July 2018

Friends of the Earth

The future of heating

Meeting climate targets through electric heating backed by renewably-produced hydrogen.

Contents

Update

This briefing shows how the UK can meet its climate targets while keeping homes warm and eradicating fuel poverty.

There has been a lot of policy development since this briefing was posted in August 2018. The Prime Minister has published his 10 Point Plan for a Green Industrial Revolution which set a target for 600,000 heat pump installations a year by 2028 and the Heat and Building Strategy came out just ahead of COP26. While both adopt an electric-first approach to home heating – as we advocated – neither have coherent plans to meet the targets. Both have also failed to rule out the use of dirty hydrogen for home heating – made from fossil fuel gas – which has left the door ajar for fossil fuel advocates to lobby for more gas extraction from the North Sea.

Summary

Following the Paris Agreement on climate change, the government asked the Climate Change Committee to recommend more stringent carbon reduction targets which will require faster and deeper action to decarbonise home heating – the subject of this briefing.

Decarbonising home heating will cost money and it will involve disruption to householders but it can also bring significant economic opportunities for the UK.

It is critical that householders are actively involved in deciding how their heating is decarbonised. They must be able to make choices informed by impartial, trusted and evidence-based advice (advice that is currently lacking).

A whole house approach that incorporates energy efficiency and smart energy controls together with changes to heat supply will be most cost effective and less disruptive than multiple changes over time.

Our main recommendations are:

An area by area coordinated heating transformation programme – starting as soon as possible and to be completed by 2040 at the latest.

The programme needs to combine whole house upgrades and electricity grid upgrades.

These whole house upgrades need to include energy efficiency measures, smart energy controls, new heating appliances (e.g. heat pumps, hybrid heat pumps, electric storage heaters), and offer the opportunity for householders to install renewable energy (e.g. solar thermal, or solar PV coupled with a smart battery).

Local authorities will need to be at the heart of this – working with grid operators, insulation business, and energy service companies – because they are recognised, impartial and trusted.

In this briefing we also recommend:

A much stronger focus on energy efficiency – there remains very significant scope for energy efficiency measures which would both reduce the cost of energy to householders and also significantly reduce the cost of the transformation needed in energy supply for decarbonising home heating.

The advent of smart heating controls at the household and individual room level offers further energy savingsThe Behavioural Insights Team, 2017, The Nest Learning Thermostat: Making energy savings easy https://www.bi.team/blogs/the-nest-learning-thermostat-making-energy-savings-easy/. In total, energy consumption for home space heating (i.e. excluding hot water for washing) could probably be reduced by around a third or moreVerco and Cambridge Econometrics, 2014, Building the Future: The economic and fiscal impacts of making homes highly energy efficient, E3G, https://sustainableenergyassociation.com/publications/684/.

Home heating should largely be provided by electricity, with hydrogen providing a secondary role – the UK has unparalleled renewable energy resources which we should exploit to provide the UK with greater energy independence, to provide energy export opportunities (as electricity and hydrogen) and enable the UK to be a global leader in the offshore wind industry and the electrolysis industry.

Using electricity directly to heat homes is the most efficient use of electricity.

Hydrogen produced from electricity can however be an important source of energy for use in conjunction with hybrid heat pumps (which work alongside a boiler). Hydrogen can also provide an energy store for back-up electricity production.

A strategy to exploit our huge renewable energy resources would require increasing the scale and deployment of renewable energy by eight fold to provide all the electricity the UK needs, including for heating and transport. This increase should particularly come from offshore wind, which fell in price by a third between 2012 and 2016BVG Associates and Wind Europe, 2017, Unleashing Europe's Offshore Wind Potential, https://windeurope.org/wp-content/uploads/files/about-wind/reports/Unleashing-Europes-offshore-wind-potential.pdf .

It would also require an orders of magnitude increase in the roll-out of heat-pumps (including hybrid heat pumps), and electric storage heaters.

The electricity grid upgrades need to enable electric home heating – it is recognised that the electric grid system needs significant upgrading to accommodate electric vehicles, particularly local electricity grid networks. The upgrade should in addition include enabling the majority of home heating to be electric.

An end to the use of natural gas in home heating – attempts to provide this significant source of greenhouse gases with a lifeline through converting natural gas to hydrogen and capturing and storing a proportion of the resultant carbon dioxide under the North Sea (CCS) are, in our view, wrong. It would keep the UK hooked on imports of natural gas, and indeed will increase the amount needed to be imported. A strategy based on this would also be incompatible with existing Climate Change Act carbon budgets, let alone more stringent cuts required as a result of the Paris Agreement.

Instead, we argue any hydrogen needed should be produced by electrolysis from renewable power.

Funding the transition

How to fund the decarbonisation of heat is not straight-forward as some heating options for householders involve high capital costs but minimal reductions in energy bills (e.g. heat pumps), whereas others have low capital costs but on-going higher running costs (e.g. using hydrogen in a hydrogen boiler).

And some costs may change very significantly over coming years. For example, Adair Turner, former chair of the Climate Change Committee, has suggested that electrolysis to produce hydrogen could easily follow the same rapid downward path in costs as solar panels and batteries haveTurner, 2018, The low cost of a zero carbon economy, Project Syndicate, https://www.project-syndicate.org/commentary/low-costs-zero-carbon-economy-by-adair-turner-2018-04.

Along with National Energy Action, we warn against funding the cost via a levy on energy bills because of the impact on fuel povertyFreck and MacLean (2017), Heat decarbonisation, potential impacts on social equity and fuel poverty, National Energy Action http://www.nea.org.uk/resources/publications-and-resources/heat-decarbonisation-potential-impacts-social-equity-fuel-poverty/.

Further, we suggest that whichever funding mechanism is chosen has to be an attractive option for householders, which implies options that bring no direct upfront costs for householders (e.g. capital grants) or have fast payback periods (e.g. around 5 years).

The changes required can also be delivered via obligations on, for example, network operators, energy supply companies, landlords and others. If the change is delivered through this approach it will be necessary to ensure that costs are carefully monitored and that householders are well informed of their options and their rights.

Costs are only one-side of the equation, as a recent report to the National Infrastructure Commission by Element Energy has pointed outElement Energy, 2018, Cost analysis of future heat infrastructure, National Infrastructure Commission, https://www.nic.org.uk/publications/cost-analysis-of-future-heat-infrastructure/. On the other side of the equation is the potential for new industries (e.g. electrolysis) and businesses (e.g. energy service businesses), jobs and export markets as well as the avoided costs of climate change. In other words, the transformation should be viewed as an investment.

Context

Deep decarbonisation of home heating is needed quickly.

The Paris Agreement, which the UK signed-up to, commits governments to:

“Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change”.

The government has asked the Climate Change Committee for its advice on what this means for UK action, including the targets within the Climate Change Act, recognising that it will undoubtedly require increased action.

Recent academic research suggests that ‘pursuing efforts to limit the temperature increase to 1.5 degrees C would require the UK to reduce greenhouse gases by around 70-80 per cent by 2030 and be almost net zero by 2045Robiou et al, 2017, Equitable mitigation to achieve the Paris Agreement goals; Nature Climate Change volume7, pages38–43, doi:10.1038/nclimate3186. Their website http://paris-equity-check.org/ allows you to identify carbon reduction trajectories for different countries for 1.5 or 2 degrees and different treatments of equity. The carbon budget they use is for CO2e (i.e. including non-CO2 GHGs). Some non-CO2 emissions are very difficult to eliminate (e.g. from livestock) and therefore require net zero CO2 earlier. The budget they identify for >66% chance of avoiding 2 degree is 1, 523 GtCO2e. The budget they identify for >50% chance of avoiding 1.5 degree is 1, 134 GtCO2e. The estimates in this briefing are based on the 2 central equity approaches they identify. – and even this makes heroic assumptions about future negative emissions.

Home heating in the UK, which is the focus of this briefing, uses around a third of fossil-fuel gas use in the UK, and is responsible for around a quarter of UK carbon dioxide emissionsNational Grid, 2018, The Future of Gas. The report states “Currently 80% of the UK’s 26 million homes use gas for heat, and this is responsible for over a quarter of current UK carbon emissions. 80% of current housing stock will still be in use in 2050. If decarbonisation of heat is to be successful, around 20,000 homes per week for the 25 years from 2025 to 2050 will need to move to a low carbon heat source”. This is based on current climate change targets and not the deeper targets needed as a result of the UK signing up to Paris. http://futureofgas.uk/wp-content/uploads/2018/04/The-Future-of-Gas_Conclusion_web_2.pdf.

Decarbonising this sector is recognised as a knotty problem with no one clear pathway whereas in other sectors the pathway is clearer (e.g. electrification of surface transport). There are a number of approaches, which we look at below.

Home heating options for a Paris compatible pathway

A home heating pathway compatible with the Paris agreement will have several components. These could include:

Insulation – insulation has a critical role both in reducing energy costs for consumers and in reducing the quantity and costs of infrastructure needed to decarbonise home heating.

There are currently 19 million homes in the UK with an Energy Performance Certificate (EPC) rating below C, out of a total 27 million homes. The government has said it wants as many of these as possible to be upgraded to EPC C by 2035 as possible, but according to the Climate Change Committee it does not yet have all the mechanisms in place to do soCommittee on Climate Change, 2018, An independent assessment of the Government's Clean Growth Strategy: from ambition to action, https://www.theccc.org.uk/publication/independent-assessment-uks-clean-growth-strategy-ambition-action/ .

A 2014 study by Cambridge Econometrics and Verco suggested that an energy efficiency programme to do so would lead to a 19% reduction in total UK gas consumption and much greater reduction in gas for home heating)Verco and Cambridge Econometrics, 2014, Building the Future: The economic and fiscal impacts of making homes highly energy efficient, E3G, https://sustainableenergyassociation.com/publications/684/.

In addition, the advent of smart controls for home heating offers further reduction potential.

A recent study by the Behavioural Insights Team on the NEST smart heating controller suggested additional saving of around 5% in gas consumption is likely for homes that already have good heating controls (radiator valves, programmer) but much higher for homes without thisThe Behavioural Insights Team, 2017, The Nest Learning Thermostat: Making energy savings easy https://www.bi.team/blogs/the-nest-learning-thermostat-making-energy-savings-easy/. Smart controls at an individual room level are also now on the market, offering potential for even greater savings.

Overall, this suggests that total energy consumption for home space heating (i.e. excluding hot water) could be reduced by around a third, as a conservative estimate, and perhaps much more than this.

Although it should also be recognised that many homes are under-heated in the UK (e.g. due to fuel poverty) and greater insulation in these cases may increase comfort but not lead to predicted savings in energy usage.

Heat-pumps – in the USA there are over 10 million homes using heat pumps for heating and cooling Lapsa et al, 2017, The U.S. Residential Heat Pump Market, a Decade after "The Crisis", 12th IEA Heat Pump Conference, 2017, Rotterdam, http://hpc2017.org/wp-content/uploads/2017/05/O.2.1.2-The-U.S.-Residential-Heat-Pump-Market-a-Decade-after-The-Crisis-and-Regional-Report-North-America.pdf. In Sweden and Switzerland heat pumps now occupy the largest market share of all heating system installationsFrontier Economics and Element Energy, 2013, Pathways for high penetration of heat pumps, report prepared for the Committee on Climate Change, Committee on Climate Change https://www.theccc.org.uk/wp-content/uploads/2013/12/Frontier-Economics-Element-Energy-Pathways-to-high-penetration-of-heat-pumps.pdf. By comparison, in the UK the vast majority of homes use gas.

Heat pumps have the advantage of capturing heat from the environment (air or ground) to warm the home, and they work down to temperatures as low as -20^{o}CThe co-efficient of performance drops as temperatures drop, but are still close to 3 (3 units of warmth for 1 unit of electricity) even around freezing.. They are powered by electricity. For every unit of electricity they use they provide roughly 3 units of warmth (or higher for ground-source heat pumps), therefore very significantly cutting the amount of energy a household needs to buy or the energy industry to generate (although at low temperatures, e.g. <5 degrees, they are much less efficient at capturing heat from the environment).

Heat pumps can provide an entire home’s water and space heating requirements if the house is well insulated although in many older solid wall homes radiators will need replacing with larger radiators.

There are also hybrid heat pumps which work in conjunction with a home’s gas boiler, with the gas boiler kicking in alongside the heat pump when temperatures drop below a designated temperature. These hybrid heat pumps are more suitable for homes where a traditional heat pump may struggle to provide the heat needed, or where radiator replacements are infeasible or unwanted. A trial in Wales has explored how to use hybrid heat pumps most cost efficientlyPassiv, FREEDOM – decarbonised heating with hybrid heat pumps, https://www.passivuk.com/case-studies/freedom/.

A report for the Climate Change Committee identified that the majority of homes are already suitable for heat pumps or will be once insulation goals are met. The report estimated that in 2013 already 46 per cent of properties were suitable for heat pumps, taking into account issues of space, noise and insulation levels. It also said this proportion would also increase with the use of hybrid heat pumps Frontier Economics and Element Energy, 2013, Pathways for high penetration of heat pumps, report prepared for the Committee on Climate Change, Committee on Climate Change https://www.theccc.org.uk/wp-content/uploads/2013/12/Frontier-Economics-Element-Energy-Pathways-to-high-penetration-of-heat-pumps.pdf.

Electric radiators, storage heaters and infrared heaters – currently, using electric radiators leads to more greenhouse gases than gas-fired boilers as they use electricity at times when the carbon intensity of the electricity grid is highest (peak demand in winter).

In 5-10 years the carbon intensity of the grid may have declined enough to make the use of electric radiators less polluting than gas boilers in terms of carbon emissions (although this is unlikely to be the case in Northern Ireland).

Currently, high heat retention storage heaters are only slightly worse than gas-fired boilers for greenhouse gases but they will be a better option within a few years as the grid decarbonises, and from then on they will improve on this position year on year.

High heat retention storage heaters perform better on cost and carbon pollution than electric radiators.

New on the market are far infrared heaters, which some retailers claim to reduce energy demand by more than a third compared to electric radiators by heating ‘objects’ and not the air. However we have not found any published independent verification of these figures yet. If accurate these will be much better than electric radiators and storage heaters but still not as good as heat pumps and still slightly worse than gas-fired boilers.

Fuel cell micro CHP – there is a lot of innovation into fuel cell micro-combined heat and power boilers (fuel cell micro CHP) that can utilise natural gas, hydrogen or a mix of the two, and therefore be well suited to a gradual increase on hydrogen in the grid.

Japan is leading the field in terms of deployment, with over 200,000 units sold. Germany is best in class in Europe with 1500 fuel cell micro CHP units installed.

Because theses provide homes with both heating and electricity and export electricity to the grid they can also help overcome issues with intermittency of renewable power.

According to a recent European trial this option is better than heat pumps while the electricity grid has high carbon intensity but is not as low carbon as heat pumps when the grid has low carbon intensity Pudjianto et al, 2017, Benefits of Widespread Deployment of Fuel Cell Micro CHP in Securing and Decarbonising the Future European Electricity System, Imperial College http://enefield.eu/wp-content/uploads/2017/10/WP-5.4-Impact-of-widespread-deployment-of-fuel-cell-mCHP-041017-Final_.pdf.

In the UK now, apart from in Northern Ireland, they will deliver virtually no carbon savings compared to natural gas boilers and grid electricity and will be worse as the electricity grid decarbonises further.

Hydrogen – there is currently much debate on the future of the gas grid, including whether for domestic properties it should switch to hydrogenHydrogen may also be an option for heavy industry, such as steel. A pilot has been announced in Austria; see FCH, 2018, Hydrogen Meeting Future Needs of Low Carbon Manufacturing Value Chains, http://www.fch.europa.eu/project/hydrogen-meeting-future-needs-low-carbon-manufacturing-value-chains. A recent report identified that a strategy only based on switching to hydrogen would be incompatible with the Climate Change Act carbon budgets because the roll-out would take too longElement Energy, 2018, Cost analysis of future heat infrastructure, National Infrastructure Commission, https://www.nic.org.uk/publications/cost-analysis-of-future-heat-infrastructure/.

There are a number of projects being rolled out or considered to test this switch, with the most ambitious being in Leeds where there is a proposal to rapidly switch the whole city’s gas supply from natural gas to 100 per cent hydrogen.

And a feasibility study by Northern Gas Networks has suggested that switching the gas grid to hydrogen is both desirable and technically feasibleNorthern Gas Networks, 2018, NGN and ITM Power hail compelling power-to-gas energy storage study results https://www.northerngasnetworks.co.uk/2018/04/24/ngn-and-itm-power-hail-compelling-power-to-gas-energy-storage-study-results/, although further work on the safety of gas within homes is needed.

There are planned trials in the UK, France and Australia for assessing how much hydrogen can already be injected into the gas supply without changing appliancesEuropean Commission, 2018, Hydrogen admixtures into the natural gas grid, http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/fch-04-2-2018.htmlGTM, 2018, Australia seeks hydrogen to soak up excess renewable energy production, https://www.greentechmedia.com/articles/read/australia-looks-to-hydrogen-to-soak-up-excess-renewable-energy-production#gs.rv=mtGA and UK gas distribution company Cadent believes levels of around 20 per cent are possibleThe Guardian, 2017, Trial to phase in hydrogen as fuel to begin in the North West, https://www.theguardian.com/business/2017/aug/07/trial-to-phase-in-hydrogen-as-fuel-to-begin-in-north-west.

A switch to hydrogen beyond 20 per cent needs to be carefully managed, in an area by area approach, because although current appliances can probably burn 10-20 per cent hydrogen safely new appliances will needed to be developed for higher concentrations of hydrogenCurrently research is focussed on appliances for burning 100% hydrogen, but as Stephen Livermore from Frasier Nash Consultancy points out (pers. comm.) different blends should also be possible given that previously UK gas was around 50% hydrogen when the UK was supplied by town gas . Also pipework within homes may need replacing, which may not in all cases be practical.

The government is currently exploring this issue and a report for it recommended the development of ‘hydrogen ready appliances’ that can be easily switched from natural gas to hydrogen when needed (analogous to the HD ready televisions). Driving the development of these new hydrogen burning appliances will require strong signals from the governmentFraser Nash Consultancy, 2018, Appraisal of Domestic Hydrogen Appliances, BEIS, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/699685/Hydrogen_A For_Publication-14-02-2018-PDF.pdf·

Biogas – according to a recent assessment, replacing natural gas with bio-methane made from wastes such as sewage and plants could reduce the total current fossil fuel gas consumption in the EU by around 5 per cent by 2030Oxford Institute for Energy Studies, 2017, Biogas: a significant contribution to decarbonising gas markets? Oxford University. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/06/Biogas-A-significant-contribution-to-decarbonising-gas-markets.pdf. Biomass can also be converted to hydrogen. This proportion would be larger if accompanied with better home insulation. However, as with any use of biomass there will be issues around sustainability that needs to be considered.

Heat networks – A report for the Climate Change Committee has suggested as a central estimate that heat networks could provide almost 10 per cent of heating (domestic and non-domestic) by 2030 Element Energy Ltd, Frontier Economics, and Imperial College, 2015, Research on District Heating and local approaches to heat decarbonisation, Committee on Climate Change https://www.theccc.org.uk/wp-content/uploads/2015/11/Element-Energy-for-CCC-Research-on-district-heating-and-local-approaches-to-heat-decarbonisation.pdf.

Householder choice

Given the transition to low carbon heating involves disruption to households and brings costs, householder choice will necessarily be central. And to secure support for the programme the transition has to bring clear benefits for the householder, recognising that finances are not the only issue householders consider. A trustworthy, impartial source of information will be necessary.

Electricity grid challenges

In the near future most of the energy we use is likely to be electric. Electricity will power the vast majority of our transport and is likely to provide the majority of our home heating.

The electricity network operators are currently writing their draft business plans for the 2020s which they need to submit for approval to the regulator, Ofgem. They are also beginning the process of changing into Distribution System Operators to recognise their role is changing from simply facilitating the movement of electricity from centralised electricity generators to local users to managing a smart grid with distributed generation and storage.

Already they are thinking about grid changes due to the growth of electric vehicles. While the existing grid can accommodate some electric vehicle charging using slow speed chargersNick Storer, Electric Nation, 2017, How will the growth of electric vehicles impact the grid, Energy World, November 2017, pp32-34, http://www.electricnation.org.uk/wp-content/uploads/2017/11/14-How-will-the-growth-of-electric-vehicles-impact-the-grid.pdf without change it will not be able to accommodate the rapid growth in electric vehicles necessary to meet the Paris Agreement on climate change, nor the faster charging of newer electric vehicles (with charging of 7kW+). For example, around a third of electric grid networks will need upgrades when 40-70% of households have electric vehicles and this does not account for the challenge of much greater penetration of electric heatingWestern Power Distribution, 2017, Next generation networks, marketing and PR report, https://www.westernpower.co.uk/docs/Innovation/Current-projects/CarConnect/Electric-Nation-Marketing-and-PR-Report-October-20.aspx .

It makes sense for the network operators to include in their business plans updates to the grid which accommodate both the rapid roll-out of both electric vehicles and a very high penetration of electric heating, particularly heat pumps.

The Electric Networks Innovation Strategy, published in March 2018, identified that they need to focus on a 'whole system' approach from 2022 that recognises significant penetration of electric vehicles and electric heatEnergy Networks Association, 2018, Electricity Network Innovation Strategy, http://www.energynetworks.org/assets/files/electricity/futures/network_innovation/electricity_network_innovation_strate %20Electricity%20Network%20Innovation%20Strategy-March%202018.pdf.

The industry will need to consider the possible rapidity of uptake of electric vehicles as up-front costs of EVs converge with petrol and diesel cars, and that when the gas grid is decarbonised many householders and perhaps the majority will switch to electric heating.

Consumers will not be forgiving for their choice to be constrained because the grid is not ready for the shift.

How to make hydrogen

The Leeds H21 hydrogen proposal intends to produce hydrogen for use in household boilers and industry using natural gas, known as Steam Methane Reforming (SMR).

SMR produces lots of carbon dioxide as a by-product and without carbon capture and storage it is worse than simply burning gas in the home. In other words, without CCS it is a non-starter.

According to a recent report for the National Infrastructure Commission even when using CCS this approach would at best only reduce the cumulative carbon emissions between now and 2050 by a third compared to a status quo approach of continuing to use natural gas in boilers (assuming carbon capture efficiency could be increased to 90%)Element Energy, 2018, Cost analysis of future heat infrastructure, National Infrastructure Commission, https://www.nic.org.uk/publications/cost-analysis-of-future-heat-infrastructure/. This is largely due to the time needed to roll out SMR and CCS.

Other downsides of the SMR approach include:

- The SMR process cannot rapidly switch off and on or dial up and down, which means it cannot help balance the electricity grid or respond to availability of cheap energy, unlike producing hydrogen from water using electrolysisElement Energy, 2018, Cost analysis of future heat infrastructure, National Infrastructure Commission, https://www.nic.org.uk/publications/cost-analysis-of-future-heat-infrastructure/.
- The process would increase the use of natural gas for heating at a time when the UK is heavily dependent on imports of natural gas. According to the Leeds project it would require an approx. 50% increase in natural gas useNorthern Gas Networks et al, 2016, H21, https://www.northerngasnetworks.co.uk/wp-content/uploads/2017/04/H21-Report-Interactive-PDF-July-2016.compressed.pdf and it would therefore create further challenges to the UK's balance of trade.
- Carbon capture and storage is only 75-85% efficient. The Leeds H21 project suggests emissions may be as high as 85g/KWhNorthern Gas Networks et al, 2016, H21, https://www.northerngasnetworks.co.uk/wp-content/uploads/2017/04/H21-Report-Interactive-PDF-July-2016.compressed.pdf. It is an energy intensive process. Therefore this approach will continue to contribute significantly to UK carbon pollution. In addition, the extraction of natural gas also contributes fugitive emissions of methane, a powerful greenhouse gas.

Friends of the Earth will oppose the use of natural gas for hydrogen production and instead will promote the use of electrolysis to make hydrogen using renewable energy.

Some of this renewable energy may need to be from dedicated sources, such as offshore wind, and some will come from the excess renewable energy available, as recommended by the Institute of Mechanical Engineers.

A recent German study suggested that “with a share of 55% wind and solar energy, we can expect excess production of approximately 1,000 hours per year.

When wind and solar energy reach a 65% share, we can expect excess production of approximately 2,000 hours per year, and when they reach at 90% share, we can expect nearly 4,000 hours per year of excess production”*Frontier Economics, 2018, The future cost of electricity based synthetic fuels, Agora Energiewende, – https://www.agora-*

verkehrswende.de/fileadmin/Projekte/2017/Die_Kosten_synthetischer_Brenn-_und_Kraftstoffe_bis_2050/Agora_SynKost_Study_EN_WEB.pdf.

A similar picture is likely to be true in the UK. 4,000 hours is the same as 5½ months, which illustrates the potential huge waste of resources if this is not captured and stored.

The carbon footprint from hydrogen produced using wind energy in particular and ‘excess’ renewable energy will be much lower than that produced from natural gas with CCS. It will however require a rapid speeding up and scaling up of renewable energy, particularly offshore wind.

Currently UK renewables produce around 110 TWh a year of electricity from 40GW of renewable energy sources, while total heating requirements in the UK’s homes are currently around 450 TWh a year, although this could be reduced significantly through energy efficiency measures and the wide-spread deployment of heat pumps.

The offshore wind industry in Europe suggests that offshore wind could produce 6000 TWh of electricity per year at less than €65 MWh, much of this around UK watersBVG Associates and Wind Europe, 2017, Unleashing Europe’s Offshore Wind Potential, https://windeurope.org/wp-content/uploads/files/about-wind/reports/Unleashing-Europes-offshore-wind-potential.pdf .

Why not just electric?

It is possible to provide all the heating needed directly by electricity for use in heat pumps, radiators, storage heaters, induction hobs, electric showers and water heaters, etc. However this approach brings some challenges:

Electricity demand – peak heating demand is currently around 350GW for very short winter periods (peak electricity is only 60GW).

Even if a good programme of energy efficiency reduced this demand for heating by a third or more, in an electric heating future this still means peak electricity demand roughly four times current peak electricity demand. High penetration of heat pumps could reduce this demand further but would still mean having to increase the capacity of the grid significantly for short periods of time.

Electricity supply – the greater the penetration of renewables into electricity supply leads to increasing periods when excessive electricity is produced, particularly in summer, but also periods in the winter when there is insufficient renewable electricity supply.

There is a range of storage options which can provide back-up during this period and all will have pros and cons. Hydrogen is one of these and is suitable for long-term storage, for example, producing hydrogen from excess renewable energy outside of winter for use during the winter, much as water reservoirs store excess winter water for use in the summer)

The hydrogen could be used in gas-fired power stations to produce electricity or used directly in homes. The latter is more efficient because the gas-fired power stations are only around 50-60 per cent efficient.

An all-electric system is a viable option but it would reduce householder choice. If a large majority of householders choose this route then it may ultimately be the most cost effective route, however this is some way off.

Cost of the transition

The transition to a low carbon heating system will clearly incur costs, but as stressed before also provides economic opportunities for the UK to exploit our abundant renewable energy resources and develop export industries.

This briefing does not identify these costs in detail nor the economic opportunities, as much further work is needed on both of these.

The recent National Energy Action report on decarbonising heat provides some of this data but not all of these costs. It also stresses the need to avoid using funding approaches which exacerbate fuel povertyFreck and MacLean (2017), Heat decarbonisation, potential impacts on social equity and fuel poverty, National Energy Action http://www.nea.org.uk/resources/publications-and-resources/heat-decarbonisation-potential-impacts-social-equity-fuel-poverty/.

In this briefing we provide some illustrations of costs and benefits.

Insulation – a 2014 report into upgrading the UK's housing stock identified the significant economic gains to the nation and to householders through investing in energy efficiencyVerco and Cambridge Econometrics, 2014, Building the Future: The economic and fiscal impacts of making homes highly energy efficient, E3G, https://sustainableenergyassociation.com/publications/684/.

It found for every pound spent by the government it would get £1.27 returned as taxes and that the investment had a cost benefit ratio of 2.27:1.

Upgrading would create 100,000 jobs over the period and these would be across the regions of the UK.

It also found £8.61 billion annual savings in energy bills. This already very positive picture would be enhanced by the savings in additional energy infrastructure.

Smart heating controls – the Behavioural Insights Team identified that smart heating controls would have a payback of 4.5-6.5 years from homes that already have heating controls, and quicker for others. They also identified that this is payback is likely to get much shorter as the cost of the controls fall rapidly in price.

Heat pumps – currently heat pumps need a substantial upfront investment from house owners, and even though this is largely offset through Renewable Heat Incentive payments these are paid out over 7 years. In practice this means that this option is only really attractive to people who are both strongly motivated by climate change and have access to capital. It is therefore not readily available to most households.

Only 22,000 heat-pumps were installed in 2017Open Access Government, 2018, UK heat pump market is growing again, https://www.openaccessgovernment.org/uk-heat-pump-market-is-growing-again/44301/.

The cost of heat pumps depends on the type (ground-source, air-source, air to air, hybrid) plus the installation costs (which might include replacement of radiators, etc.). Currently the running costs for householders is likely to be neutral because although heat pumps produce 3 units of energy for 1 unit of electricity the cost of electricity is currently around 3 times higher than gas. However these costs will likely converge as the gas on the grid has increasing levels of more expensive hydrogen.

Fuel cell micro CHP – One model is currently in sale in the UK at £9500Installer online, 2018, Viessmann's fuel cell boiler is more financially attractive, http://www.installeronline.co.uk/33549-2/ although one provider of the technology has told Friends of the Earth he expects the cost to be less than £2,500 by 2030 as long as production is scaled upwards.

Hydrogen – The future price of hydrogen is highly contested. The Leeds H21 project suggests that they can produce hydrogen using natural gas and SMR at approximately 8p/KWh, although this assumes readily available CCS. This economic assessment has been questioned.

A recent German study suggested that hydrogen from electrolysis can be produced for 9p KWh using locations where low cost renewable power is plentiful (e.g. Iceland or N Africa), falling to half that by 2050, or cost around 13p KWh in other locations by 2030Frontier Economics, 2018, The future cost of electricity based synthetic fuels, Agora Energiewende, – https://www.agora-verkehrswende.de/fileadmin/Projekte/2017/Die_Kosten_synthetischer_Brenn-_und_Kraftstoffe_bis_2050/Agora_SynKost_Study_EN_WEB.pdf, excluding the cost of appliance replacements.

Adair Turner, the former chair of the Financial Services Authority and former chair of the Climate Change Committee, has said large-scale development of a hydrogen economy could drive the cost of electrolysers onto a downward path similar to that observed with solar panels and batteries Turner, 2018, The low cost of a zero carbon economy, Project Syndicate, https://www.project-syndicate.org/commentary/low-costs-zero-carbon-economy-by-adair-turner-2018-04.

The Royal Society suggested that electrolysis from renewable energy has a greater scope for future price reductions than hydrogen produced from natural gasRoyal Society, 2018, Options for producing low carbon hydrogen at scale, policy briefing https://royalsociety.org/~/media/policy/projects/hydrogen-production/energy-briefing-green-hydrogen.pdf.

Hydrogen compatible appliances – the cost of replacing appliances with ones that are hydrogen compatible depends how many existing boilers need to be replaced ahead of their end of life and how quickly the appliance industry can manufacture appliances that are easily able to be switched to burn hydrogen i.e. be hydrogen ready.

The Leeds H21 project has estimated the cost of changing appliances at around £4,000 per household but this is assuming all appliances need changing at once and before any hydrogen ready appliances are already installed. The cost also doesn't include changing the gas pipes within homes which bring additional costs and in some cases may be overly disruptive.

Grid updates – as previously mentioned, the electricity grid needs to be significantly updating anyway due to electric vehicles.

A report for the National Infrastructure Commission identified costs of grid upgrades for electrification of heating could cost £20 billion but did not consider whether these would be much lower if the grid needed to be upgraded anyway to facilitate a very high penetration of electric vehiclesElement

Energy, 2018, Cost analysis of future heat infrastructure, National Infrastructure Commission, https://www.nic.org.uk/publications/cost-analysis-of-future-heat-infrastructure/. Doing the upgrade together is likely to be the economically most prudent route.

Overall, the transition needs to be costed as a whole energy transformation including energy efficiency, smart heating controls, heat pumps, grid updates and the production of hydrogen, and its storage and/or storage of energy in other forms.

The whole system cost may be much more attractive than at first apparent due to the very significant energy efficiency savings possible and the continued rapid decline in renewable energy costs, plus the possibility of deep cost reductions in electrolysis. In addition, both sides of the equation need considering so that as well as estimating costs the benefits to the economy need to be considered.

Conclusions, pathway and policy recommendations

The UK government made a bold and necessary commitment in signing the Paris Agreement. In doing so, and by asking the Climate Change Committee to recommend new carbon budgets, it has signalled that the UK will need to cut carbon pollution faster than currently envisaged.

In practice this means that carbon pollution from home heating needs to be fully decarbonised by around 2040. Below is our suggested pathway for government action:

Between now and 2020

Require and fund local authorities to develop a heat strategy for their area, working with grid operators and businesses. These should encompass action on energy efficiency (including smart energy controls), the installation of new heating appliances such as heat pumps, electric storage heaters, the installation of renewable energy such as solar thermal or solar PV coupled with a smart battery, and where necessary fuel cell micro CHP or boilers that can burn hydrogen.

Local authorities should be particularly encouraged to work with many of the new market entrants in retail energy, services and products and not only work with the incumbent energy companies and networks.

Roll out a nation-wide insulation programme that at least delivers on the commitment to ensure all homes are EPC C by 2035, and as part of this include smart heating controls. This is also necessary to address existing fuel poverty and prevent future fuel poverty arising.

Commit to protecting low income householders from the costs of funding the transition to low carbon heating.

Instruct the electricity grid operators to include in their 2020s business plans an increase in electricity grid capacity to enable the majority of home heating to be electrically powered, in addition to ensuring the electricity grid can accommodate the wholesale switch to electric vehicles.

Also require operators to lead the development of an electricity storage strategy, including working with gas grid operators to develop a strategy for using hydrogen as an energy store for direct heat and electricity production.

Work with sources of trusted advice, such as the Consumer Association or energy advice centres, to provide impartial advice to householders on heating options. This should be particularly targeted at people considering replacing their boiler. There are approximately 1.6 million gas boiler replacements each yearFrontier Economics and Element Energy, 2013, Pathways for high penetration of heat pumps, report prepared for the Committee on Climate Change, Committee on Climate Change https://www.theccc.org.uk/wp-content/uploads/2013/12/Frontier-Economics-Element-Energy-Pathways-to-high-penetration-of-heat-pumps.pdf. We suggest that providing this independent advice in advance of boiler replacement should be a condition of an installation engineer holding a gas safe certificate.

Amend the Renewable Heat Incentive or similar to increase annual uptake of heat pumps by at least ten-fold by 2020, targeting properties which are most suitable.

Instruct the gas grid operators to plan for a hydrogen grid and hydrogen storage system based on the electrolysis of water, and with an understanding that the majority of heating is likely to be electric.

Rule out the production of hydrogen for home heating from natural gas because it will lock-in and increase the UK's dependence on imported natural gas, with the associated balance of trade impacts.

Require OFGEM as part of price control functions (RIIO-2) to assess the business plans of the electricity and gas network operators in the context of much tighter carbon budgets as a result of the UK supporting the Paris agreement.

Bring together gas appliance manufacturers and financially support the rapid development of boilers and other appliances (such as fuel cell micro CHP) that can utilise different mixes of hydrogen.

Between 2020 and 2030

Begin the roll out of the area by area heating transformation programme with a target completion date of 2035 as a stretch target and a deadline of completion by 2040.

Set a cut-of date (e.g. 2023) after which it will be illegal to sell or replace fossil fuel heating systems or appliances without proper consideration of other approaches (e.g. heat pumps, electric storage heaters), and unless they are able to utilise hydrogen or can simply and cheaply be adapted to do so.

In addition to the area to area programme, steadily increase the national uptake of heat pumps to 1 million per year by 2030 (targeting areas where the electricity grids can most cope) with the aim that at least 1 in 3 homes have heat pumps by the end of the decade.

Significantly speed-up and scale-up the deployment of offshore wind and other renewables for much faster grid decarbonisation and the production of much more electricity. Capacity will need to increase around eight fold by around 2040.

After 2030

Aim to complete the area by area programme by 2035 and ensure it is completed by 2040 at the latest.

Complete the transition to 100% hydrogen from electrolysis by 2040.

Acknowledgements

We would like to thank the following people for their helpful comments on earlier draft: Professor Nigel Brandon, Imperial College; Professor Kevin Anderson and Dr Christopher Jones, Tyndall Centre for Climate Change at Manchester University; Dr Richard Lowes at Exeter University; Dr Grant Wilson at Sheffield University; Robyn Jenkins at National Grid; Dan Sadler at Northern Gas Networks and Leeds21 Project; Marcus Newborough at ITM Power Ltd; Dudley Moor-Radford at Moixa; Pedro Guertler at E3G and colleagues at Friends of the Earth. The content and views in the paper are Friends of the Earth's and do not necessarily represent the views of these contributors.