Unlocking the Economy Wide Benefits of Heat Pumps

The Role of Electricity and Gas Prices

Policy brief

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Summary

The 'Delivering a sustainable and equitable heat transition' project is delivered by UKERC researchers based at the University of Strathclyde Centre for Energy Policy. The project is analysing a range of scenario simulations to understand the household real income and wider economy implications of decarbonising residential heat through the deployment of heat pumps.

In this briefing, the first in a series of three, we consider the challenge of realising the potential household energy bill savings associated with switching to more energy efficient heat pumps posed by the high retail price of electricity relative to gas.

We focus on a scenario simulation for the deployment of heat pumps that sees almost 50% of households using low carbon heating by 2035 and nearly all by 2050. Combined with other electrification actions, this can ultimately lead to almost a 40% reduction in energy demand across the residential sector[1]. This extensive energy saving is due to electric heat pumps being almost three times more energy efficient in average than natural gas boilers. However, under prevailing market conditions where the retail price of a physical unit of electricity remains high relative that of gas, the significant bills savings and wider economy benefits (triggered by increasing and freeing up household spending power) usually associated with substantial energy efficiency increases are not evident.[2] In turn, this limits the extent to which wider economy expansion is triggered due to households having more money to spend on other goods and services.

Our analysis shows that the difference between the retail electricity and gas prices faced by consumers has a strong controlling factor on the household real income and spending power. The full economic efficiency gains of heat pumps will only be realised if the price ratio of electricity compared to gas is 1:1.

At present, we estimate that the current electricity:gas retail price ratio is 3.3:1 which compares to 4:1 in Spring 2022, with the price of gas rising faster than that of electricity. Thus, the potential efficiency gains of switching to heat pumps do not fully translate to monetary savings in households' bills. However, under current prices, switching UK households to heat pumps still delivers wider economic benefits. We estimate that, under our heat pump uptake scenario, households perceive an average annual 0.1% increase in real disposable income, which ultimately supports +0.015% (£0.3billion) per annum sustained uplift in GDP, and a net increase in employment of 4,660 full-time equivalent (FTE) jobs across the economy. Thus, further efforts are required to ensure that the difference between gas and electricity prices is reduced further, making heat pumps cheaper to run than existing gas boilers and triggering greater bill savings and wider economy benefits.

1. The 40% reduction in energy use was calculated based on the higher efficiency of heat pumps. This assumed around 50% of the building stocks have been equipped with heat pumps without considering other interventions such as energy efficiency improvement measures (e.g. insulation). Certainly, improving the buildings energy performance could lead to further reductions in their annual heat demand. However, the focus of this work is on the heat pump deployment and electrification of heat more generally, not directly accounting for other energy efficiency measures. Furthermore, a fundamental assumption is that, consumers do not change their consumption behaviour regarding heating and energy use more generally. However, we do capture changes in household consumption behaviour, which includes the consumption of energy, driven by the income effects that the use of heat pumps triggers. 2. Turner, Karen and Katris, Antonios (2022) 'What does increasing residential energy efficiency do for the economy?' CEP Policy Brief (drawing on our body of peer reviewed research in this area). Available to download at https://strathprints.strath.ac.uk/82777/

Introduction

The UK Government's Net Zero Strategy sets the ambition and level of system wide changes required to meet emission reduction targets. Meeting net zero targets will involve virtually all heat in buildings to be decarbonised.

The electrification of heat is proposed to be a key pathway in reducing emissions from homes, the majority of which are associated with boilers that are currently fuelled using natural gas. Therefore, significant changes to the energy system - with an electrification pathway involving upgrade of energy networks and increasing electricity generation capacity - will be needed alongside the installation of new heating systems in people's homes. Such system wide changes are set within a dynamic policy environment where surging global gas prices have driven a significant increase in energy prices for GB energy consumers (to date reaching a £2,500 rise in annual energy costs for the average household under the Energy Price Guarantee implemented from October 2022). Combined with wider cost-of-living challenges, affordability and increasing fuel poverty are growing concerns, with these being increasingly acute for the lowest income and the most vulnerable households.

Understanding how the costs of decarbonising heat are distributed, specifically through a central policy focus on heat pump deployment, where benefits might accrue and how the wider economy might be impacted, is a key aim of the project.

In this first of three policy briefs explaining our findings, we address a fundamental issue: the net cost implications of UK households operating more energy efficient heat pumps where retail electricity prices are traditionally high relative to gas. Specifically, we focus on how, and to what extent, the electricity-gas price differential determines whether the physical energy efficiency properties of heat pumps will lead to energy bills saving for UK households. This issue becomes increasingly important when we consider how the changes in household energy bills and real spending power can drive a wide range of economy wide impacts. This further affects a wider economy landscape already challenged by labour supply constraints and volatile energy prices.

Going forward, the second and third policy briefs in this series will consider other key drivers of household and wider economy impacts of the electrification of residential heat through heat pump deployment. This includes analyses of the impacts of 'who pays' for purchasing and installation costs associated with the heat pump rollout (e.g., via loans, grants etc.). It will extend to the exploration of how different factors, such as where heat pumps are manufactured, may affect the potential outcomes, including mitigating cost pressures and/or providing additional sources of wider economy gains. We will also discuss the regional and wider labour market implications of this widespread rollout of heat pumps and will reflect on whether the necessary skills exist within the current labour force.

Key findings

Heat pump deployment can reduce energy demand across the residential building stock by up to 40%

Realising decarbonisation of residential heat through switching to heat pumps requires both an 'enabling' stage from the supply side (upgrade and reinforcement of the current grid network), and a 'realising' stage in terms of the uptake of/demand for deployment of heat pumps in domestic buildings. Here we focus on the latter, where we simulate the practical use of heat pumps considering their relatively higher energy efficiency than gas boilers.

Informed by our energy system modelling,[3] the simulation scenario involves almost 50% of households using low carbon heating by 2035 and nearly all households by 2050[4]. Given the physical energy efficiency of heat pumps[5] (as the dominant electrification option), the outcome is almost a 40% reduction in energy demand across the residential sector compared to a base case where the energy use for residential heating largely remains unchanged without additional decarbonisation measures.

As shown in Figure 1, a range of mainstream energy sources are covered in the comparison of residential energy use evolution, including biomethane, electricity, gas, hydrogen and oil. Compared to the base case, where the main heating fuel is gas, the total energy use is reduced by 39.45% towards 2050, where the proportion of gas use is almost zero. In this scenario the use of electricity will surpass the share of gas by 2040 and will continue to increase to dominate the energy mix by 2050. There is also an increase in hydrogen use but under the scenario considered here, it only accounts for a relatively small share. The point here is that the electrification of heat could drive an important reduction on total residential energy use by 2050, where a key driver is electric heat pumps being almost three times more efficient (in terms of energy required to deliver a given level of heat) than existing natural gas boilers.

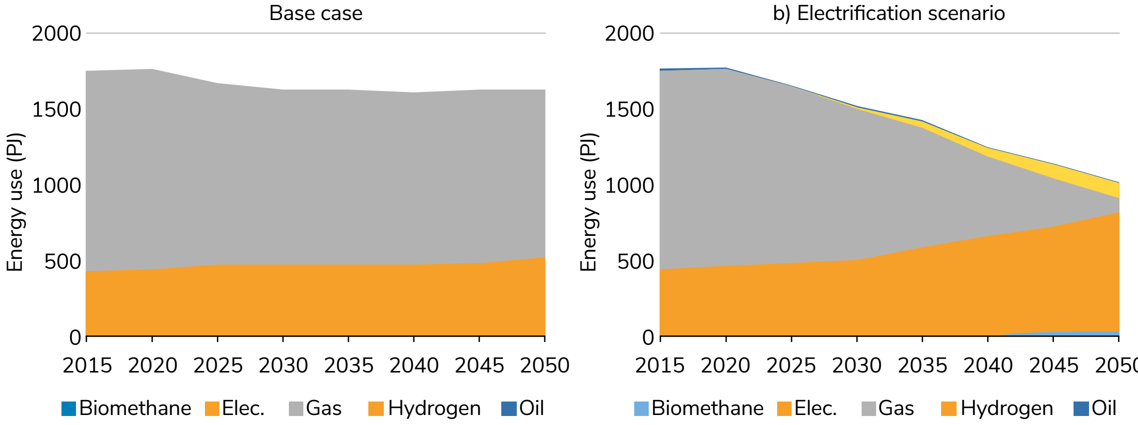

Figure 1. Residential energy use changes of our electrification scenario compared to a baseline 'business-as-usual' scenario.

3. Details are provided in a paper titled 'Analysing the energy system impacts of decarbonising residential heat in the UK', currently under peer review with the journal Energy Strategy Reviews please email cep@strath.ac.uk to request a copy. 4. Our electrification scenario roughly follows National Grid's FES2021 'Consumer transformation' scenario and the policy targets set in the Net Zero Strategy, high electrification scenario, and the Heat in Buildings strategy, stating that 600,000 heat pump systems are to be installed per annum from 2028 and 1.9 million per year by 2035. 5. Here we assume an average heat pump coefficient of performance (COP) of 2.52. That is, per each unit of electricity input, the output is 2.52 units of heat.

Unlocking the efficiency gains of heat pumps could lead to a range of economic benefits

Crucially, the physical energy efficiency gains enabled by households switching from gas boilers to electric heat pumps has the potential to trigger a range of wider economic gains through the increase and reallocation of real income and spending enabled by lower energy bills. This is something that we can simulate in our economy-wide model, which is calibrated on 2018 data (the most recent available), taken to represent the economy with no other change in 2022.[6]

This second finding concerns a case where households fully realise the potential household energy bill savings associated with switching to more energy efficient heat pumps and assumes a hypothetical price parity (1:1) between electricity and gas. This scenario can be seen as a control case that isolates and helps understand the economic benefits that could be unlocked through efficiency gains associated with the switch before we turn to other, and likely more realistic cases. At this stage we also abstract from other factors such as the costs involved in enabling heat pump deployment (transitory investment activity and cost recovery – which will be the focus of the second policy brief in this series) to focus on long-run outcomes achieved within 40 years, that are governed by the operation of heat pumps alone.

Such a scenario generally shows a positive picture for both households and the wider economy, with economy-wide gains beginning to manifest, albeit at a small scale, as soon as households start using the newly installed heat pump systems. The reduction in household energy bills from the switch to heat pumps, frees-up household income that can be used for spending on other goods and services. The sustained (long run) gain in the real disposable income of households, once all costs have been met, equates to an average increase of £300 per household per year for the 20% of households on the lowest incomes, and over £770 per year for the 20% on the highest incomes (in base year 2018 prices). Despite these differences in absolute terms, the distribution of household income gains is marginally progressive with the lowest income households benefiting slightly more in percentage terms (as shown later, in Figure 4).

6. Our analyses are presented in detail in our forthcoming paper titled 'How will electrifying residential heating via heat pumps impact the wider UK economy?'. The modelling approach we use is similar to the one employed in our peer-reviewed paper Katris, Antonios and Turner, Karen (2021) 'Can different approaches to funding household energy efficiency deliver on economic and social policy objectives? ECO and alternatives in the UK' published at Energy Policy. The paper is available open access at: https://doi.org/10.1016/j.enpol.2021.112375

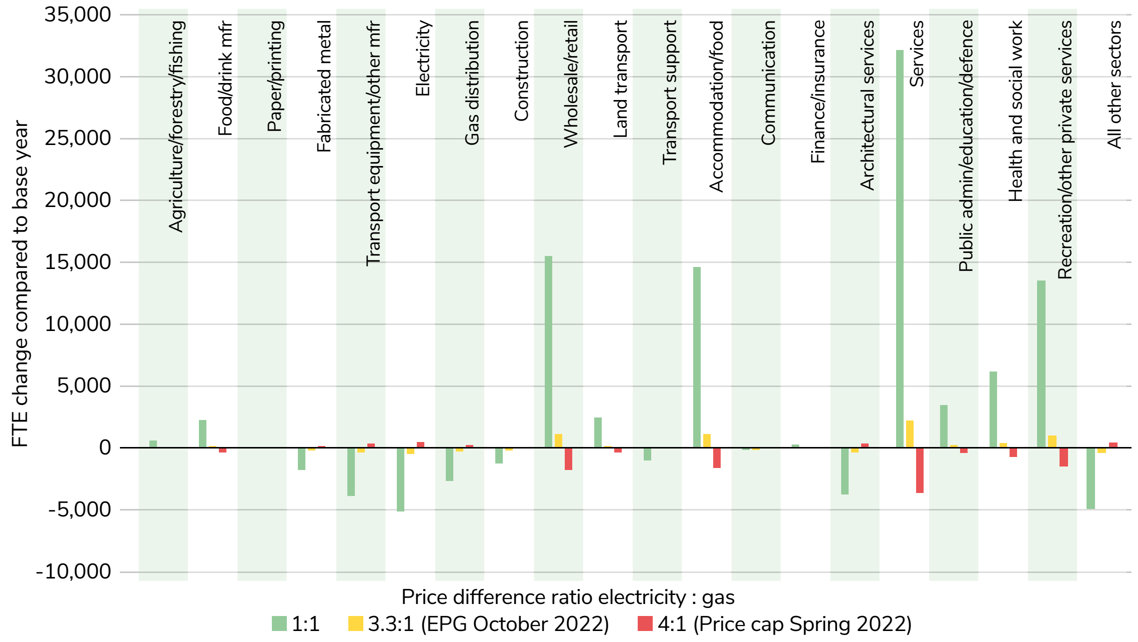

Figure 2. Long-run sectoral employment impacts due to heat pump uptake different electricity: gas price ratios

The switch to heat pumps in the 1:1 scenario leads to a sustained increase in total UK household consumption of approximately 1.2% (£15.9billion).

Our results show this increase in household demand driving sustained GDP gains of 0.2% (£3.8billion) in the long run (see Figure 4 below), leading to the net creation of around 67,245 full-time equivalent (FTE) jobs (0.2% increase) across different sectors of the economy. As the economic expansion is mainly driven by the increased household consumption, we find large employment gains can be delivered in sectors associated with this household spending. For instance, in this 1:1 scenario, our results suggest over 15,550 additional FTE jobs in the 'Wholesale/retail' sector, approximately 14,600 new FTE jobs in 'Accommodation/food', while the biggest gains of over 32,100 FTE jobs are observed in the highly aggregated 'Services' sector (see green bar case in Figure 2).

However, the expansion is limited by the persistence of a national labour supply constraint with wage bargaining driving up labour costs to all producers. This means that the increased household demand triggers price rises across the economy, as reflected by the CPI (which rises by 0.5%). We also find some displacement of employment in sectors not directly enjoying a boost through increased real spending and/or where other sources of demand (e.g., exports) are 'crowded out'.

In distributional terms at the UK household level, the efficiency gains largely shield the 40% of households with the lowest income, who do not experience any overall price increase in their consumption basket. Moreover, despite the public spending adjustments necessary to maintain the purchasing power of transfers including benefits and pensions in face of economy-wide price increases, the additional tax revenue delivered due to increased economic activity and associated wage increases, enable government budget savings of £1.2billion in the long-run.

7. We take this as our standard assumption. However, the performance of a heat pump system can vary depending on the external temperatures, the efficiency of the property where it is installed and whether an appropriately sized system has been installed for each property. We explore the effect of different coefficients of performance in our associated peer-reviewed paper.

Under existing market arrangements heat pumps can be more expensive to run than gas boilers.

Our first two findings relate directly to the fact that heat pumps are almost three times more energy efficient on average than gas boilers. However, historically, electricity has been more expensive than gas, which erodes the effect that the physical energy savings of using heat pumps have on households' energy bills, real income gains and spending power, which triggers the wider economy expansion considered above. In Figure 3 we show how the running cost of heat pumps relative to gas boilers changes depending on the price ratio between electricity and gas. Our analysis shows that when electricity is 3.4 times more expensive than gas, then there is no difference in the running cost of heat pumps and gas boilers; the effect of the more efficient heat pumps on energy bills is completely offset. The implication is that, for the switch to heat pumps to deliver energy bills savings, the price gap between electricity and gas needs to narrow. The closer the two prices, the greater the energy bills savings enabled by the switch to heat pumps.

By the end of 2020, the ratio between the retail electricity and retail gas price in GB was around 4.8:1 (far right of Figure 3). Ironically, the 2022 shock on the prices of natural gas, albeit feeding through to the electricity price, narrowed this gap. The April 2022 Ofgem price cap (effective until 30 September 2022, where the unit rates of electricity and gas were 28p and 7p per kWh respectively) narrowed the price ratio to 4:1. As the energy price shock continued throughout 2022 the UK Government implemented the Energy Price Guarantee (EPG), effective from October 2022 where the electricity and gas prices were set at 34p and 10.3p per kWh respectively.

This means that the current ratio is fixed at 3.3:1. The key point for the heat pump rollout is that, for the first time, this moves into the left-hand side on Figure 3, where the physical efficiency gains are not entirely offset with the implication that some expansionary power is released into the economy. Referring back to Figure 2, this gives us the yellow bar outcomes for employment, where net gains are more limited but, with the labour supply constraint not 'biting', there is reduced price pressure across the economy that risks displacing activity in sectors that benefit less from increased household spending. This also compares positively with the 4:1 price ratio case that applied between April and October 2022, where the red bar reductions in sectoral employment in Figure 2 are associated with falling household consumption where heat pumps are more expensive to run than gas boilers (as shown in Figure 3). Figure 4 helps us summarise the associated long-run macroeconomic impacts and drivers. Note that HG1 refers to the household group at the lowest quintile (i.e. the lowest 20% earners of the population), HG2 refers to the second lowest income quintile, etc.

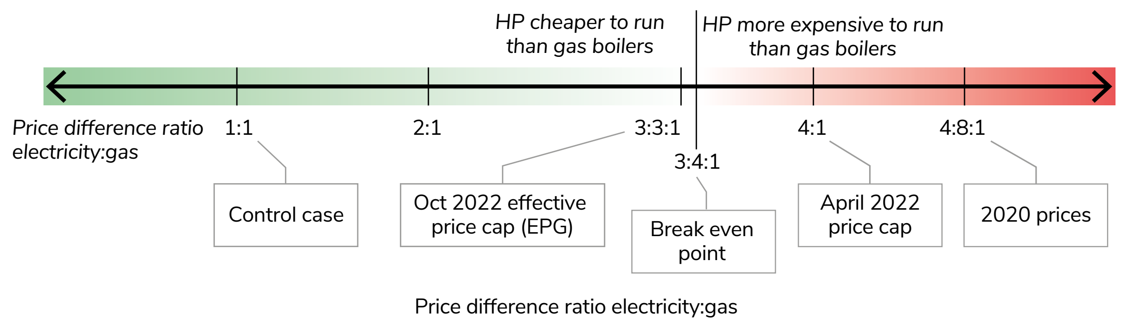

Figure 3. Impact of different GB energy market conditions on the electricity:gas retail price difference ratio

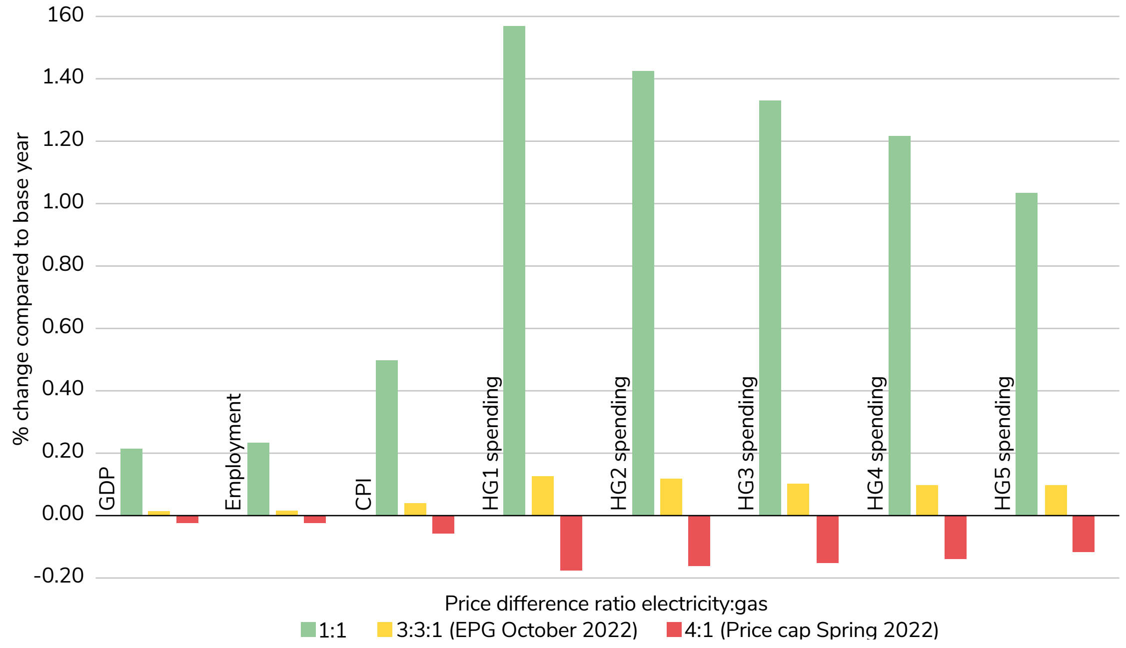

Figure 4. Macroeconomic long-term impacts due to the switch to heat pumps different electricity:gas price ratio

As noted above and compared to the extreme case discussed where there is no price gap and the energy efficiency gains of switching to heat pumps are fully realised, the current 3.3 to 1 electricity-gas price differential allows only moderate sustained gains in household spending (after all heat pump uptake costs are met). This triggers a more limited expansion, with only marginal GDP and total employment gains (the distribution of employment impacts is shown above in Figure 2), albeit with reduced CPI pressure to further restrict real household spending power.

Moreover, the picture remains favourable relative to the 4 to 1 electricity-gas price differential that applied between April and October 2022, where the energy efficiency gains of heat pumps are entirely eroded with the implication that household energy bills rise and total consumer spending contracts -0.14% (-£1.8billion). This is what triggers a contraction in the 4:1 case in Figure 4, where long-run GDP declines by -0.03% (-£0.4billion) relative to what it would be otherwise (i.e., with no other changes in the economy), at the cost of 7,640 FTE jobs (a 0.03% contraction in employment). In distributional terms, the household real disposable income losses in the pre-October 2022 4:1 case range from £34 (lowest income households) to £88 (highest income households) per household per year, but with the associated proportionate changes shown in Figure 4 reflecting a picture that is mildly regressive.

In short, if the price differential between electricity and gas is in the red zone of Figure 3, the use of heat pumps becomes more expensive than the use of gas boilers with the implication that (with no other changes or interventions in the economy), real incomes and spending power across households will fall and contractionary pressures will be triggered across the economy. If the price differential lies in the green zone, some expansionary power will be triggered, but with the cautionary note that resulting wage cost and wider price pressures in the presence of the persisting UK labour supply constraint will bring trade-offs through potential displacement of other activities, sources of income generation and cost-of-living pressures.

Conclusions, policy implications and next steps

Through the deployment of heat pumps, there is potential not only to reduce household energy bills but to trigger a process of sustained wider economy expansion through reallocation of increased household spending power.

Crucially, this depends on the price of electricity which has historically been significantly more expensive than gas for households, eroding and in some cases eliminating any efficiency gains delivered by heat pumps. This highlights the importance of a broader rethink around how not only the absolute (monetary) but also the relative prices of electricity and gas are determined. A potential net zero strategy focus on electrification could require that electricity become comparably less expensive than the current dominant heating fuel, which is gas for most UK households. In fact, the analysis presented here could deliver insight supporting electrification in other contexts (e.g., remote areas where households currently choose other heating options over electrified ones).

The price ratio issue is not the only one determining the outcomes of potential large-scale heat pump deployments on UK households and the wider economy. Other factors such as how the costs of heat pumps uptake are met, to the location of the manufacturing activity involved are also critical. These will be explored further in the second policy brief (due May 2023), where we will focus on the importance of two issues in determining the likely wider economy outcomes. First, whether heat pumps are manufactured within the UK or imported, and how a reduction in heat pump costs may affect outcomes for households and the wider economic picture. Second, how the funding model used to cover the cost of heat pump installation and uptake, impacts household budgets in determining the real disposable income trigger for any wider economy expansion associated with this route to electrifying heat in the UK. Our third policy brief (due in July 2023) will focus on the implications on jobs and skills resulting from the electrification of residential heat, also highlighting potential labour market constraints and regional economic impacts coming from the shift in economic activity.

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