ie/table/G0701>.
- John Curtis, Niamh Devitt, and Adele Whelan. Using census and administrative records to identify the location and occupancy type of energy inefficient residential properties. *Sustainable Cities and Society*, 18:56–65, November 2015. ISSN 2210-6707. doi: 10.1016/j.scs.2015.06.001. URL <https://www.sciencedirect.com/science/article/pii/S2210670715000682>.

- John Curtis, Gianluca Grilli, and Muireann Lynch. Residential renovations: Understanding cost-disruption trade-offs. *Energy Policy*, 192:114207, September 2024. ISSN 03014215. doi: 10.1016/j.enpol.2024.114207. URL <https://linkinghub.elsevier.com/retrieve/pii/S0301421524002271>.
- Ivan Dimchev, Angel Terziev, and Martin Ivanov. Estimation of the Seasonal Coefficient of Performance of Air-to-Water Heat Pumps in Temperate Climate. In *2024 9th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE)*, pages 1–6, June 2024. doi: 10.1109/EEAE60309.2024.10600630. URL <https://ieeexplore.ieee.org/document/10600630/>.
- Eurostat. Electricity prices for household consumers - bi-annual data (from 2007 onwards), February 2025a. URL https://ec.europa.eu/eurostat/databrowser/product/page/NRG_PC_204.
- Eurostat. Gas prices for household consumers - bi-annual data (from 2007 onwards), May 2025b. URL https://ec.europa.eu/eurostat/databrowser/product/page/NRG_PC_202.
- Eurostat. HICP - annual data (average index and rate of change), July 2025c. URL https://ec.europa.eu/eurostat/databrowser/product/page/PRC_HICP_AIND.
- William J. Fisk, Brett C. Singer, and Wanyu R. Chan. Association of residential energy efficiency retrofits with indoor environmental quality, comfort, and health: A review of empirical data. *BUILDING AND ENVIRONMENT*, 180:107067, August 2020. ISSN 0360-1323, 1873-684X. doi: 10.1016/j.buildenv.2020.107067. URL <https://www.webofscience.com/api/gateway?GWVersion=2&SrcAuth=DynamicDOIArticle&SrcApp=WOS&KeyAID=10.1016%2Fj.buildenv.2020.107067&DestApp=DOI&SrcAppSID=EUW1ED0B0BJ6n0D8DdEbBprw1mKpw&SrcJTitle=BUILDING+AND+ENVIRONMENT&DestDOIRegistrantName=Elsevier>. Num Pages: 12 Place: Oxford Publisher: Pergamon-Elsevier Science Ltd Web of Science ID: WOS:000562687200002.
- Mengpin Ge, Johannes Friedrich, and Leandro Vigna. Where Do Emissions Come From? 4 Charts Explain Greenhouse Gas Emissions by Sector. December 2024. URL <https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors>.
- Hala Hassan, Asit Kumar Mishra, Nina Wemken, Paul O’Dea, Hilary Cowie, Brian McIntyre, and Ann Marie Coggins. Deep energy renovations’ impact on indoor air quality and thermal comfort of residential dwellings in Ireland - ARDEN project. *BUILDING AND ENVIRONMENT*, 259:111637, July 2024. ISSN 0360-1323, 1873-684X. doi: 10.1016/j.buildenv.2024.111637. URL <https://www.webofscience.com/api/gateway?GWVersion=2&SrcAuth=DynamicDOIArticle&SrcApp=WOS&KeyAID=10.1016%2Fj.buildenv.2024.111637&DestApp=DOI&SrcAppSID=EUW1ED0B0BJ6n0D8DdEbBprw1mKpw&SrcJTitle=BUILDING+AND+ENVIRONMENT&DestDOIRegistrantName=Elsevier>. Num Pages: 13 Place: Oxford Publisher: Pergamon-Elsevier Science Ltd Web of Science ID: WOS:001246115400001.
- Carsten Herbes, Lorenz Braun, and Dennis Rube. Pricing of Biomethane Products Targeted at Private Households in Germany—Product Attributes and Providers’ Pricing Strategies. *Energies*, 9(4):252, April 2016. ISSN 1996-1073. doi: 10.3390/en9040252. URL <https://www.mdpi.com/1996-1073/9/4/252>. Publisher: Multidisciplinary Digital Publishing Institute.
- Carsten Herbes, Benedikt Rilling, and Marc Ringel. Policy frameworks and voluntary markets for biomethane – How do different policies influence providers’ product strategies? *Energy Policy*, 153:112292, June 2021. ISSN 0301-4215. doi: 10.1016/j.enpol.2021.112292. URL <https://www.sciencedirect.com/science/article/pii/S0301421521001610>.
- IEA. Energy System - Buildings - Heating, August 2023. URL <https://www.iea.org/energy-system/buildings>.
- IEA. Clean Energy Market Monitor – March 2024. Technical report, IEA, March 2024a. URL <https://www.iea.org/reports/clean-energy-market-monitor-march-2024>.
- IEA. Clean Energy Market Monitor – November 2024. Technical report, IEA, November 2024b.

- Athar Kamal, Sami G. Al-Ghamdi, and Muammer Koc. Revaluing the costs and benefits of energy efficiency: A systematic review. *Energy Research & Social Science*, 54:68–84, August 2019. ISSN 2214-6296. doi: 10.1016/j.erss.2019.03.012. URL <https://www.sciencedirect.com/science/article/pii/S2214629618310405>.
- Spyridon Karytsas and Ioannis Choropanitis. Barriers against and actions towards renewable energy technologies diffusion: A Principal Component Analysis for residential ground source heat pump (GSHP) systems. *Renewable and Sustainable Energy Reviews*, 78:252–271, October 2017. ISSN 1364-0321. doi: 10.1016/j.rser.2017.04.060. URL <https://www.sciencedirect.com/science/article/pii/S136403211730566X>.
- Janez Kren, Eoin Kenny, Conor O’Toole, Eva Shiel, and Rachel Slaymaker. Exploring investment requirements for energy efficiency upgrades in the private rental sector. Technical report, ESRI, February 2024. URL <https://www.esri.ie/publications/exploring-investment-requirements-for-energy-efficiency-upgrades-in-the-private-rental>.
- Steffen Künn and Juan Palacios. Health implications of housing retrofits: Evidence from a population-wide weatherization program. *Journal of Health Economics*, 98:102936, December 2024. ISSN 0167-6296. doi: 10.1016/j.jhealeco.2024.102936. URL <https://www.sciencedirect.com/science/article/pii/S016762962400081X>.
- Manuel Lämmle, Jakob Metz, Michael Kropp, Jeannette Wapler, Thore Oltersdorf, Danny Günther, Sebastian Herkel, and Constanze Bongs. Heat Pump Systems in Existing Multifamily Buildings: A Meta-Analysis of Field Measurement Data Focusing on the Relationship of Temperature and Performance of Heat Pump Systems. *Energy Technology*, 11(12):2300379, 2023. ISSN 2194-4296. doi: 10.1002/ente.202300379. URL <https://onlinelibrary.wiley.com/doi/abs/10.1002/ente.202300379>. eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/ente.202300379>.
- Tensay Hadush Meles and Lisa Ryan. Adoption of renewable home heating systems: An agent-based model of heat pumps in Ireland. *Renewable and Sustainable Energy Reviews*, 169:112853, November 2022. ISSN 1364-0321. doi: 10.1016/j.rser.2022.112853. URL <https://www.sciencedirect.com/science/article/pii/S1364032122007353>.
- Lucie Middlemiss and Ross Gillard. Fuel poverty from the bottom-up: Characterising household energy vulnerability through the lived experience of the fuel poor. *Energy Research & Social Science*, 6:146–154, March 2015. ISSN 2214-6296. doi: 10.1016/j.erss.2015.02.001. URL <https://www.sciencedirect.com/science/article/pii/S2214629615000213>.
- J. D. Murphy and N. Power. Technical and economic analysis of biogas production in Ireland utilising three different crop rotations. *Applied Energy*, 86(1):25–36, January 2009. ISSN 0306-2619. doi: 10.1016/j.apenergy.2008.03.015. URL <https://www.sciencedirect.com/science/article/pii/S0306261908000901>.
- ODYSSEE-MURE. EU Heating Energy | Sectoral Profile - Households | Heating energy consumption by energy source, August 2025. URL <https://www.odyssee-mure.eu/publications/efficiency-by-sector/households/heating-energy-consumption-by-energy-sources.html>.
- Richard Kingsley Padi, Sean Douglas, and Fionnuala Murphy. Techno-economic potentials of integrating decentralised biomethane production systems into existing natural gas grids. *Energy*, 283:128542, November 2023. ISSN 0360-5442. doi: 10.1016/j.energy.2023.128542. URL <https://www.sciencedirect.com/science/article/pii/S0360544223019369>.
- Benedikt Rilling and Carsten Herbes. Invisible, intangible, irrelevant, yet inevitable? Qualitative insights into consumer perceptions of heating tariffs and drop-in renewable gases in the German domestic heating market. *Energy Research & Social Science*, 91:102744, September 2022. ISSN 2214-6296. doi: 10.1016/j.erss.2022.102744. URL <https://www.sciencedirect.com/science/article/pii/S2214629622002481>.
- L. Ruiz-Valero, N. Makaremi, S. Haines, and M. Touchie. Co-benefits of residential retrofits: A review of quantification and monetization approaches. *Building and Environment*, 270:112576, February 2025. ISSN 0360-1323. doi: 10.1016/j.buildenv.2025.112576. URL <https://www.sciencedirect.com/science/article/pii/S0360132325000587>.

- SBCI. Home Energy Upgrade Loan Scheme, August 2025. URL <https://sbci.gov.ie/products/home-energy-upgrade-loan-scheme>.
- SEAI. National Heat Study: Low Carbon Gases for Heat - Potential, Costs and Deployment Options in Ireland. Technical report, SEAI, February 2022a. URL <https://www.seai.ie/publications/Low-Carbon-Gases-for-Heat.pdf>.
- SEAI. Heating and cooling in Ireland today: Archetype Profiles, Spatial Analysis, and Energy Efficiency Potential. Technical Report Report 1 of the National Heat Study, SEAI, February 2022b. URL <https://www.seai.ie/data-and-insights/national-heat-study/heating-and-cooling-in-ir>.
- SEAI. Better Energy Homes and Solar PV Grants, August 2025a. URL <https://www.seai.ie/grants/home-energy-grants/individual-grants>.
- SEAI. Heat Pump System Grants | Home Energy Grants, 2025b. URL <https://www.seai.ie/grants/home-energy-grants/individual-grants/heat-pump-systems>.
- SEAI. National Home Energy Upgrade Scheme, August 2025c. URL <https://www.seai.ie/grants/home-energy-grants/one-stop-shop>.
- SEAI. National Retrofit Plan: Full Year Report 2024. Technical report, SEAI, April 2025d. URL <https://www.seai.ie/sites/default/files/publications/SEAI-Retrofit-Full-Year-Report-2024.pdf>.
- SEAI. Warmer Homes Scheme, October 2025e. URL <https://www.seai.ie/grants/home-energy-grants/fully-funded-upgrades-for-eligible-homes>.
- Selectra. How Much Does a New Gas Boiler Cost in Ireland?, July 2025. URL <https://selectra.ie/energy/guides/boilers/gas-boiler>.
- Miguel A. Tovar Reaños. Fuel for poverty: A model for the relationship between income and fuel poverty. Evidence from Irish microdata. *Energy Policy*, 156:112444, September 2021. ISSN 03014215. doi: 10.1016/j.enpol.2021.112444. URL <https://linkinghub.elsevier.com/retrieve/pii/S0301421521003141>.
- Trading Economics. EU Natural Gas TTF - Price - Chart, August 2025. URL <https://tradingeconomics.com/commodity/eu-natural-gas>.
- Utilityfair. Wholesale Gas Prices in Ireland (2025), August 2025. URL https://www.utilityfair.ie/business-energy-insights/{page_url}.
- Truc T. Q. Vo, Ao Xia, David M. Wall, and Jerry D. Murphy. Use of surplus wind electricity in Ireland to produce compressed renewable gaseous transport fuel through biological power to gas systems. *Renewable Energy*, 105:495–504, May 2017. ISSN 0960-1481. doi: 10.1016/j.renene.2016.12.084. URL <https://www.sciencedirect.com/science/article/pii/S0960148116311491>.
- Benteng Wu, Richen Lin, Archishman Bose, Jorge Diaz Huerta, Xihui Kang, Chen Deng, and Jerry D. Murphy. Economic and environmental viability of biofuel production from organic wastes: A pathway towards competitive carbon neutrality. *Energy*, 285:129322, December 2023. ISSN 0360-5442. doi: 10.1016/j.energy.2023.129322. URL <https://www.sciencedirect.com/science/article/pii/S0360544223027160>.