UKERC
UK Energy Research Centre

The pathway to net zero heating in the UK

A UKERC policy brief

Authors: Jan Rosenow, Richard Lowes, Oliver Broad, Graeme Hawker, Jianzhong Wu, Meysam Qadrdan and Robert Gross

DOI: 10.5286/ukerc.edc.000941

Key findings

- Current progress on heat decarbonisation is not commensurate with the rate of change required for net zero by 2050.
- A combination of energy efficiency, heat pumps and district heating is the least-cost technology pathway for heat decarbonisation in the next 10 years.
- The scale and speed of the transition means that decarbonisation progress for areas currently on the gas grid will be required before more about hydrogen is known.
- The electricity system impacts of heat electrification can be reduced by smart operation of heating systems in well-insulated buildings.
- Current policy ambition falls far short of delivering residential heat decarbonisation in line with the UK's net zero emissions target.

Introduction

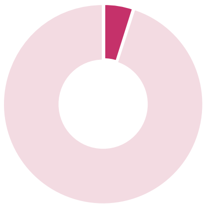
The heating of homes is a major contributor to the UK's greenhouse gas emissions accounting for 13% of total emissions.[1] This is comparable to the carbon emissions of all petrol and diesel cars in the UK.[2] Meeting the UK government's net zero emissions goal for 2050 will only be possible by complete decarbonisation of the building stock (both existing and new). While emissions from heating have fallen by 11% since 1990[1], much of which was driven by efficiency programmes and regulation in the period 2002-2012[3], continuing decarbonisation at this pace would get us to zero emissions from buildings in 235 years and fall far short of meeting the 2050 target.

Home heating energy consumption is also at risk of increasing further. Home working has developed substantially during the COVID-19 lockdown and is widely expected to remain at higher levels than pre-crisis[4] meaning that people may require houses which are on average warmer during the heating seasons. Data shows that domestic heating energy use was up by 15% during March when the lockdown started compared to March 2019[5,6]. The potential for more time spent at home will make heat decarbonisation and the thermal comfort and health associated with homes even more important.

There is uncertainty over the extent to which heating might practically be decarbonised in the future and what the optimal technologies may be. The aim of this paper is, to provide some clarity about the pathways forward, focusing on the next 5-10 years. We also draw on lessons learned from international examples for smart electrification of heating which we identify as one of the key strategies for decarbonisation of residential heat – at least in the short term.

1 Committee on Climate Change. (2019). Net Zero. Technical Report. Access here.
2 BEIS. (2019). Final UK greenhouse gas emissions national statistics 1990-2018. Access here.
3 Rosenow, J., Guertler, P., Sorrell, S., Eyre, N. (2018). The remaining potential for energy savings in UK households. Access here.
4 Parungao, A. (2020): The future of remote work after COVID-19: 3 common predictions. Access here.
5 Tado. (2020). Corona lockdown: British households use 15% more heating at home. Access here.
6 Not temperature corrected.

Understanding the challenge



5%
of the UK's total heat demand in buildings is currently met by low carbon sources

Currently, and not accounting for closed stoves or wood used on open fires, fewer than 500,000 homes are equipped with some form of low-carbon heating system[7]. As a result, only about 5% of the UK's total heat demand in buildings is currently met by low carbon sources.[7]

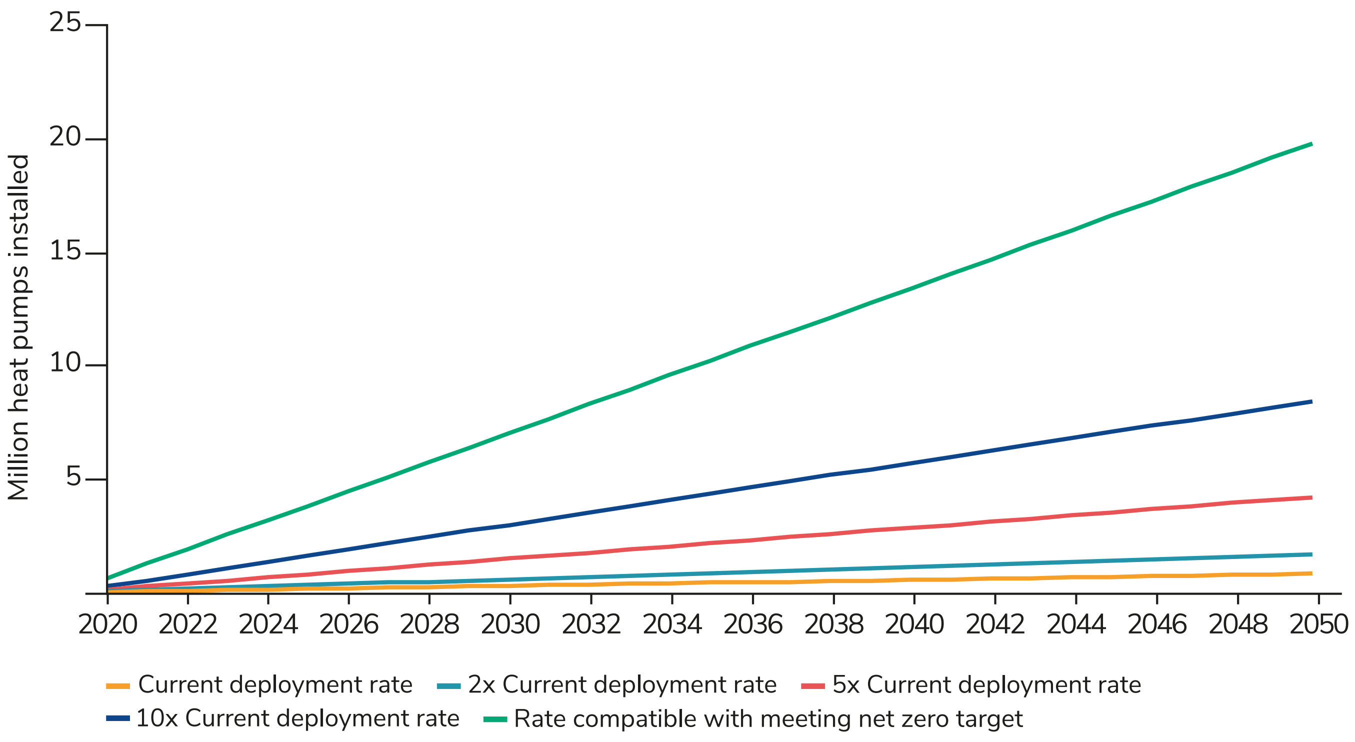
At the same time, energy efficiency retrofits have stalled with the installation of loft and wall insulation (both cavity and solid wall) at just 5% of peak market delivery in 2012.[7] Previous research by UKERC has shown improving energy efficiency of buildings has significant potential for cost-effective savings by 2035 equivalent to a 25% reduction in demand.[8]

Almost all of the UK's 29 million homes will require upgrading by 2050, that is about 1 million homes per year, and is equivalent to more than 19,000 homes per week.

Current retrofit rates are inadequate for achieving even a significant portion of the required level of decarbonisation to meet the 2050 targets. In 2017/18 fewer than 200,000 homes were improved with significant energy efficiency measures supported by government programmes.[9]

The replacement of fossil fuel-based heating systems is happening at an even slower pace. In 2018 only 27,000 heat pumps were installed in the UK[10] and the vast majority of new build homes were connected to the gas grid. As a result, the proportion of homes heated by gas is increasing. Ignoring new homes, at the current rate of deployment, it would take more than 700 years to reach the 19 million heat pumps the Committee on Climate Change (CCC) suggests are needed to meet net zero goals.[1]

Figure 1: Heat pump deployment rates under different scenarios



However, decarbonising heat is not an impossible feat. Some European countries with even higher heating demands due to colder outside temperatures (e.g. Norway and Sweden), rely predominantly on electricity, renewables, and waste and derived heat.[11] The UK does have an unusually old housing stock; pre-1940 buildings in particular tend to have poor thermal insulation, which contributes to the UK having some of the least energy efficient housing in Europe.[12] At the same time, fossil gas is familiar, widely used and relatively affordable, due in part to historic government strategies that promoted the expansion of the gas system.[13]

One of the current strategies to reduce fuel poverty in the UK has been to connect "off-grid" properties to the gas networks and to fit fossil gas boilers.[14]

Advice from the CCC that no new dwellings use fossil gas from the year 2025[7] has attracted scepticism from incumbent heating interest groups[15].

Heat systems transitions can take many decades and policy decisions can have implications for many years.[16] However, recent UKERC research has highlighted that policy makers view heat decarbonisation technology options as both 'disruptive' and 'uncertain'.[17] If heat decarbonisation is to be achieved, progress is needed immediately.

This briefing will explain the key issues associated with technology challenges and consider some of the potential areas for action.

the proportion of homes heated by gas is increasing

[7] Committee on Climate Change. (2019). UK housing: Fit for the future? Access here.
[8] UKERC. (2017). Unlocking Britain's First Fuel: The potential for energy savings in UK housing. Access here.
[9] BEIS. (2019). Energy efficiency: building towards net zero. Access here.
[10] European Heat Pump Association. (2019). EHPA market report and statistics outlook 2019. Access here.
[11] EUROSTAT. (2020). Energy Consumption in Households. Access here.
[12] MacLean, K., Sansom, R., Watson, T., Gross, R. (2016). Managing heat system decarbonisatio. Access here.
[13] Arapostathis, S., Carlsson-Hyslop, A., Pearson, P.J.G., Thornton, J., Gradillas, M., Laczay, S., Wallis, S. Governing transitions: Cases and insights from two periods in the history of the UK gas industry. Access here.
[14] Madhura, R. (2016). Ofgem Scheme Connecting More Households to Gas Grid. Ofgem News Blog. Access here.
[15] The Guardian. Access here.
[16] Gross, R., Hanna, R. (2019). Path dependency in provision of domestic heating. Access here.
[17] Lowes, R., Woodman, B. (2020). Disruptive and uncertain: Policy makers' perceptions on UK heat decarbonisation. Access here.

Basis for our analysis

This paper is based on recent modelling that has applied the UK TIMES model (UKTM) to examine the implications of ambitious national decarbonisation targets on residential heating.[18] The model also considers other important sectors, including transport, services and the industry, helping to put key results into context within the wider energy system. From a technical perspective, UKTM is a cost optimisation tool that accounts for all techno-economic aspects of energy production, distribution and use from the bottom-up. More details on the modelling can be found in the annex of this briefing.

Pre-insulated district heating pipes ready to be laid

[18] Broad O., Hawker G., Dodds P. E. (2020). Decarbonising the UK residential sector: The dependence of national abatement on flexible and local views of the future. Access here.

Energy efficiency and electrification: important solutions for clean heating

Focusing on residential heat, the model was run to analyse UK futures that span both ambitious emission targets and more liberal technology investment options[18] and includes two pathways:

- **Conservative:** This accounts for the recent change in UK 2050 targets and covers reduction targets ranging from 80 to 100% in 5 point increments.
- **Progressive:** This acknowledges that current views of investment options and their limitations may be conservative and therefore explores increased freedom in choosing heating system options across the sector.

The analysis also differentiates existing houses and flats, with and without cavity wall insulation, from new build.

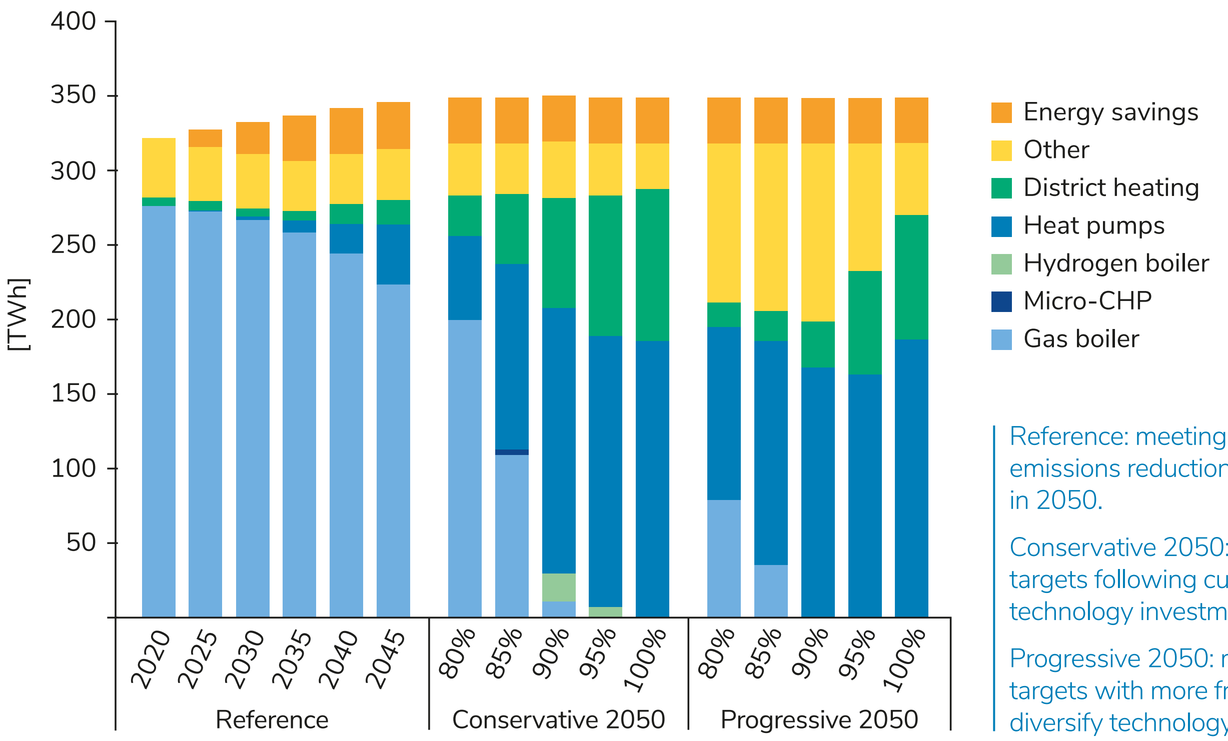
Results highlight the scale of change required in the residential sector. Figure 2 shows how the share of the technologies change with increasingly ambitious carbon reduction targets, depicting conservative and progressive scenarios, relative to 1990 levels.

Taken together, the results highlight the significance of the change that is required to move towards the new net zero emissions target for the UK. Residential heat supplied via natural gas in 2050 is near halved for an 85% emissions reduction target and is non-existent beyond a 95% reduction.

Instead, results suggest a dominant role for energy efficiency (termed energy savings), community heating (in majority heat pump based), and individual air source heat pumps. Considering additional freedom to roll out alternative heating technologies over time cements part of these results and adds detail to others (see conservative and progressive panels). While natural gas is typically phased out earlier, leaving emissions head-room for other important sectors of the economy, air source heat pumps make a larger contribution, as do flexible electric solutions. The comparatively high investment cost of district heating used in the model means that it is only applied in stringent emissions futures to areas with high demand density.

Installation of external insulation cladding on a block of flats

Figure 2 Heat technology change under different emissions reduction targets



Reference: meeting an 80% emissions reduction target in 2050.

Conservative 2050: meeting targets following current technology investment patterns.

Progressive 2050: meeting targets with more freedom to diversify technology investment.

Looking at the results in more detail, and contrasting them with local network analysis for representative urban and sub-urban areas of the UK[19], this analysis concluded that:

- Energy saving measures in line with fabric-first building stock refurbishment are always a cost-effective first step to reducing emissions in the residential sector. The UK has an older housing stock with lower energy efficiency than most European countries. Significant home insulation is a cost-effective abatement strategy under all assessed scenarios, indicating it to be a no regret option.
- Electrical systems could provide significant shares of future residential heat supply, whether through individual systems or large-scale heat pumps connected to district heating networks. Moving away from natural gas is unavoidable and long-term trajectories combine end-use electrification, at household or collective levels, with supply-side decarbonisation. This is preferable to alternative gases that continue to carry uncertain emission impacts, but requires local power network reinforcement.
- Network reinforcement costs could be deferred where technically difficult, by using near-term hybrid approaches. Flexibility, taking advantage of thermal storage can further reduce the need for network upgrades.
- The results confirm government policy that no new homes should be connected to the gas grid after 2025. This is particularly true as new, more ambitious, emission targets are to be achieved. This highlights that the phase out of fossil gas heating in new builds provides an opportunity to solve a problem before it occurs.

The findings are consistent with recent work undertaken by the European Commission's Joint Research Centre.[20] This comparative analysis of European modelling studies assessing pathways for decarbonisation – aiming at emission reduction higher than 50% by 2030 – suggests that this may require the replacement of between 10% and 35% of the individual fossil-fuelled boilers or heating stoves, mainly by heat pumps and district heating fuelled by low or zero carbon energy. Extending the timeline to 2050 shows that electrification and energy efficiency remain the two main strategies for decarbonising the building sector in all scenarios.[21]

The potential role for hydrogen

Uncertainty currently exists and will exist for some time, regarding the optimal mix of low carbon heating technologies for the UK. While electrification and district heating (alongside energy efficiency) are widely seen as key options, a number of recent analyses have proposed and explored the potential to convert the gas grid to provide low carbon hydrogen for use in domestic heating systems.[22] Despite emerging in policy and technology debates relatively recently[23], the idea appears to have gained some traction as an option with UK policymakers.[24]

Yet significant uncertainties over the viability of converting the gas network to hydrogen exist. These include the suitability of pipework, both external and internal to homes and buildings, how and where hydrogen will be produced or imported from, and how much this approach would cost. Various UK projects are investigating many of the technical issues associated with converting the gas grid to hydrogen including H21, H100 and HyNet, but as yet no UK city or region has been converted from natural gas to low carbon hydrogen. This is despite the fact that the Government has previously stated that serious decisions on the future of heating need to be made in the mid 2020s.[25]

The uncertainty of heat decarbonisation in the eyes of policy makers has been considered in recent UKERC research.[17] Research by the authors has also investigated the role of incumbent gas providers in advocating for the potential to repurpose the gas grid to provide hydrogen.[25] Our analysis suggests that policy makers may need to attempt to reduce uncertainty with trials and research, focus on low regrets options initially but also accept some level of uncertainty – or risk goals for heat decarbonisation being missed.

The off-gas grid sector would benefit from an initial focus on the electrification of heating and the deployment of heat pumps. This has been recognised by government previously who have suggested a phase out of high carbon fossil fuels in off-gas-grid areas during the 2020s.[26] However, the scale and speed of the UK heat transition means that some decarbonisation progress for areas currently on the gas grid may be required before the potential for hydrogen is known.

The following sections of the paper suggest some ideas how this initial progress can be made most cost-effectively and efficiently, based on a review of some relevant experience.

[19] Hawker, G. (2018). Spatial and temporal disaggregation of whole system energy models through exemplar local multi-carrier networks. Access here.

[20] JRC. (2020). Towards net-zero emissions in the EU energy system by 2050. Access here.

[21] ibid

[22] E.g. Element Energy, E4tech. Cost analysis of future heat infrastructure options. Access here. And KPMG. (2016). The UK Gas Networks role in a 2050 whole energy system. Access here.

[23] Lowes, R., Woodman, B., Clark, M. (2018). Incumbency in the UK heat sector and implications for the transformation towards low-carbon heating. Access here.

[24] HM Government. (201)7. The Clean Growth Strategy: Leading the way to a low carbon future. Access here.

[25] Lowes, R., Woodman, B., Speirs, J. (2020). Heating in Great Britain: An incumbent discourse coalition resists an electrifying future. Access here.

[26] BEIS. (2018). A future framework for heat in buildings call for evidence: Government Response. Access here.

Heat decarbonisation needs to be smart and integrated

The electrification of existing fossil fuel heat demand will increase the peak capacity and throughput requirements for electricity systems. This is widely anticipated and should come as no surprise, since expanding electricity systems are a principal feature of many scenarios of decarbonisation.[21] There is some space in the electricity system to electrify new end uses including heating without the need for network upgrades, especially in rural areas.[27] However, with this expansion for heating there will be challenges and specific issues around electricity generation and network capacity.

While it is apparent that electrification and energy efficiency can play a key role in heat decarbonisation, these changes may have impacts on energy consumers and the wider energy system. Recent analysis has suggested that system impacts of electrification can be minimised through an integrated approach that focusses on the operation of electrified heating loads in a way that minimises system costs and supports the integration of variable renewable electricity generation.[28]

Reducing additional electricity demand through efficiency

Through reducing heat demand, the required maximum capacity of heating systems can be reduced. This means that energy efficiency can reduce both average energy throughput and reduce peak capacity requirements on the electricity system. However, energy system flexibility has the potential to reduce and, in some cases, eliminate potential capacity issues associated with heat electrification.[29] Flexibility can increase electricity asset utilisation rates, support renewable electricity integration and therefore potentially reduce consumer costs.

Taking advantage of heat pump flexibility

While most past attention has been paid to specific within-electricity-system flexibility, the scale of heat demand as a proportion of total demand means that heating flexibility could become increasingly important. Pilot studies indicate that heat pump flexibility at portfolio level (i.e. a fleet of heat pumps) can reduce the peak contribution from heat pumps by around 30%.[30]

[27] Delta EE. (2018). Technical Feasibility of Electric Heating in Rural Off-Gas Grid Dwellings. Access here.
[28] Rosenow, J., Lowes, R. (2020). Heating without the hot air: Principles for smart heat electrification. Access here.
[29] This is certainly possible under initial limited electrification.
[30] Dong Energy Distribution. (2012). The eFlex Project. Access here.

Storage of heat within the thermal mass of efficient buildings or as hot water in water cylinders can be much cheaper than storing electricity.[31] Evidence suggests that there are three key routes through which heat pumps can support flexible electricity systems: provide grid benefits, such as capacity reductions and voltage control; offer a price benefit, through making the most of variable pricing; and support the integration of renewable electricity through load shifting.[32]

Combinations of other technologies in households such as solar PV, electric batteries, and heat pumps may be able to provide further system flexibility but the performance and economics is complex and sensitive to sizing.[33] Heat batteries based on phase change materials may also be able to provide heat demand flexibility[34] and while at an early stage of deployment, these technologies are currently being supported by the Scottish Government.[35]

Getting the pricing right

Flexibility can be driven through the use of 'smart' and time-of-use electricity pricing. Variable time of use (ToU) tariffs and more dynamic tariffs which can reflect changing wholesale prices and potentially the carbon intensity of electricity can encourage consumers to move electricity demands outside of certain periods.[36]

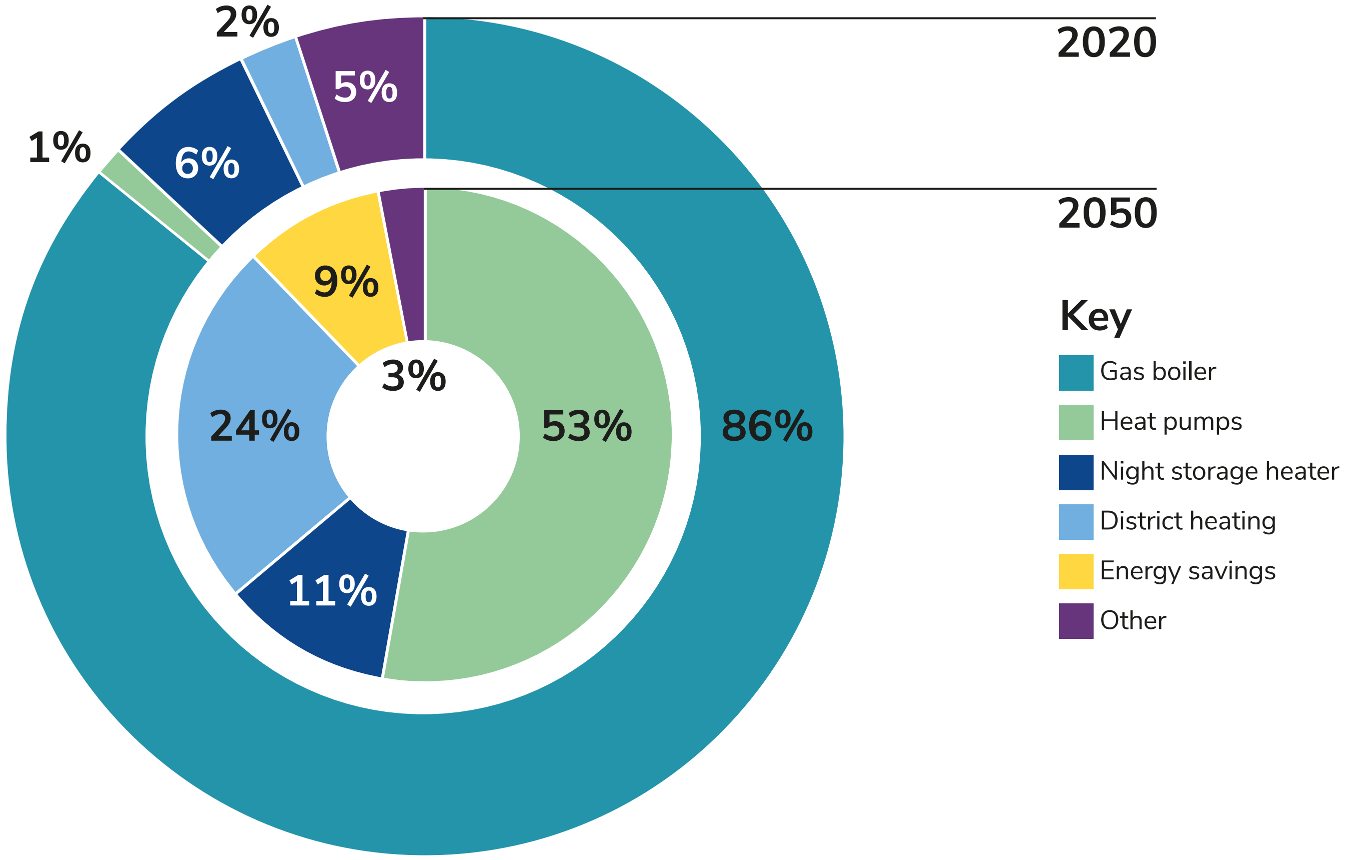
Dynamic tariffs can significantly reduce consumer costs of operating heat pumps. Customers taking advantage of dynamic tariffs in the UK who scheduled their heat pumps to avoid peak hours have seen average prices of less than 8p/kWh[37] compared to the average rate paid of 15p/kWh. This makes the business case for heat pumps much stronger and households could potentially see their energy bills fall significantly – compared to using gas or heat pumps with flat electricity tariffs – when installing a heat pump if coupled with energy efficiency and dynamic tariffs.

solar PV, electricity batteries, and heat pumps may be able to provide further system flexibility

[31] Zhai, Z., Abarr, M.L.L., Al-Saadi, S.N.J., Yate, P. (2014). Energy storage technologies for residential buildings. Access here.
[32] Fischer, D., Madani, H. (2016). On heat pumps in smart grids: A review. Access here.
[33] Angenendt, G., Zurmühlen, S., Rücker, F., Axelsen, H., Sauer, D.U. (2019). Optimization and operation of integrated homes with photovoltaic battery energy storage systems and power-to-heat coupling. Access here.
[34] National Energy Action. (2018). Various heating solutions for social housing in North Lincolnshire Ongo Homes Technical Evaluation Report. Access here.
[35] Power Technology. (2018). Heat batteries to be included in Scotland home energy loans scheme. Access here.
[36] Farnsworth, D., Shipley, J., Lazar, J., Seidman, N. (2019). Beneficial Electrification: Ensuring Electrification in the Public Interest. Access here.
[37] This is based on the experience reported by several heat pump owners on social media including two of the authors of this briefing.

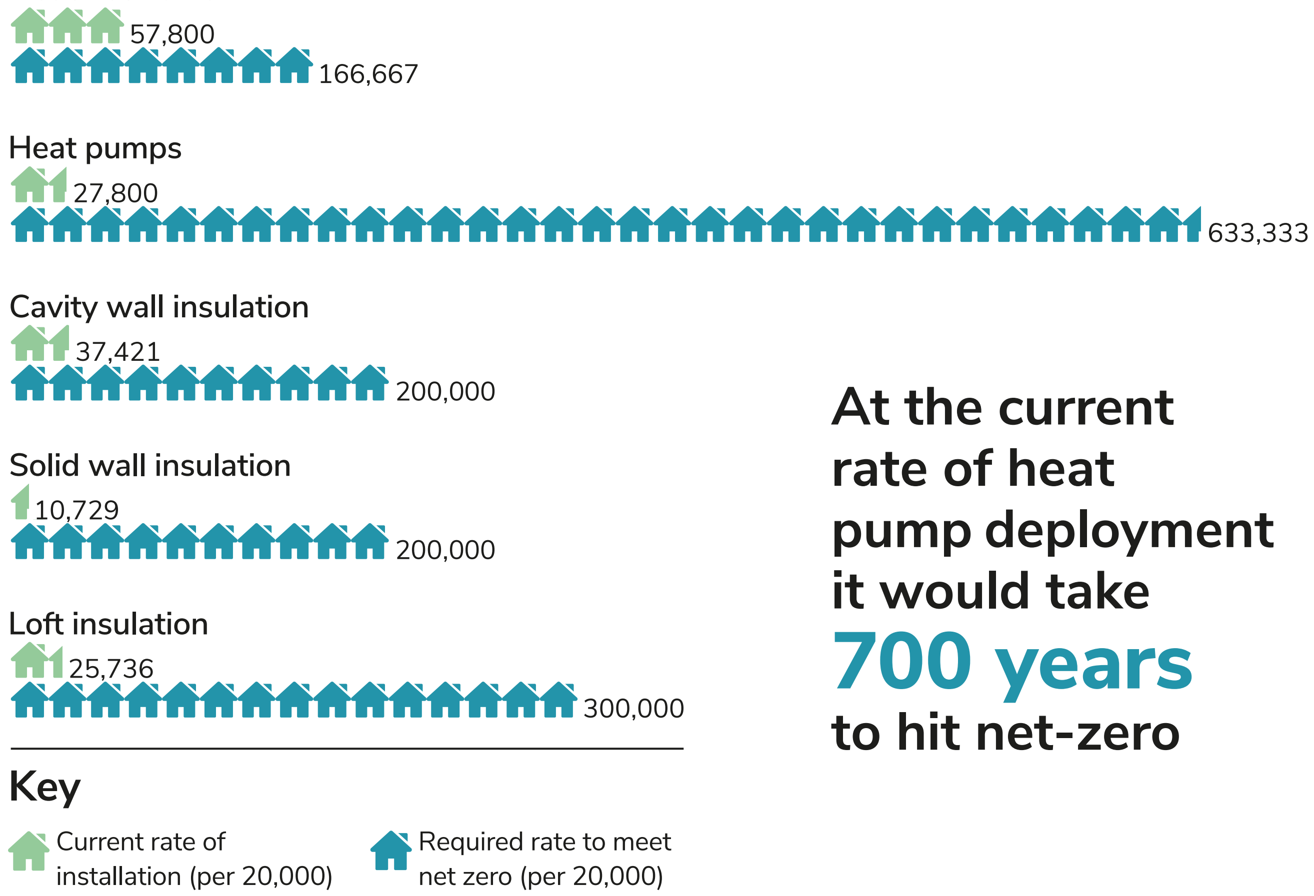
Residential heating: reaching net zero

Heating system usage



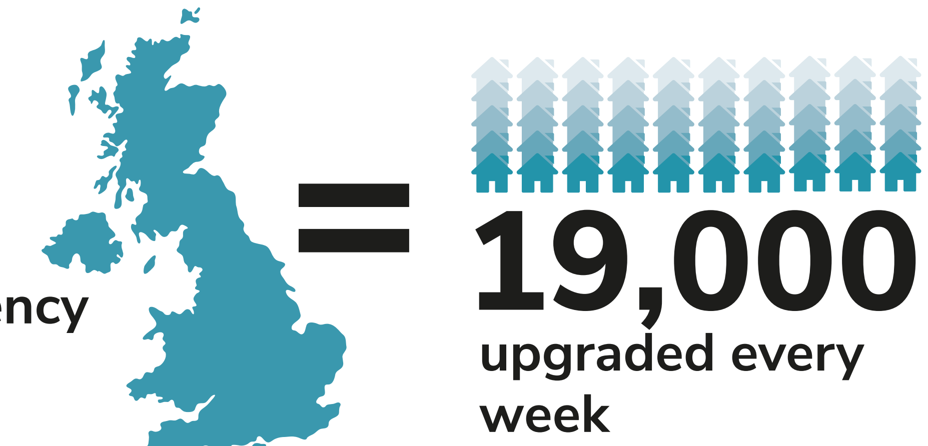
To meet net zero the most cost-effective options are: heat pumps, district heating and energy savings

Average annual number of installations across low-carbon heating technologies compared to the number required to meet net-zero by 2050 in the housing sector



At the current rate of heat pump deployment it would take 700 years to hit net-zero

Almost all of the UK's 29M homes need energy efficiency upgrades



Policy suggestions

12,500

the proposed Clean Heat Grant would provide support for 12,500 homes to switch to low carbon heating

It is extremely unlikely that heat decarbonisation will be achieved without significant policy interventions. The key active policy to support low carbon heat is currently the Renewable Heat Incentive (RHI). It is due to close to non-domestic applicants in 2021 and the domestic scheme is being replaced with a new capital grant-based scheme for smaller installations as outlined in recent proposals by BEIS.

Fundamentally it is important to recognise that the speed and scale of the required heat transformation means that relying on consumer led schemes such as the RHI and the planned Clean Heat Grant, are not sufficient. Incentives for consumers need to be part of a suite of policy measures based around skills, financial support and packages, local area-based planning approaches and cross-industry strategy will be needed.[38]

The recent policy proposals for the Clean Heat Grant published in April 2020 would provide support for 12,500 homes per year for switching to low carbon heating solutions, largely air source heat pumps, in the financial years 2022-23 and 2023-24[39]. Last year saw a record number in gas boiler sales of 1.67 million units installed in British homes, up 1.8 per cent from 2018.[40]

The Clean Heat Grant proposals seem likely to maintain a flat heat pump market while the boiler market grows, in part due to the fact that the majority of new homes are being connected to the gas grid. The Clean Heat Grant is intended only as an interim measure, but if heat is to be decarbonised, heat pump sales will need to increase significantly driven by more ambitious future policy.

We also note that structural inequalities in pricing appear to be having a negative impact on the potential for electrification. Previous research demonstrates that consumers still pay a lot more of the costs of the energy transition through their electricity bills than their heating bills, with gas carrying a much lower environmental and social policy cost burden than electricity, and having no carbon price applied.[41] This unequal sharing of costs between electricity and gas makes heat pumps less financially attractive because of the higher operating costs of heat pumps on standard (non-variable) tariffs. Unless consumers can see a financial benefit in the form of lower operating costs, it is unlikely that a modest upfront grant will provide sufficient incentive. Experience from countries such as Sweden and Finland shows that once fossil fuel heating is no longer the cheapest option the market changes rapidly, provided that other issues such as skills, certification of installers and equipment and performance are addressed.[42]

[38] Hanna, R., Parrish, B., Gross, R. (2016). Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply. Access here.
[39] BEIS. (2020). Consultation Stage IA: Future Support for Low Carbon Heat. Access here.
[40] Installer Magazine. (2020). 2019 was record year for gas boiler sales. Access here.
[41] Barnes, J., Bhagavathy, S. (2020). The economics of heat pumps and the (un)intended consequences of government policy. Energy Policy 138, 111198. Access here.
[42] BEIS. (2020). Future support for low carbon heat. Access here.

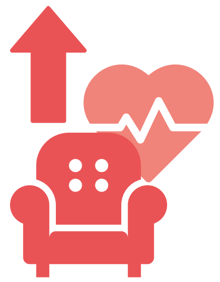
It is laudable that the clean heat consultation document acknowledges "*the need for a consistent, long-term policy framework*" and that it "*is clear that regulations will be needed to underpin the transformation of our building stock*".[42] The Heat and Buildings Strategy, due later this year, will lay out immediate actions for reducing emissions from buildings. This needs to go far beyond the current proposals for clean heat and existing energy efficiency policies. The Heat and Buildings Strategy should spell out a trajectory to net zero in 2050 or earlier and set out the policies that will deliver on this.

Key policies required include a large-scale financial support programme for energy efficiency and low-carbon heat to ramp up delivery rates and bring about innovation. The exact nature of what financial support should look like is unclear, however we offer some generalisations which have emerged from UKERC research:

- Long term policy stability is required to grow low carbon heat markets efficiently and successfully.[43]
- Various financial tools can have value including grants but the value of these depends on the context, and they need to be combined with strong regulation and consumer protection.[44]
- While the public generally supports the energy transition, citizens do not generally think they should finance it themselves.[45]

We also make the following strategic technology suggestions which reflect a wide range of UKERC research:

- There remains significant potential for cost-effective energy efficiency in UK homes.
- The roll-out of district heating in dense urban areas has repeatedly been shown to be an important technology from a system wide perspective, but also entails large capital costs.
- The electrification of heat in rural areas not on the gas grid can be a widely beneficial technology transition and could be progressed rapidly.
- The uncertainty over long term options and the role of the gas grid is worthy of a significant and rapid research programme, but uncertainty should not delay action over what is possible and known to currently work.
- There are likely to be wider benefits to heat decarbonisation including increased comfort and health outcomes, reduced imports and the development of new skills and industries.



greater focus on increased comfort and better health outcomes

[43] Hanna, R., Parrish, B., Gross, R. (2016). Best Practice in Heat Decarbonisation Policy. Access here.
[44] Ibid
[45] Pidgeon, N., Demski, C. (2018). Paying for transitions, public perspectives and acceptability. Access here.

Annex: Basis for our analysis

While UKTM does not cover the entire economy, the TIMES framework that it uses and the long-term technical approach it applies to assess investment requirements in the energy system are widely used to represent local, regional or national energy systems.[46] The model was built in 2014 by UCL Energy Institute as a successor to UK MARKAL[47], and recent versions have been developed collaboratively with HM Government's Department for Business, Energy and Industrial Strategy (BEIS, previously DECC) and by the CCC to underpin the fifth UK Carbon Budget.[47] It has also been used for a number of academic energy scenario analyses of the UK.[47, 48, 49, 50, 51, 52]

Structurally, UKTM contains a stylised representation of UK energy supply chains. That is, it consists of a network of technologies that turn upstream resources, like natural gas, into end-user energy services, such as heat.

These technologies are used to both model existing infrastructure and include new options for developing the energy system of the future. Taken as a whole, this structure covers demand for energy in the residential, industrial, service, transport and agricultural sectors; accounts for upstream supply of fossil and renewable energy options; and includes a representation of international trade for selected energy commodities. This approach is essential when building energy scenarios as it provides a holistic framework within which to track emissions under national climate targets, trading off mitigation efforts between sectors.

Operationally, the model is used to compare investment decisions over the medium to long term. It looks at the UK as a single region and designs a cost-effective supply system for the energy needs that are specified in each of its five sectors.

[46] Loulou, R., Goldstein, G., Noble, K. (2004). Documentation for the MARKAL Family of Models. Access here.
[47] Fais, B., Keppo, I., Zeyringer, M., Usher, W., Daly, H. (2016). Impact of technology uncertainty on future low-carbon pathways in the UK. Access here.
[48] Fais, B., Sabio, N., Strachan, N. (2016). The critical role of the industrial sector in reaching long-term emission reduction, energy efficiency and renewable targets. Access here.
[49] Fuso Nerini, F., Keppo, I., Strachan, N. (2017). Myopic decision making in energy system decarbonisation pathways. A UK case study. Access here.
[50] Pye, S., Li, F.G.N., Price, J., Fais, B. (2017). Achieving net-zero emissions through the reframing of UK national targets in the post-Paris Agreement era. Access here.
[51] Zeyringer, M., Fais, B., Keppo, I., Price, J. 2018. The potential of marine energy technologies in the UK – Evaluation from a systems perspective. Access here.
[52] Daly, H. and Fais, B. (2014). UK TIMES Model Overview. Access here.

To do this it breaks time down into representative pieces: days within a given year are represented using 16 average blocks that cover daytime, evening peak, late evening and night-time across the four seasons. Modelling data are calibrated to 2010 energy statistics, and the analysis period to 2050 is broken down into five-year time-steps.[53, 54] Finally, technologies are compared on the basis of standard techno-economic data that cover costs (capital and operational), efficiencies, availability and intermittence, lifetime (economic and technical), emissions, etc. Discounting is applied both on individual projects and, from a social planner perspective, on the system cost as a whole. It is the total cost of investing in, and operating, a given system design that the model is designed to minimise. Further details are found in Daly and Fais (2014).

Rolls of rock wool insulation

[53] DECC (2011). Renewable Heat Incentive. Access here.
[54] DECC. (2011). Digest of United Kingdom Energy Statistics. Access here.

Authors

Jan Rosenow, University of Oxford & University of Sussex
Richard Lowes, University of Exeter
Oliver Broad, University College London
Graeme Hawker, University of Strathclyde
Jianzhong Wu, Cardiff University
Meysam Qadrdan, Cardiff University
Robert Gross, Imperial College London

About UKERC

The UK Energy Research Centre (UKERC) carries out world-class, interdisciplinary research into sustainable future energy systems. It is a focal point of UK energy research and a gateway between the UK and the international energy research communities. Our whole systems research informs UK policy development and research strategy. UKERC is funded by the UK Research and Innovation Energy Programme.

ukerc.ac.uk

Follow us @UKERCHQ

Remote control heating system on a digital tablet

UK Energy Research Centre,
Central House, BSEER,
14 Upper Woburn Place,
London, WC1H 0NN
T: +44 (0)20 3108 7564
@UKERCHQ