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Pathways for decarbonising heat

Executive Summary

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Background

“...a transformation in the way heat is provided will be required in order to meet the UK’s carbon budgets and longer-term 2050 greenhouse gas (GHG) emission target.”

Almost half of the UK’s current final energy consumption is used to provide heat-related services in buildings and industry. Over two-thirds of this heat demand is currently provided by natural gas, with electricity and coal dominant in the remainder. With the direct and indirect (electricity) reliance on fossil fuels a transformation in the way heat is provided will be required in order to meet the UK’s carbon budgets and longer-term 2050 greenhouse gas (GHG) emission target. In the nearer term, heat from renewable sources is also expected to play a key role in meeting the UK’s Renewable Energy Directive (RED) target.

Previous studies have shown that the UK can adapt to a low carbon economy in a way that reduces risks associated with security of supply and yet remain affordable to UK customers. Such studies place a high reliance on decarbonising electricity and making greater use of this for heat and transport. However, there remain concerns about the costs of additional electricity generation and network infrastructure to manage the swings (both seasonal and within day) and peak requirements associated with electrifying heat; which are currently far greater than those seen for electricity.

National Grid commissioned Redpoint Energy (a business of Baringa Partners) to explore cost-optimal future pathways for decarbonising heat across all sectors to 2050, which address these issues explicitly and which are consistent with both the GHG and RED targets.

Approach

The analytical approach for this study is based around Redpoint’s Energy System Optimisation Model (RESOM). This is a least-cost optimisation framework which builds upon the energy system model developed by Redpoint as part of an earlier project for the Department of Energy and Climate Change (DECC) and the Committee on Climate Change (CCC) on Appropriate Uses of Bioenergy (AUB)[1]. Data has been compiled from the most recent available public sources, in particular; from DECC, CCC, and Department for Transport (DfT) as well as from National Grid’s analysis of domestic heating and network costs.

RESOM is driven by the aim of minimising the total costs of the energy system (capital, operating, resource, etc) to 2050. The model effectively decides what technologies to build and how to operate them to meet future energy service demands[2], whilst ensuring all other constraints (such as the GHG target) are satisfied.

The solution for heating is generated as part of the cost-optimal solution for the energy system as a whole; including transport, electricity and other conversions. The optimisation effectively allows all trade-offs in technologies and energy vectors, in all periods on the pathway to 2050 to be resolved simultaneously.

1 Redpoint (2012) Assessment of the appropriate uses of bioenergy feedstocks in the UK energy market http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/bio-energy/5128-assessment-of-the-appropriate-uses-of-bioenergy-fe.pdf

2 To better explore seasonal, diurnal and peak demands for heat and electricity RESOM models five characteristic days within each year (winter, spring, summer, autumn, and a 1-in-20 winter peak day), and 4-hourly time periods within each of these days

Scenarios

“Electrification of heat in buildings, facilitated primarily by heat pumps, is a critical component of decarbonising heat and meeting the 2050 target.”

To explore future pathways for decarbonising heat we have focused on the relative importance of affordability versus UK abatement action in driving the long-term energy system solution. Two core scenarios were created in discussion with National Grid:

- Abatement Cost Cap (ACC) – whereby the UK can purchase international emissions credits to meet its GHG targets, which acts as a cap on marginal abatement costs
- All UK Action (AUKA) – the UK effectively has to meet the GHG emission target from abatement action only within the UK

The core scenarios broadly reflect ‘central assumptions’ on factors such as fuel prices and energy service demands from recent Government studies. An extended set of sensitivities was then undertaken to explore how robust key elements of the core solutions are to potential changes. These explored different: fuel prices; technology costs; demands; bioenergy availability; the absence of low carbon options (nuclear, CCS, hydrogen), and restrictions on use of gas in buildings.

Key Findings

Cost of the energy system

The overall costs of meeting the 2050 GHG target are likely to be in the range of 1-2% of Government’s projected GDP, which is consistent with a number of earlier studies. However, this is dependent on the successful commercialisation and large-scale deployment of a number of key existing and developing technologies including the large-scale use of CCS (both in power generation and in conversion processes such as hydrogen), wind, nuclear generation and the mass deployment of heat pumps.

The overall costs of the energy system are driven strongly by the end-point in 2050, given that costs of abatement increase disproportionately as the target tightens in later years. Early planning to position the system to meet this end point could offer significant long-term cost savings.

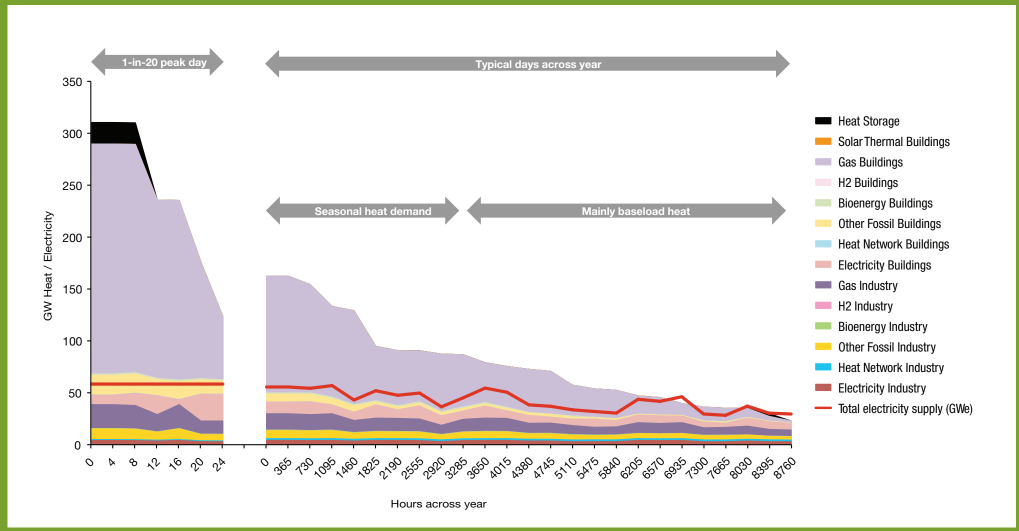
Decarbonising building heat and tackling swings in demand

Electrification of heat in buildings, facilitated primarily by heat pumps, is a critical component of decarbonising heat and meeting the 2050 target. This re-emphasises the need for widespread and early decarbonisation of the electricity system, which is important to facilitate long-term decarbonisation of other sectors such as transport and heat. Under all scenarios examined, both peak and annual electricity demand rise rapidly from the 2030s onwards, requiring timely reinforcement.

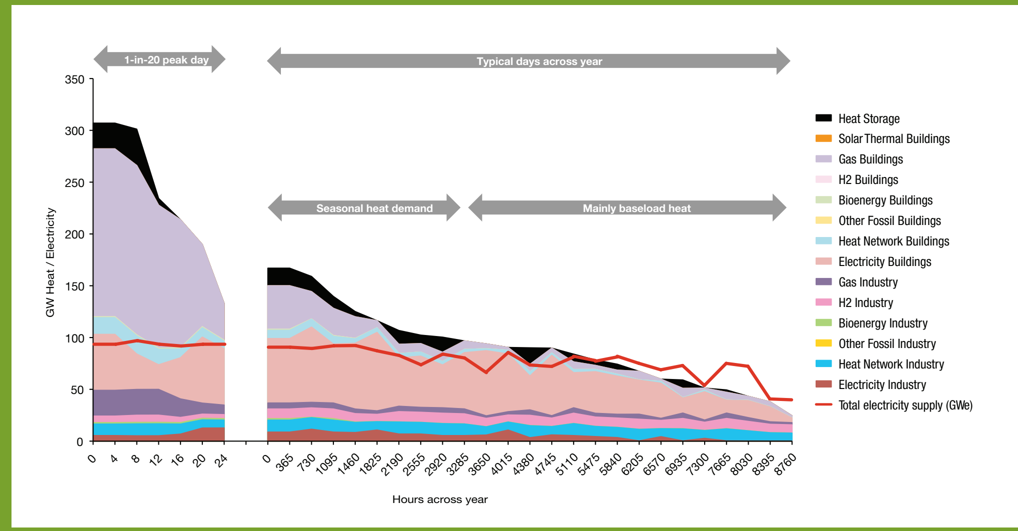
Energy efficiency has a crucial role to play, both in terms of reducing annual and peak demand, although there is a limit to what is likely to be cost-effective for the most expensive options even under very high carbon prices. Even with extensive improvements in efficiency, heat demand is likely to remain significant by 2050 along with sizeable seasonal and diurnal swings in demand, particularly in winter. These will need to be managed carefully to avoid excessive costs of electricity generation and network reinforcement if heat is provided from electric options.

One potentially cost-effective way of tackling these swings is via hybrid electric / gas heating and heat storage strategies. A low risk way to achieve this is by maintaining, significantly reduced, flows of gas in buildings for use in dual-fuel gas / heat pumps devices as illustrated in the graphs on the following page. This is more important for domestic buildings than those in the service sector, given the overall scale and shape of demand in the former.

Total heat supply duration curves by energy vector
Modelled 2011/2012



Total heat supply duration curves by energy vector
AUKA scenario 2050



An alternative to retaining gas to manage peak demand is to make more extensive use of heat networks, however, their use in the core scenarios was focused more in industry than buildings. In sensitivities where gas is forced out of buildings by 2050 the costs for home heat and power rise approximately by 10% - 15%, attributed to the wider use of heat networks and additional biomass and electricity for seasonal heating.

Decarbonising industrial heat

Heat for industry is subject to far less seasonal variation than buildings and can be split into three broad groups. Low temperature space heat requirements are similar to service sector buildings and are primarily decarbonised via a mix of electric ground- and air-source- heat pumps.

Low temperature process heat is provided primarily via localised heat networks (ie reflecting industrial clusters), which expand organically over time. High temperature industrial process heat has fewer abatement options[3]. Whilst gas use declines to 2050, a significant level still remains across all the scenarios. Direct use of bioliquids is not generally a preferred route for what is a relatively scarce bioenergy resource, but significant use is made of hydrogen by 2050 in a number of scenarios.

Long term role of gas

Total gas use declines significantly to 2050 in a number of sectors, particularly buildings and to a lesser extent industry. However, there is still potentially a large scale, albeit different, role by 2050 enabled by a combination of CCS and hydrogen production. The continued use of gas is not reliant on widespread biomethane use as bioenergy resources can be used for abatement elsewhere in the energy system, particularly in conjunction with CCS, providing 'headroom' for greater remaining emissions in other sectors.

The long-term role for direct gas in buildings shift towards winter seasonal top-up and peaking, particularly for domestic buildings, to help manage seasonal and diurnal swings in heat demand. Direct gas use in industry is retained primarily for high temperature industrial process heat where there are fewer abatement alternatives.

Gas use in dedicated power and CHP shifts strongly towards the latter, in the form of large scale CCGT CHP with CCS, with the heat used predominantly for lower temperature process heating in industrial clusters. The use of gas in hydrogen production (via steam methane reforming with CCS) is also potentially significant as the hydrogen is then used to help decarbonise specific parts of industry and transport, however this use is sensitive to gas prices.

Evolution of the system to 2050 and infrastructure planning

Finally, the evolution of the energy system is characterised by a number of key transition points, such as the rapid growth in electricity demand and roll-out of CCS from the 2030s onwards, followed by wide-scale hydrogen use in the 2040s.

All of these transitions need to be facilitated by the appropriate supporting infrastructure; electricity network reinforcements, CO2 transport and storage, and a hydrogen distribution network. Given how rapid these transitions can become, it is important that the foundations for the supporting infrastructure are laid sufficiently early. Existing infrastructure that is cost-effective to maintain, particularly the gas network, can be retained to provide optionality (for example repurposing to hydrogen) and greater long-term flexibility for the energy system as a whole.

3 Novel high temperature electrical routes are another potential option, but have not been included due to data uncertainty

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