Department
of Energy &
Climate Change

European Commission Heating & Cooling Strategy Consultation

DECC Commentary

September 9th 2015

Contents

Executive summary

Overview

1. DECC welcomes this opportunity to provide comment on the Commission's Issue Papers. We have sought to provide input on the evidence presented, provided a response to the questions posed and identified key omissions where appropriate. We look forward to providing further clarity on our response at the Forum on September 9th.

2. The European Commission's proposed Heating & Cooling Strategy is a positive opportunity for EU-wide energy policy. Energy used for heat represents a third of the UK's carbon emissions and nearly half of all the energy we use. The proportions are similar at a European level, and although the south tends to have higher cooling demand and the north higher heating demand, both heating and cooling are significant across all Member States. Therefore a pro-active approach to tackling decarbonisation of the sector is a crucial part of our fight against climate change and ensuring the EU remains at the centre of international climate change action.

Objectives

3. The Strategy should:

   a. *Explore the potential for re-use of recoverable heat*. Our industrial research over the last two years has identified significant potential for the recovery and re-use of heat in industrial settings, both on site and 'over the fence' into heat networks. This represents a low cost form of heat that could offer economic benefits to industry, and one of the reasons why it has NOT been supported in many member states including the UK is because it is not classified as renewable. This is a distortion caused by technology-specific targets that ought to be corrected, by ensuring any future goals are technology-neutral and measured in carbon terms (or by expanding the definition of what counts as renewable).

   b. *Explore the potential for CCS for industry*. Work in the UK on industrial roadmaps for energy intensive industries confirms that Industrial Carbon Capture and Storage will be a vital technology for decarbonising sectors such as steel, oil refining, cement and chemicals where there are substantial process emissions or where options for fuel switching are extremely costly or not available.

   c. *Explore the role of biomass and biogas for buildings and for industry*, in the wider context of overall bio energy strategy and sustainability. Many industries can be decarbonised through switching from fossil to biofuels of many kinds, and in particular hard-to-treat properties – especially historic buildings – are not readily amenable to low carbon heating technologies such as heat pumps. In rural areas, biomass may play a cost-effective role for providing heat to these buildings.

   d. *Explore the role for heat networks*, in line with UK long term thinking on urban development and harnessing otherwise untapped sources of existing large scale low carbon heat that can be recovered from industrial and other processes. Secondary sources of heat in the environment, including rivers, the sea and the ground, could also play a significant role in decarbonising our heat demand, especially in urban areas. Many of these can only be accessed via heat networks rather than building-level solutions. The UK has already started supporting a new generation of heat networks through its Heat Network Delivery Unit (HNDU) Local Authority support scheme.

e. *Focus on decarbonisation outcomes,* as well as inputs. For example, a significant challenge for decarbonising heat in the UK are those suburban areas not dense enough for heat network deployment and where the mass deployment of electrical solutions could result in excessive grid reinforcement costs. For these properties – especially those that are hard to treat - multiple solutions could be appropriate, including hybrid devices combining a smaller electric heat pump with a gas boiler for winter heat, gas-powered heat pumps to use gas more efficiently, or some kind of low carbon gas such as biomethane or hydrogen. There is no single solution to this issue, and many of these choices will be better made at local levels – on a street by street basis, if need be. Equally, where networks are built, mixtures of different heating solutions are likely to be used. The metrics that matter in these cases are carbon intensity of the heat, efficiency of the system and costs paid by the consumer. It should not be relevant whether the heat is fully, partly or not renewable (eg recovered and recycled heat should be properly valued on carbon grounds).

f. *Link building heat to building energy efficiency*. While energy efficiency measures are highly unlikely to eliminate demand for heat from existing building stock, any heat strategy must take these measures into account. A whole building solution, taking in energy efficiency measures as well as the heat source, will often be the most cost effective approach to decarbonisation.

g. *Focus on providing a framework for Member State heat decarbonisation pathway development*. As in (d), many Member States will have issues around heat decarbonisation that are inherently spatial and particular to their specific geography. Member States, working with Local Authorities/municipalities, are best placed to identify their own pathway, and should have the flexibility to do so.

h. *Focus on low carbon heat rather than renewable heat*. The objective of the Strategy has been stated to be identifying a cost effective pathway for heat decarbonisation. This is a clear objective, and bringing in additional requirements for renewable heat sources over and above their role in providing heat would be a distraction from the primary focus of the Strategy.

Considerations

4. While long term decarbonisation is and should be the primary focus of the Strategy, the UK and other Member States will have other considerations which the Strategy should have regard to:

   a. **Security of supply**, especially gas and oil imports into the EU, much of which is used for heating and industrial processes;

   b. Linked to this, **economic competitiveness**;

   c. **Costs to consumers** and how changing fossil fuel costs impact on the affordability of heat;

   d. **Fuel poverty** where it is not directly covered by the above, including the health and social impacts of heat supply.

Paper I: Decarbonisation of Heating & Cooling Use in Buildings

Commentary on Evidence Presented in the Paper

This paper repeatedly uses the word ‘renewable’ rather than ‘low carbon’. These two words do not mean the same thing, and for heating as much as for electricity generation, there are low carbon solutions which do not count as renewable. Focusing this analysis on a specific set of “renewable” technologies rather than on the full range of low carbon solutions will miss important cost-effective opportunities for decarbonisation. For example, this paper briefly refers to hybrid devices, which typically combine a smaller electric heat pump with a gas boiler. While not fully renewable, DECC’s work indicates that these may be a key part of delivering decarbonisation. Other examples include gas heat pumps and micro CHP units.

This paper states that the EU’s Emissions Trading Scheme (ETS) contributes to the energy efficiency of buildings through the incentivisation of district heating. DECC does not understand the point being made here. Individual building solutions using gas are dominant in the UK and are not subject to the ETS, while district heating primarily uses larger installations of gas-powered devices and is sometimes subject to the ETS, but this affects only a small number of district heating systems in the UK.

District heat networks can be supplied by a wide range of heat sources, and as a result separating heat networks as a different heat source to biomass or electric heat pumps – as this paper does – fails to reflect that heat networks can be also be supplied by biomass or electric heat pumps. Dividing the analysis into heat sources and the networks used to deliver heat will provide a more accurate picture, as well as encouraging analysis of the role that existing infrastructure, such as gas networks, could play in delivering the solution.

The paper doesn't consider the risks of poorly carried out refurbishment. Refurbishment is a difficult policy to get right; if solid wall insulation is not applied correctly, serious architectural problems may result, putting the building at risk of structural damage. Damp can also be a serious issue. A cost benefit analysis of poor implementation needs to be carried out. It may be better to provide low carbon heat centrally.

1. **What are the trade-offs between and how can we assess the cost-optimal balance of the following in decarbonising building heating and cooling?**

   i. **Measures to reduce energy consumption in buildings;**

   ii. **On-building renewable energy;**

   iii. **Remote low-carbon electricity; and**

   iv. **Waste heat and renewable energy based district heating and cooling**

In general, modelling by DECC to date suggests that a “whole house” approach where energy efficiency and energy supply measures are carried out at the same time is the most efficient way of analysing these trade-offs, not least because it allows the heating supply to be correctly sized in line with reduced demand.   However, evidence from DECC schemes suggest that supply chains are not set up to be able to offer consumers "whole house" packages covering both energy demand reduction measures and energy supply measures, for several reasons, including lack of customer demand and the degree of specialism needed for the installation of each of the types of measure; and that co-operation between installers to provide such packages can often produce a less flexible and more costly offer to the consumer compared to purchasing and installing each element separately.

As DECC uses a carbon metric (£/tCO2e/per annum and £/tCO2e/m2/per annum) to assess the public benefit of energy related measures (both those that reduce energy demand and those that supply low carbon energy), trade-offs between the measures above are often built into the mechanisms used for making assessments. For example, the UK's national calculation methodologies (NCMs) to meet the purposes of the Energy Performance of Buildings Directive, also help building developers to meet a carbon emissions target. To do that, the contribution from both energy efficiency measures and low carbon building services has to be calculated in the same model – and developers calculate the most cost-effective way to meet that carbon emissions target.

The National Heat Map (see http://tools.decc.gov.uk/nationalheatmap/) is available to help developers identify sufficiently dense populations to aid analysis of cost effectiveness of heating solutions which require heat networks.

UK Government Schemes

Schemes in the UK are designed to encourage people think about installing energy efficiency measures at the same time as they install a new heating source or renewable electricity on their building.

Domestic Renewable Heat Incentive (RHI)

It is a requirement for homeowners to carry out a full assessment of opportunity for cost effective energy saving measures (through a Green Deal Assessment Report with Energy Performance Certificate) as part of the application for the Renewable Heat Incentive. Eligibility requirements for the RHI mean that if your mandatory Energy Performance Certificate recommends loft installation you have to have it put in before you can be eligible for the scheme.

From the evaluation of the UK's Domestic Renewable Heat Incentive:

- Nearly a third (27%) of all RHI applicants surveyed reported home upgrade/refurbishment as a motivation for installing renewable heat.
- Just under a quarter (22%) of RHI applicants surveyed did no other energy efficiency or renewable measures when the installed a renewable heating technology under the RHI.
- Conversely, those that did install other energy efficiency or renewable energy measures (e.g. loft insulation 32%, efficient lighting 32%) did this as a requirement of the scheme or technical requirements related to the fitting of renewable heating technology (eg new radiators or underfloor heating).

Green Deal and Energy Companies Obligation

Both energy efficiency and low carbon energy supply measures, including renewable heating, are eligible for support through the Green Deal and the Energy Companies Obligation. A Green Deal Assessment Report (based on the national calculation methodology and supported by an Energy Performance Certificate) identifies the most cost effective measures for each house for the Green Deal. This uses a metric on the cost effectiveness of installing the measure (to meet a "Golden Rule") to understand if energy efficiency measures would be more cost effective than energy supply measures. This relies on the National Calculation Methodology but adds a factor to account for sensitivities in the cost-effectiveness of measures relating to factors such as poor installation.

Under the Energy Companies Obligation, energy companies calculate the measures which produce the greatest level of carbon saving most cost effectively to meet the obligation. To date, under ECO1[1] which ran from January 2013 to March 2015, the following range of measures were installed:

Measure Category	CERO	CSCO	HHCRO	Cumulative Total
Solid Wall Insulation	61,560	9,631	9	71,200
Park Home Insulation	204	-	-	204
Cavity Wall Insulation	107,482	120,382	10,255	238,119
HTTC Wall Insulation[1]	234,039	6,965	55	241,059
Loft Insulation	113,429	178,569	35,940	327,938
Other Insulation[2]	2,338	9,085	92	11,515
Boiler – Replacement	N/A[4]	N/A	284,592	284,592
Boiler – Repair	N/A	N/A	557	557
Other Heating[3]	N/A	N/A	74,968	74,968
District Heating System	1,003	3,723	-	4,726
Micro-generation	N/A	N/A	-	-
Total	520,055	328,355	406,468	1,254,878

[1] Hard-to-treat cavities (HTTCs) include narrow cavities, cavity walls in tall buildings, and in certain non-standard construction types, and those which are too difficult to treat with standard materials or require works to be carried out before installation.
[2] Includes hot water cylinder insulation, draught proofing and window glazing.
[3] Includes heating controls, heat recovery ventilation and warm air units.
[4] N/A - this measure category is not eligible to be claimed under this obligation.

As you can see, this provides for a range of energy efficiency and heating supply solutions, including district heating.

Feed-in Tariff for renewable electricity

The energy efficiency requirement applies to solar PV installations, with the exception of stand-alone, with a capacity up to 250kW and an Eligibility Date on or after 1 April 2012. These installations must demonstrate that the building which they are wired to provide electricity to has achieved an Energy Performance Certificate (EPC) rating of level D or above in order to receive the higher tariff rate.

Modelling for carbon budgets: issues around trade-offs.

The Climate Change Act established a target for the UK to reduce its emissions by at least 80% from 1990 levels by 2050. This target represents an appropriate UK contribution to global emission reductions consistent with limiting global temperature rise to as little as possible above 2°C.

To ensure that regular progress is made towards this long-term target, the Act also established a system of five-yearly carbon budgets, to serve as stepping stones on the way.

The first four carbon budgets, leading to 2027, have been set in law. The UK is currently in the second carbon budget period (2013-17). Meeting the fourth carbon budget (2023-27) will require that emissions be reduced by 50% on 1990 levels in 2025.

This means the UK Government has to model to project likely levels of carbon emissions and possible interventions. Modelling to date suggests:

- What is cost-optimal for the UK economy may not be cost optimal for individual consumer. So in new heating system purchasing decisions, the individual consumer

[1] CERO: Carbon Emissions Reduction Obligation; CSCO: Carbon Saving Community Obligation; HHCRO: Home Heating Cost Reduction Obligation.

does not think about grid impact. Too many new heat pumps may require additional electricity generation and electricity grid reinforcement – but the individual consumer will not see those costs at point of purchase.

- Decentralised electricity (eg solar PV) can be a cost effective way to meet carbon emissions targets for individual consumers in individual dwellings, but at a national level, it is less helpful as the emissions are in the traded sector – and as the UK national grid decarbonises, the cost benefit per tonne CO2 from building-mounted solar PV per kwe compared to national infrastructure worsens.
- The UK Government is considering the degree to which having drivers that promote low carbon encourages people to choose technologies which are good for carbon abatement in the short term but not as grid decarbonises (eg generating own electricity through gas Combined Heat and Power).
- Energy efficiency tends to drive down demand for heat on heat networks, but the heat networks are only viable if there is sufficient heat demand over their lifetime.

Paper II: Heating & Cooling use in Industry and the Tertiary Sector

Commentary on Evidence Presented in the Paper

A key technology for the decarbonisation of industrial heat is Carbon Capture & Storage, which is not covered by the paper. This is a serious omission: the Industrial 2050 Roadmaps commissioned by the UK Government [2], which involved working closely with industry to identify pathways towards decarbonisation for eight heat-intensive sectors, indicated that this technology is vital to deliver emissions reduction most cost-effectively in at least four major energy intensive sectors – steel, cement, oil refining and chemicals. DECC would hope that the Commission can further consider the evidence presented in these Roadmaps, as many of the lessons learned will be applicable to other Member States.

1. **What would help to improve our understanding of heating and cooling use in industry and in the service sector to better assess the technical potential for energy efficiency and renewable deployment?**

If we are to understand the full potential for increasing energy efficiency and the use of low carbon technologies in industry and business, it is essential to have a robust evidence base in place. Whilst a certain amount of data has been gathered on costs and performance for the more mature technologies, there remain substantial evidence gaps, both in terms of less-mature technologies and in how mature technologies can be deployed in specific processes and sites. More data is therefore needed to provide a solid foundation for long term policy development and to help target government intervention in the most efficient and effective way.

A key challenge is to understand future, rather than historical, heating and cooling use in industry and the service sector. Whilst we have some site-specific data related to historic use, estimates of heat supply and demand over long timescales (10yrs +) are needed for consideration of systems where industry is part of a heat network.

Collection of further site-specific data across a range of industries, covering 'sources' and 'sinks' for use / demand would increase our understanding of, for example, where clustering or heat networks could be an appropriate solution for decarbonisation.

Additional research into the costs associated with solutions such as heat recovery technologies, use of biofuels in direct fired processes, industrial carbon capture and storage and low carbon technologies for space heating and cooling would help us better assess how such technologies can be supported. In some cases, this would best be delivered by running pilots and building demonstration projects, as well as by supporting early stage research.

[2] https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050

2. What are the most important barriers for companies to deploy existing energy efficiency and renewable energy solutions and how can these barriers be overcome?

The Industrial 2050 Roadmaps, corroborated by other studies[3], identified a series of barriers that are preventing companies from deploying existing solutions. The key barriers are set out below:

- **Business Case Barriers:** Industrial stakeholders reported a number of barriers to implementation of energy efficiency and decarbonisation options under this theme, including payback periods that are longer than company-defined thresholds, competition for corporate funding and shortage of technical or managerial resource, including to undertake the necessary feasibility studies and develop robust business cases. There are also technical risks to the manufacturing process itself (both real and perceived) that can hinder project implementation such as potential negative impacts on output and product quality. Therefore projects that link decarbonisation with other business benefits such as output and quality will have a better chance of moving forward.
- **Development capital:** Development capital could be considered for more uncertain projects with higher potential for decarbonisation. Recycling of energy-related policy costs back to energy efficiency projects in industry might be one way to provide a direct incentive for companies to invest. More generally, the investigation of different sources of finance may assist companies to invest in projects, for example, equipment manufacturer packages or ethical investment funds.
- **Policy and Legislation:** Uncertainty (perceived or real) around policy or legislation weakens investors' confidence and reduces the ability of sectors to justify the business case for major investments in energy efficiency and decarbonisation technologies in the UK. This risk applies to any industry in whichever national regulatory regime it is operating, so there is a case for more analysis on whether the reported additional risk of UK policy uncertainty is real or perceived for these sectors. The policy context needs to carefully balance industrial regulation and investment support. Many in the sectors have emphasised that a long-term energy and climate change policy framework alongside policy support for industrial competitiveness is key to investor confidence.
- **People and Skills:** An ageing workforce and shortage of engineers were identified as challenges in several sectors, and this is likely to present a barrier to finding innovative ways to decarbonise (as well as the many other activities that sector resources are needed for). A highly skilled workforce who can tackle new challenges including implementing advanced decarbonisation and energy efficiency technologies will be required. Lack of knowledge about the options and the routes to develop a company's energy efficiency programme can be a barrier.

3. Are there technical limitations to substitute fossil fuels with biomass in heating and cooling supply in industry? Are there environmental and economic limitations?

There are few technical limitations concerning substituting fossil fuels with biomass in applications creating steam or hot water as part of an industrial process. The key issue preventing widespread adopting of biomass over fossil fuel alternatives is cost – offering

---

[3] The potential for recovering and using surplus heat from industry (March 2014): https://www.gov.uk/government/publications/the-potential-for-recovering-and-using-surplus-heat-from-industry

Bespoke natural gas CHP analysis (December 2014): https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis financial support to organisations installing biomass boilers (through the renewable heat incentive) has resulted in almost 4TWh of renewable heat being generated. Without the additional financial support, it is unlikely that organisations would install biomass over conventional fuel systems due to the costs involved.

Substituting fossil fuels in high temperature industrial processes is more technically challenging. These in general use heat directly within the industrial process (which we term ‘direct applications’), for example in cement, ceramics, glass as well as some lower temperature direct applications for drying (for example in the paper sector). These processes and sectors are more difficult to decarbonise. In these applications, for some industrial sectors renewable and low carbon fuels should be clean burning and be gaseous in order to be compatible with existing manufacturing processes– this is particularly pertinent for example in the Glass sector, and also applies to large proportions of for example the Ceramics and Food and Drink sectors. In these sectors, biomass would need to be transformed to syngas or biogas before use. Other sectors (without the same clean burning requirements) looking to displace natural gas could also use pulverised biomass.

There is limited technical potential for pulverised biomass consumption in heat intensive industries, and a lack of cost data on pulverised biomass burners limits our understanding of how deployment can be increased in this area.

Solid fuels constitute the overwhelming majority of fuel consumption in the Cement sector. This indicates that the solid renewable and low carbon fuels of waste wood chip and Solid Recovered Fuel (SRF) are likely to be the most suitable for this sector. For the Iron and Steel sector the overwhelming majority of fuel consumed in the blast furnace is in the form of the solid fuels of coke and coal. The cost effective potential for some of this fuel to be substituted by biomass charcoal was investigated.

Deployment of biomass in direct applications of heat in industrial processes in the UK are expected to be through retrofitting existing furnaces or kilns, and therefore technical challenges relate to replicating as closely as possible the performance of natural gas in terms of the flame characteristics, fuel quality consistency and products of combustion (e.g. ash deposits). As there has been very little deployment of renewable fuels in these applications, some technical demonstrations will reduce risk and uncertainty, and could lead to cost reductions through design optimisation.

When substituting existing fossil fuel use for solid biomass, existing research suggests that the new technology would not be cost effective without some form of intervention / support. This applies to situations where the biomass is being gasified to produce syngas as well as where the biomass is being consumed as a solid fuel.

From an environmental perspective, biomass should only be supported if it is making a genuine contribution to climate change mitigation, and does not cause significant detrimental environmental impacts. The UK is introducing mandatory sustainability criteria in line with the Commission’s guidance for solid and gaseous biomass so that renewable heat incentivised by Government meets minimum standards. Waste derived from biomass has lower environmental impacts but a more constrained supply compared to virgin biomass, and there can be supply-chain barriers to leveraging biomass waste out of the residual waste stream.

There are further ‘non-technical’ considerations to be aware of, such as the ability of the site to cope with the practicalities of fuel deliveries, availability of the fuel and security of supply. Furthermore, the cost of biomass compared to the counterfactual can be prohibitive, and consideration also needs to be given to both the calorific value of the fuel for use in specific industrial processes and the reliability (actual and perceived) of the technology.

4. Are there technical limitations to substitute fossil fuels with other alternative energy sources in heating and cooling supply in industry? Are there environmental and economic limitations?

Whilst some industrial sectors may be susceptible to syngas and hydrogen substitution, there is ongoing uncertainty about the extent to which these fuels can be utilised in existing burner systems, and full displacement may be necessary. There is also uncertainty about the extent to which these fuels can be substituted without triggering the need for wider process changes, which would incur significant additional costs.

Similar non-technical limitations also need to be taken into consideration, such as the reliability of alternative energy technologies (actual or perceived), calorific value of the fuel, availability and security of supply.

As above, from an environmental perspective, biomass should only be supported if it is making a genuine contribution to climate change mitigation, and does not cause significant detrimental environmental impacts. The UK is introducing mandatory sustainability criteria in line with the Commission's guidance for solid and gaseous biomass so that renewable heat incentivised by Government meets minimum standards. Waste derived from biomass has lower environmental impacts but a more constrained supply compared to virgin biomass, and there can be supply-chain barriers to leveraging biomass waste out of the residual waste stream.

As with biomass, the key barrier to organisations adopting alternative low carbon heating and cooling systems is cost, as they are generally more expensive to install than fossil fuel alternatives – even if they may offer savings over time in terms of operating or fuel costs.

Even with the substitution of renewable fuels which are zero or low carbon in these industrial processes, many sectors (iron and steel, oil refining, chemicals, cement) are also responsible for process emissions (CO2 emissions as a result of the chemical reaction in the manufacturing process) which remain unabated. Overall process change or industrial carbon capture and storage are then required to abate these emissions.

5. What are the areas where industrial and tertiary sectors would need support from national and local authorities and what are the mechanisms to establish better cooperation and coordination between companies and national and local authorities?

There is substantial scope for collaboration between industry, government and others to take steps in the short term that could enable companies to make deeper emissions reductions over the longer term while staying competitive. Crucial areas for support include finance, knowledge and expertise.

At a national level, we have already identified the need to emphasise why energy intensive industries are important for the UK economy, and that some technological changes need to take place in the energy system itself (e.g. grid decarbonisation) in order to meet our long term carbon reduction goals. In addition some major technology solutions, such as carbon capture, whilst site-specific are not likely to be taken forward by industry alone.

Ultimately, implementation of measures will depend upon individual action at company level, for example through the adoption of corporate sustainability targets. The increased importance of decarbonisation on the business strategy agenda, based on commercial considerations of profitability and cost reduction, would be a key enabler. This would be further helped by the willingness and commitment of senior management to actively decide to drive programmes of action.

For areas where implementation would not be commercially viable – either in terms of the length of payback period for investment or overall rate of return – government intervention may be necessary. Financial support, either through grants or more flexibly via debt or equity, would help overcome capital expenditure barriers and increase deployment of low carbon heating and cooling technologies.

Further research into renewable and low carbon alternatives would help increase technical readiness levels of developing technologies and help reduce costs of more established technologies.

In addition to this there are barriers relating to information, in terms of knowledge / trust in a particular technology, and expertise in terms of how a particular technology could be applied on a specific site. Further engagement on a local level could help increase understanding of the benefits of low carbon heating and cooling solutions, and match existing expertise with the needs of the industrial and commercial sectors.

6. What are the best practices of an enabling framework which facilitates the uptake of short and long-term efficiency solutions in heating and cooling in enterprises?

Interventions in this area include both incentives and obligations being put in place to help increase energy efficiency and reduce carbon emissions.

In November 2011, UK Government implemented the non-domestic Renewable Heat Incentive (RHI) for to commercial, industrial, public sector, not for profit and community generators of renewable heat. The RHI is the world's first long-term financial support programme for renewable heat, providing financial incentives to install renewable heating in place of fossil fuels. The scheme is designed to bridge the gap between the cost of fossil fuel heat sources and renewable heat alternatives through financial support for owners of participating installations.

Support is offered for a range of technologies and fuel uses including air source heat pumps, deep geothermal, energy from waste, ground and water source heat-pumps, on-site biogas and injection of biomethane into the grid, solar thermal and solid and gaseous biomass. Payments are made on a tariff basis, with a set tariff provided for each technology, paid out on the basis of metered heat use (per kilowatt hour).

As of the end of July 2015, almost 12,000 installations have been supported, representing an installed capacity of nearly 2GW. Since the start of the RHI, 4.3 TWh of renewable heat has been generated and paid for through the scheme.

Regulatory measures can also have a considerable impact on energy use. For example, Energy Performance Certificates can introduce comparatively small changes in energy performance and the way a building is used, which can have a significant effect in reducing total energy consumption. Regulations governing product design (such as ERP for heat pumps) can also improve performance of low carbon technologies, whilst local planning conditions can help improve energy efficiency in buildings and increase the use of fossil fuel alternatives for heating and cooling.

7. What are the best practices of industrial networks/clusters which facilitate the uptake of short and long-term efficiency solutions in heating and cooling in enterprises?

The 2,000 heat networks currently in the UK supply approximately 2% of buildings heat demand, but this is a fraction of the cost effective potential. Almost all economic modelling for meeting carbon budgets shows a much more significant role for heat networks, with cost effective deployment in the range 14-43%[4] of buildings heat demand by 2050. Heat networks are particularly cost effective in urban areas which have high heat demand densities. For example, one of the largest schemes in the UK, in Sheffield, serves around 1,000 households and 140 large non-domestic buildings in the city with over 100GWh of heat.

Recognising the capacity and capability challenges which local authorities identified as barriers to heat network deployment in the UK, the Heat Network Delivery Unit (HNDU) was established by DECC in 2013 to provide grant funding and guidance to local authorities in England and Wales. The HNDU is staffed by experts, who have gained experience developing heat networks outside the civil service working on technical, financial or commercial aspects of heat networks for consultancies or local authorities. The HNDU support local authorities through the following stages: heat mapping, energy master planning, feasibility studies and detailed project development. Local authorities apply for HNDU support through bidding rounds, of which there have been four to date. Grant funding of no more than 67% of eligible costs is provided to successful local authorities. Since its inception the Unit has awarded support to 180 unique projects across 115 local authorities including £9.7 million of grant funding.

Clustering for decarbonisation benefits is the integration between industrial sites to deliver energy savings. It can reduce emissions by optimising the use of resources (waste- or by-products such as CO2 from one process to be used beneficially by another process), while costs are shared, heat is used wisely and other benefits increase.

Clustering is a long-term, gradual option that requires new or replacement plants to be encouraged to locate where clustering benefits can be realised, and existing plants to maximise local opportunities. The barriers to clustering are generally related to organisational collaboration and include the perceived risk of becoming reliant on a partner who may not be present in the long term.

An example of clustering in action can be seen with the Tees Valley area in the north of England, which houses 20% of the top CO2-emitting industrial plants. The area is home to over half of the UK chemical industry, and one of the country's largest clusters of steel and cement companies. The Teesside Collective, a cluster of leading industries in the area, is working together with Government to develop a business case to support the creation of Europe's first Carbon Capture and Storage (CCS) equipped industrial zone.

Additional evidence on similar themes

Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 (March 2015)

Suite of reports looking at long-term decarbonisation and energy efficiency roadmaps for the eight most heat-intensive industrial sectors: cement, ceramics, chemicals, food and drink, glass, iron and steel, oil refining, and paper and pulp. The reports draw together conclusions from the evidence and pathways analysis to identify potential ways that progress could be made to help enable transition towards a low carbon economy with a competitive industrial sector.

https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050

Bespoke natural gas CHP analysis (December 2014)

Reports to examine what type of electricity generation would be displaced if additional gas CHP was brought forward, the potential CHP capacity that might be brought by financial support, the net impact on carbon emissions and the costs to society.

---

[4] Range of projections from a number of energy system models. Lower end reflects Redpoint Energy System Optimisation Model (RESOM), 52TWh/year of heat demand could be met by heat networks by 2050 (March 2013). Upper end reflects Energy Technologies Institute (ETI), Macro Distributed Energy Project report (March 2013)

https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis

Evidence gathering on potential renewable heating technologies (November 2014)

Research into the cost and performance of technologies which are not currently eligible for the RHI but could be considered for future inclusion: air to air and gas driven heat pumps, bioliquids for heat, biopropane for injection to grid, and direct applications of renewable heat.

https://www.gov.uk/government/publications/evidence-gathering-on-potential-renewable-heating-technologies

CO2 capture in the UK cement, chemicals, iron, steel and oil refining sectors (May 2014)

A study of industrial CO2 capture for storage or use in the cement, chemicals, iron, steel, and oil refining sectors.

https://www.gov.uk/government/publications/co2-capture-in-the-uk-cement-chemicals-iron-steel-and-oil-refining-sectors

The potential for recovering and using surplus heat from industry (March 2014)

Focusing on the eight most heat-intensive industrial sectors, as part of the Roadmaps project, the report looks to quantify the contribution towards the 2050 target that could be technically and economically achieved through the recovery of waste heat and the use of this heat to supply low carbon energy within the UK energy system.

https://www.gov.uk/government/publications/the-potential-for-recovering-and-using-surplus-heat-from-industry

The future of heating: meeting the challenge (March 2013)

The Future of Heating: Meeting the challenge sets out specific actions to help deliver low carbon heating across the UK in the decades to come. It focuses on four different aspects of the heat challenge – industrial heat, networked heat, heat in buildings, and grids and infrastructure.

https://www.gov.uk/government/publications/the-future-of-heating-meeting-the-challenge

Paper III: Technologies for Heating & Cooling

Commentary on Evidence Presented in the Paper

The section of the paper on hybrid devices does not consider the combination of an Air Source Heat Pump (ASHP) with a gas boiler, which DECC's research points to having considerable potential for medium-term emissions reduction for buildings on gas networks in less dense urban areas.

Like the previous paper, this paper does not cover the industrial use of Carbon Capture & Storage. This is a key technology for cost-effective decarbonisation.

1. What is needed to accelerate the deployment of energy efficient and renewable heating and cooling technologies in buildings?

The development of a stable/long-term policy framework which is targeted at achieving the scale of heat decarbonisation the paper identifies is needed across all sectors.

While there are common and well understood barriers to deployment, details are specific across EU member states and different technologies and strategies for accelerating deployment need to be tailored accordingly. In the UK we have an extensive gas network combined with highly efficient and easy to use gas boilers and cheap gas prices. This presents unique challenges in making the case for lower carbon alternatives from a cost and user acceptability perspective.

Driving cost reductions is essential to reduce the cost discrepancy between traditional and low carbon technologies. Unit prices need to be reduced through increased innovation and market forces and efficient and effective supply chains need to be established and developed. Strategies for tackling non-financial barriers need to be tailored in each member state and the application of each technology needs to be proved in each relevant country, climate and business context. Innovation is required to enable technologies to better meet users demands and to minimise hassle factors such as the need to replace heat emitter systems.

The market for renewable heating and cooling technologies in buildings is still developing and needs a catalyst to drive development. Therefore, retrofit trigger points need to be identified and exploited and considered in the round with the installation of energy efficiency measures. There is also evidence to suggest that owner-occupiers lack the necessary knowledge and confidence to invest in these technologies. They also lack of trusted and appropriate information. In addition, it is also important to address the split incentives issue. These include the split incentives with landlords (>60% UK commercial properties are leased) and between those responsible for maintaining a building and purchasing capital equipment and those responsible for energy costs.

Collaboration between member states on measuring, demonstrating and improving the in-situ performance (in terms of thermal efficiency and carbon savings) of low-carbon heating technologies could help to accelerate the removal of information and cost barriers.

2. What is needed to secure the buy-in of installers, builders and architects of the most efficient and renewables technologies?

Appropriate professional development/skills programmes and clear market signalling and strong government commitment is needed to secure industry investment and engagement in revolutionising supply chains. Again, local contexts are important as there are significant differences in industry contexts and starting points across countries, technologies and industries. Split and competing incentives and discrepancies between design and installation performance due to 'value engineering' need to be tackled.

3. How can the deployment of energy efficient and renewables heating and cooling technologies in industry be facilitated?

The Industrial 2050 Roadmaps[5] identified six key technologies that could increase energy efficiency and decarbonisation in the eight most heat intensive industries in the UK. Some of these, such as heat recovery and other energy efficiency measures, are applicable to all eight industries (to some degree) whereas others, such as industrial carbon capture and storage (ICCS), will be suitable for a subset of these industries. ICCS has the potential to reduce CO2 emissions by 23 million tonnes per year by 2050 across the iron and steel, chemicals, cement and oil refining industries, accounting for over a third of total potential industrial emissions reductions. Further measures include fuel switching (to biofuels), electrification of heat (such as electric kilns or electric arc furnaces) and decarbonisation of the electricity grid. Clustering of industrial sites and use of heat networks (district heating) can also have a significant impact.

The Industrial 2050 Roadmaps, corroborated by other studies[6], identified a series of barriers that are preventing companies from deploying existing solutions. This is covered in more depth in our response to Paper II, but in summary the key barriers are around business case barriers, development capital, policy and legislation and people and skills.

For sites where implementation would not be commercially viable – either in terms of the length of payback period for investment or overall rate of return – government intervention may be necessary. Financial support, either through grants for feasibility studies or towards the cost of deployment, or more flexibly via debt or equity, would help overcome capital expenditure and other barriers, increasing deployment of low carbon heating and cooling technologies.

Further technical innovation research, pilots and demonstrators focused on renewable and low carbon alternatives would help increase technical readiness levels of developing technologies, improve technical performance, and help reduce costs of more established technologies.

In addition to this there are barriers relating to information, in terms of knowledge / confidence in a particular technology, and expertise in terms of how a particular technology could be applied on a specific site. Further engagement on a local level could help increase understanding of the benefits of low carbon heating and cooling solutions, and match existing expertise with the needs of the industrial and commercial sectors.

4. Are there technical limitations to substitute fossil fuels with renewable energy, including biomass, or other alternative energy sources in heating and cooling in industry? Are there environmental and economic limitations?

There are few technical limitations concerning substituting fossil fuels with biomass or other low carbon alternatives in applications creating steam or hot water as part of an industrial process. The key issue preventing widespread adoption of low carbon alternatives to fossil fuels in these applications is cost – offering financial support to organisations installing alternatives such as biomass boilers, heat pumps or biogas / biomethane injection to grid (through the renewable heat incentive) has resulted in around 4.5TWh of renewable heat being generated. Without the

[5] https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050

[6] https://www.gov.uk/government/publications/the-potential-for-recovering-and-using-surplus-heat-from-industry and https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis

additional financial support, it is unlikely that organisations would install such technologies over conventional fuel systems due to the costs involved.

Substituting fossil fuels in high temperature industrial processes is, however, more technically challenging. This has been covered in more depth in the response to Paper II, where questions 3 & 4 address the same issue.

5. How can the conditions for financing for the transition to a renewable dominated and more energy efficient heating and cooling systems be made more attractive?

Finance is not perceived as the main issue, especially from commercial intermediaries. There is accessible liquidity in the market at the moment with a variety of products available for servicing a broad range of financing needs. However, the competition for the financing of bankable projects is at the bigger end of the spectrum. Smaller projects perceived as challenging from a credit point of view. This means that projects incorporating only the installation of emerging energy efficient heating and cooling systems might be small in size and therefore could find it difficult to access competitive interest rates.

It is also worth noting that a number of business building owners restrict their capital expenditure investments to opportunities that will pay back within 2-3 years. Therefore, if the payback periods of investments in energy efficient heating and cooling systems are longer, implementation might not be commercially viable for them. This rationale also applies to the overall rate of return.

At the same time, in most organisations time and attention is limited and senior management considers energy efficiency investments as low priority, prioritising other opportunities even with a lower returns. Therefore it is not unusual to lead focus and direct investment funds to towards key demands and projects, even where efficiency projects may on paper have offered stronger investment credentials. This may be caused by lack of awareness because some businesses remain unaware of their energy use and the cost-effective efficiency opportunities available for their owned business premises.

On account of the aforementioned points, government intervention may be necessary. It could provide support, either through grants to help organisations to bring in resources to develop feasibility studies and mature projects or towards the cost of deployment via a smart combination of public and private funding sources. This support would aim not only to increase the amount of investments in low carbon heating and cooling technologies but also to overcome the awareness and prioritisation barriers, too. Public funded development banks have also an important financing role to play in de-risking or maturing projects and in providing support.

Adding to the above, In lieu of robust carbon pricing, low carbon technologies are unlikely to be cost competitive with fossil fuel alternatives and hence government intervention might also be required to facilitate deployment.

In general, the EU should seek to coordinate investment and financing across member states to maximise returns on investments and reduce duplication and inefficiencies. Focused, co-ordinated investments should be made alongside plans for how value will be transferred to other markets

Additional evidence on similar themes

A review of European biomass standards

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/376805/Review_of_biomass_performance_standards.pdf

Literature Review for the IEA Annex 36 on Quality of Installation and Maintenance of Heat Pumps

https://www.gov.uk/government/publications/literature-review-for-the-iea-annex-36-on-quality-of-installation-and-maintenance-of-heat-pumps

Renewable Heat: standards and training research

https://www.gov.uk/government/publications/renewable-heat-standards-and-training-research

Paper IV: Linking Heating & Cooling with Electricity

Commentary on Evidence Presented in the Paper

The paper focuses strongly on the role of the heating & cooling system in supporting the transition of the electricity system to one with a greater percentage of output from variable renewables. However, there are a number of key technologies that are relevant to this question that are not given due consideration, including nuclear power and Carbon Capture & Storage (CCS) equipped thermal power plants. Nuclear power in particular, by providing cheaper electricity overnight, has historically been incorporated into the UK heating system through the use of storage heaters and time-of-use tariffs. There is no particular reason why this cannot effectively be replicated again as more household and district-level heat storage solutions become available, particularly with the advent of advanced storage solutions such as phase change materials. A stronger focus on all low carbon power solutions would greatly aid the analysis presented here.

The paper endorses the use of CHP as a heat source for district heating in order to take advantage of the electricity system balancing potential this offers. DECC sees this as a short to medium term solution, but notes that the majority of our CHP are gas-powered and must be phased in the 2030s out in order to meet carbon reduction targets. This tension is not reflected in the paper, which appears to endorse the long-term use of cogeneration. While there may be a limited role for bioenergy-powered CHP, bioresources may not be best spent on this option – as the paper reflects on the electricity side.

In a number of member states including the UK, extensive gas networks provide a significant amount of fuel for heating. This provides opportunities for the electricity system through the use of hybrid devices that could potentially switch their heating source from electricity to gas depending on the relevant price signal. This is an important linkage between both systems that the paper should explore in greater depth, as it is analogous to the CHP position the paper already advocates. While not a long term solution, it provides an illustration of a household-level enabler for heating & electricity integration.

The paper focuses on the benefits that flexibility offers in the form of reduced spillage[7] of renewables. However, flexibility services can offer a number of benefits:

- Reduced need for conventional generation, including peaking plant (as demand can be shifted out of the peak period)
- Defer/avoid investment in electricity network reinforcement expenditure (as peaks are reduced, meaning a lower level of network reinforcement is needed)
- Maximise the use of low Carbon, inflexible generation to get value for money (demand shifted to meet supply and supply shifted to meet demand)
- The meeting of binding targets with a lower renewables capacity (fewer renewables needed because they are used more efficiently)

[7] 'Spillage' refers to situations in which the electricity output of variable output renewable electricity generators cannot be used by the energy system or stored, resulting in its loss.

- Optimise short term balancing of the system (increased flexibility increases the number of balancing options available to National Grid)

Flexible heating and cooling technologies can therefore help to provide all of these benefits to the electricity system.

1. What steps to take to link heating and cooling and electricity systems?

The benefits and risks associated with linking heating and electricity systems in the UK need careful analysis. On the one hand zero-carbon electricity (including electricity from CCS, nuclear and renewables) can provide zero-carbon heat. On the other-hand UK heat demand, particularly in the domestic sector, is strongly variable with peak power demand for gas being of the order of 360GW on the coldest day of the year, compared to peak electricity demand of 60GW.

As a result, electric heat pumps and other devices can provide a strong contribution to decarbonisation, but this 'peakiness' challenge suggests that significant steps need to be identified to reduce heat demand (possibly through some combination of insulation and through high pumps with high CoPs) to facilitate their delivery, if storage technology is not available.

There are some areas where 'smart' systems could provide a way to integrate heat and electricity. Air conditioning and refrigeration provides a significant demand for UK electricity, and there have already been experiments looking at utilising these systems to provide short-term (e.g. 15 minutes, 30 minutes, 1 hour) load shifting. In many UK properties hot water can be provided by electric immersion heater *or* gas boiler – it should be possible to turn on immersion heat when electricity cost is low.

However all these options depend to some degree on the costs of electricity and/or energy storage, the exact mix of electricity generation, and options for other sorts of electricity use, particularly in the transport sector.

2. How cost-effective is thermal storage?

One answer might be to say "The cost-effectiveness of thermal storage will depend upon the cost of heat, the level of insulation of buildings, the level of demand for heat and the cost effectiveness of other approaches (such as demand-shifting). Therefore it isn't possible to answer at this time. What can be said is that there are some promising studies which suggest heat storage at domestic and local level is physically possible at affordable costs"

3. How dependent is an integration of heating and cooling and electricity on collective solutions (CHP, district heating)?

There are many different approaches to balancing an energy system and not all of these depend upon collective systems. For example individual households with sufficient space could storage heat energy under their properties during low cost periods and extract this during high cost periods. Air conditioning systems can load shed without being *physically* part of a collective system (they merely need to be interconnected in some kind of 'smart' electronic way). Household appliances, including heating and refrigeration appliances, could similarly respond to changes in demand without being part of a physical collective system.

The degree to which CHP can function as part of an energy system will in part depend on how the costs compare to other technologies, and in part depend on the fuel used. Carbon intensive fuels, even natural gas, for CHP and district heating are not consistent with the level of decarbonisation required for the UK by 2050, unless CCS is employed.

What is clearly needed right now are

- Innovation programmes which bring forward technologies to demand shift, and also develop and reduce the cost of energy storage technologies and technologies such as CHP, district heating, heat pumps and micro-generation
- Better modelling tools which fully reflect the variable nature of heat and electricity supply and demand, particularly over the extreme ends of summer and winter, in order for appropriate comparisons of different system options to be considered, and decision-making on system design to be taken in view of the *true nature* of the problem rather than an oversimplified model which may hide peaks and troughs.

Paper V: Integrated Planning and Mapping Scenarios for Heating & Cooling

Commentary on Evidence Presented in the Paper

This paper acknowledges that renewable energy for heat is growing in the EU largely on the back of an expanded role for biomass in providing heat following the Renewable Energy Target, and that achieving a significant share of renewable energy in our heating supply will require a significant expansion of biomass use. The previous paper states that significant expansion of biomass use (in that context for power) is likely to be unsustainable given limited bioresources. It is not clear that the level of bioenergy use reflected in the ambitious scenarios this paper presents is sustainable or indeed the best use of limited bioresource within the energy system. This point requires significant clarification. If the RET is promoting an approach to the development of our energy system that is unsustainable, this is a significant challenge to the current regime.

This paper, like the previous one, emphasises the role of fossil fuel-powered CHP in delivering district heat. DECC's expectation is for a far stronger role for low and zero carbon heating sources in the medium to long term, taking into account the relative ease by which district heating networks can swap heat sources, compared to doing that on a house-by-house basis.

DECC strongly endorses the position taken by this paper on the role of national and local conditions being highly significant in the determination of an optimal pathway for heating & cooling decarbonisation.

This paper does not consider hydrogen in any detail, which given its potential role in a decarbonised heating system is a significant oversight.

1. What should the key features of the heating and cooling system in 2050 be?

The heating & cooling system of 2050 should be:

- Low to zero carbon, affordable and secure.
- Integrated into the entire energy system; offering possibilities for cheap storage and shifting demand and supply between vectors depending on market conditions.
- Integrated across consumer boundaries; permitting joint ways of meeting heating needs across industry and other groups when it is socially cost-effective to do so.
- Responsive to consumer demands; taking advantage of advances in technology to deliver thermal comfort and/or necessary process heat to consumers as and when they require it and for a price accessible to all.
- Efficient; making the best possible use of available resource.
- Resilient; both to external supply shocks and internal challenges.

2. What can be the benefits of an integrated approach to set pathways for the transformation of heating and cooling?

Setting a pathway for the low carbon transformation of heating and cooling needs to be undertaken in the context of the transformation of the entire energy system over the same period. This integrated approach is necessary, as demand for heat and cooling impacts on:

- The requirement for both additional electricity generation capacity and additional electricity network infrastructure in cases where thermal demand is electrified through the use of electrical heating and cooling measures.
- The availability of limited bioresources, where thermal demand is met through the consumption of biomass or processed biofuels.
- The availability of tools for managing other types of energy demand, such as the storage of electricity as hot water for heating purposes, low carbon hydrogen networks that can provide both heat and transport fuel, and additional electricity demand response from combined heat and power plants.

The appropriate management of the above through a clear pathway for heating & cooling decarbonisation can reduce the costs of decarbonising the entire energy system. However, there are a number of disbenefits from an integrated approach:

- Economic modelling that relies upon assumptions about technology growth rates and consumer uptake is not suitable for reflecting potential technological change and can lead to policymakers making inappropriate technological choices if not used under advisement.
- The benefits and costs of an integrated approach are not necessarily apparent at the level at which heating & cooling is most appropriately planned. The system-level benefits of providing cheap energy storage in a particular heat network for the wider electricity network may not be apparent to the owner of that network in the absence of an accessible price signal. Integrated planning at a local level therefore needs some way of reflecting a national picture.
- At a less local level, a design for a low carbon electricity system may not appropriately reflect the benefit of localised combined heat and power stations that are best planned at a local level. Economic models have traditionally under-valued these kinds of system-wide impacts owing to poor representations of networks and other spatial factors, typically as a result of computational complexity. An integrated approach at a national level needs to have regard to local efforts, and vice versa.

The pathways for different types of vectors are best set using different levels of granularity, and as a result cannot be integrated in order to set an overall pathway but must rather proceed iteratively. It is worth considering how socially cost-effective system-wide benefits can be translated into price signals accessible to planners at all levels.

3. What elements does such an integrated approach need to consider in terms of the options of demand reduction and the deployment of renewable energies, e.g. the share of electricity in heating, the balance between reducing demand in buildings and industry and the deployment of renewable supply sources, the role of district heating and cooling, technologies deployment, and the roll-out of smart energy networks, the empowerment of consumers?

An integrated approach does not only need to consider every single aspect of the energy system and all currently known technologies, but also the disposition of decision-makers at each level down to and including the consumer. This is why most integrated approaches currently in use opt to simplify one or more elements in order to make the problem computationally possible. The UK is pioneering an approach that involves multiple focused models of different aspects of the energy system, including domestic demand, electricity networks and heat networks, in order to compensate for this problem. By having a ‘family’ of models rather than a single integrated model the complexities of each area can be brought out more clearly, and rather than using a single pathway as the basis for policy judgements the complex interactions between energy vectors and decision makers can be studied in more detail to provide an understanding of the range of possible outcomes and how they might be shaped.

4. At what level should such integrated approach be applied, *i.e.* EU, national or local levels?

Network industries often require regulation and coordination at EU or national level: to manage market failures such as monopoly power and barriers to new entrants. However, heating and cooling demand and supply factors can be very specific to a particular local area. For instance – on the supply side: the presence of deep geothermal heat sources or an industrial complex producing recoverable heat. On the demand side the weighting of different types of demand (e.g. retired couples versus working age families) within total demand creates individual local characteristics which may be best served by different local solutions. This emerging focus on the local energy system creates a question about the appropriate level for decision making and responsibility. If this is vested at the local level, then, local democracy could provide an additional spur to decarbonisation as well as a wider range of potential solutions for study and eventual dissemination.

5. What are the best practices of integrated mapping for heating and cooling at local and national level?

Integrated energy system mapping can be part of a national awareness raising campaign which is designed to stimulate local agents to investigate further the potential for new energy solutions in their areas. It should be based on very simple allocations of heating and cooling demands. Local agents could then follow up with more detailed mapping to appraise specific options. However, disaggregated detailed mapping is of, probably, only limited value if robust data on heat demand is not available. Usually there is no data available on the time profile of heat demand by consumer. Total annual heat demand by consumer is also often not available. If most of the data is generated from a few sample cases, rather than from empirical observations, the final results could be misleading.

Relevant DECC Research

DECC are developing an integrated energy system model (UK TM) to help support the debate about future energy and carbon pathways for the UK.

A suite of more disaggregated modelling tools are also being developed including:

- National Household Model
- Industrial Heat Model
- Non-Domestic Buildings model
- Heat Networks Cost and Forecasting tool

Relevant Technical Evidence work includes:

- Business Energy Efficiency Survey
- Industrial Marginal Abatement Cost Curves [Check title] project
- Heat Storage Project
- National Comprehensive Assessment (EED Art 14)
- Comparing hydrogen, heat pump & heat network solutions for a small urban area

Evaluations and Stats:

- Heat Networks Stats due in 2016
- RHI Evaluation work continues
- Heat Networks Deployment Unit Evaluation

Annex: Corrections to data used in papers

Paper I: Heating and cooling of buildings

Page 3: Reported current levels of energy consumption for single family buildings range from 585 kWh/m2 (UK, pre-1920, detached house) to 34 kWh/m2 (Slovenia, post-2005). This is not correct; these do not represent average consumptions of the UK pre 1920 housing stock, although it may represent modelling of particularly poorly insulated stock. This would imply an annual consumption of 58500 kWh for a 100m2 house. Data from DECC indicates that very few houses have gas demands this high. Looking at data for 5.236 million properties in the UK (postcodes H to M). There are 67 post codes (out of 233135) which have mean gas consumption > 50,000 kWh. This is 0.03%. There are 7 million solid walled properties (pre 1920) out of about 27 million homes, so solid wall properties account for 26% of the housing stock. The modelling of 585kWh/m2 is not typical of the pre 1920 stock.

https://www.gov.uk/government/statistics/postcode-level-gas-estimates-2013-experimental (DECC data for 2013).

Page 6: Natural gas is the dominant fuel for heating in buildings. Its overall share is 47%. Gas is followed by oil products with 16%. Electricity (resistance heating and heat pumps) supplies 12% of space heating and hot water, while biomass boilers constitute 12%. Other renewable sources are still marginal, solar being 0.5% and geothermal 0.1% . The share of coal and coal products is 3% .

These figures don't add up to 100%. (90.4%) The rest may come from the renewable part of heat provided by heat pumps. Estimates in Paper V imply that heat pumps account for around 80 TWh of heat and this fits with the EHPA figures. Paper V puts the amount of heat generated by heat pumps at 6.87 Mtoe (approx 80 TWh). The overall heat demand in Europe is 536 Mtoe (6223 TWh) (paper I). 80/536=15%, and 1/3 of this is not renewable, so the remaining 2/3 (=53 TWh) may be the renewable component from heat pumps and this would account for the 10%.

Page 7: Space Cooling - it is worth mentioning here that EU product policy currently covers air-con units < 12 kW but outside the residential sector, almost all systems are much larger than this. Individual components of large air-con systems are covered by EU product policy but the only existing policy that applies to air-con is the requirement for inspection under EPBD. Integrating electricity demand monitoring into air-con would be really useful in reducing demand.

The paper doesn't mention peak electricity demand, which can be driven by space cooling.

Page 8 - need to include the base year - are these reductions relative to 2005?

Page 11: Once total heat demand (for space heating and hot water) is reduced by 30-50%, it is likely that the price of deploying sustainable heat supply will be cheaper than continuing to reduce the heat demand. What is the baseline for this reduction? Is it 2005?

Also, continuing to reduce heat demand may result in over heating in summer (eg a very well insulated building with large windows overheats).

Paper II Heating and cooling use in industry and the tertiary sector

Throughout - add energy consumption in TWh, EJ and Mtoe as mixed units are hard to follow.

Page 2: After 3%, delete "of this 20%" to get a sentence that is coherent with page 1.

Page 6: As the report correctly notes, supplying renewable heat at > 200^{0}C can be very difficult, although some research is ongoing (the i-stute programme has interesting progress on high temp heat pumps at the pilot stage).

Page 7: The paper notes the low level of progress in the service sector. There are many Carbon Trust studies in this field. Also Oxford University's "WICKED" study on energy use in the retail sector.

Page 8: Considerable work is ongoing on data centres and there is a BREEAM code specifically for data centres.

Page 10: This could include radio frequency driers for the textile, plastic, paper and wood industries.

Page 12: 5 year payback – many companies don't consider investing in measures unless they pay back in 2-3 years.

Paper II – Further In Depth Comments

Section	Page	Issue
1	1	A current "best estimate" is that industry consumed 173,2 Mtoe or 63% of its total final energy for heating and cooling, 35% (95,37 Mtoe) for electricity driven processes /machinery and 3% (5,4 Mtoe) for cooling (Fraunhofer et al., 2015, ongoing)[8].
DECC Comments:		
Cooling is included twice – in the 63% and the 3%? Unless %s are not meant to be additive?		

Section	Page	Issue
1	1	A current "best estimate" is that industry consumed 173,2 Mtoe or 63% of its total final energy for heating and cooling, 35% (95,37 Mtoe) for electricity driven processes /machinery and 3% (5,4 Mtoe) for cooling (Fraunhofer et al., 2015, ongoing)[9].
DECC Comments:		
By way of rough comparison/validation from UK government statistics, 'Overall energy consumption for heat and other end uses by fuel 2013' indicates the following breakdown for UK industry: • Heating (72%) • Refrigeration (2%) • Motors (13%) • Compressed Air (4%) • Lighting (1%)		

[8] Various previous studies estimated the overall energy use for heating and cooling in industry. Using a bottom-up approach based on Odyssee indicators, Fraunhofer (2014) estimated a higher value of total final industrial energy use for heating in industry of 267 Mtoe (in 2008), of which cross-cutting steam systems consumed 73 Mtoe and sector specific processes 194 Mtoe. This latter figure comprised both steam and electricity consumption, as some processes use electricity to generate high temperature heat, such as electric arc furnaces in steel making.

[9] Various previous studies estimated the overall energy use for heating and cooling in industry. Using a bottom-up approach based on Odyssee indicators, Fraunhofer (2014) estimated a higher value of total final industrial energy use for heating in industry of 267 Mtoe (in 2008), of which cross-cutting steam systems consumed 73 Mtoe and sector specific processes 194 Mtoe. This latter figure comprised both steam and electricity consumption, as some processes use electricity to generate high temperature heat, such as electric arc furnaces in steel making.

- Other (8%).

Source: DECC's Energy Consumption UK - Table 1.07

So a higher % for heating and cooling though note the ECUK definition of Industry excludes the Services sector (Commercial and Public sectors) so may differ from Fraunhofer "Industry" definition.

In general DECC's Energy Consumption UK statistics provide a useful rough comparator for many of the statistics included in this Chapter:

https://www.gov.uk/government/statistics/energy-consumption-in-the-uk

Section	Page	Issue
1	2	Overall, it has been estimated that, in 2012, out of the total thermal energy use, 40% of industry's energy consumption is for high temperature process heat (over 500°C), while medium or low temperature (below 500°C) represents 37% of heat demand[10]. Space heating is 20%[11] and 3% of this 20% is used for process cooling.
DECC Comments:		
By way of rough comparison/validation from UK government statistics, 'Overall energy consumption for heat and other end uses by fuel 2013' indicates the following breakdown for UK industry consumption of fuel for <u>heating</u>: • Space heating – 22% • High temperature processes – 29% • Low temperature processes – 36% • Drying/separation – 13% Source: DECC's Energy Consumption UK - Table 1.07		

Section	Page	Issue
1	3	Large combined heat and power (CHP) is widely used in many sectors, such as refineries and chemical, pulp and paper, food and beverage. Industry uses more and more large heat pumps, mostly operated on electricity. Solar thermal is gaining ground, but is still at a low level. Furnaces and ovens are widely used technologies, but they are of specific design depending on the sector. Industry is also supplied by district heating providing medium and low temperature process heat or space heating.
DECC Comments:		
Is it possible to indicate levels of penetration of each of these technologies in European industry and/or any countries where high levels of penetration have been achieved? Useful to understand degree to which low carbon technologies are already used in industry.		

Section	Page	Issue

[10] An earlier estimate concluded that 57% of industry's energy consumption is for high temperature process heat (over 600°C), medium temperature (between 200°C and 600°C) represents 18% of heat demand, while 15% is low temperature heat (below 200°) and 10% is space heating (JRC, 2012).

[11] Provisional data, the share of space heating is highly uncertain and might result considerably lower after data cross-check.

5	14	However, most non-energy intensive industrial enterprises are reluctant to adopt industry wide practices for energy efficiency and renewable solutions, because they consider those as risk to the core business. Industrial companies and SMEs, therefore, tend to use mainstream and often old energy supply and distribution systems and technologies, characterised by low energy efficiency, overcapacity, high energy costs and large dependency on fossil fuels, driven by conservative business models favouring risk aversion in decision-making and the use of solutions that are well-established in sector practices.
DECC Comments:		
The points in this section are seemingly asserted without evidence. Would help if referred to any surveys of industry attitudes and/or evidence of risk aversion in decision making. Or is this text also based upon ICF (2015)? A further reference would help if so.		

Section	**Page**	**Issue**
5	16	Best practice examples show that an enabling regulatory framework supporting companies to raise the importance of energy efficiency and renewable energy could facilitate access to expertise and financing and therefore overcome such barriers.
DECC Comments:		
Again – what is the source of these “Best practice examples”? References would be helpful.		

Section	**Page**	**Issue**
General		Scope
DECC Comments:		
In addition to energy efficiency, renewable heating fuels and waste heat use, the Strategy should include something on the opportunity for industrial carbon capture and storage as a means of decarbonising industrial heat and process emissions. The UK 2050 Industrial Roadmaps refer to the potential for ICCS in the UK energy intensive industries: https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050		

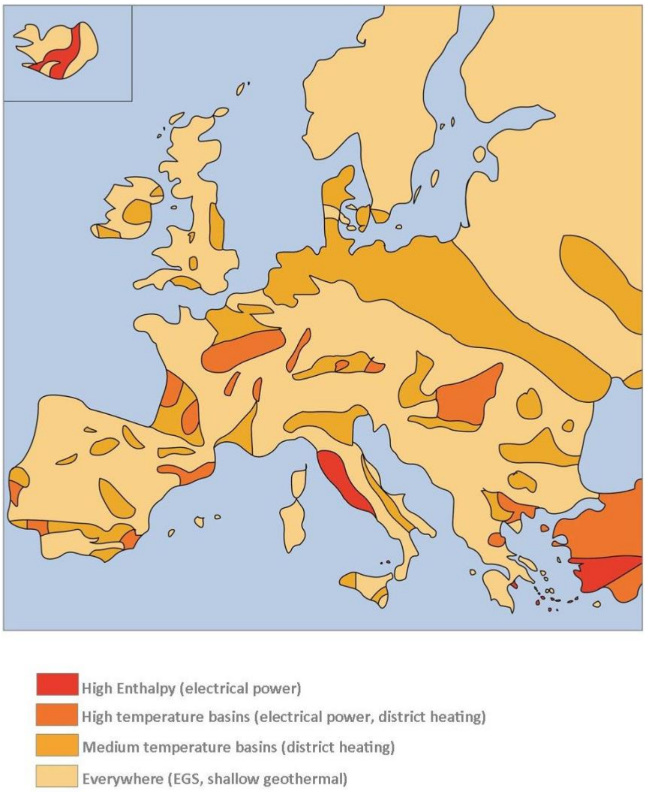
Paper III - Technologies

Page 8: The text is quite dismissive of biofuels, but biomethane is making a good contribution to the RHI. There is nothing in the paper on hydrogen.

Page 9: Another development is cascade heat pumps, which use two refrigeration circuits, each with a low to moderate temperature lift. The net result is a heat pump that is able to supply space heating at 60 degrees C with acceptable SPF. Daikin has cascade heat pumps on the market.

Page 12 - Coefficient of Performance of 8 - this is misleading. It's possible but the number of situations where a very low temperature lift is required is probably very small. Also COP is a spot figure, in the lab, at particular temperatures, not an annual average.

Page 13 - High temperature geothermal can be used to generate electricity, but it's only economic in a few places in Europe. Most of the geothermal resource is more suitable for heating:



Page 14 - References to Iceland and Turkey (non EU countries with special geographies, susceptible to earthquakes and volcanoes although the most recent Turkish eruption was in 1855) distort the chart.

The paper doesn't mention electricity demand for pumping, which is significant for both solar thermal and geothermal and reduces overall efficiency and cost-effectiveness.

Page 17 - chart should be in Celsius not Fahrenheit.

Page 18 - mixed units. Please present EJ and Mtoe and Twh.

Concentrated solar power for industrial heat - while there are lots of examples, this is restricted to Southern Europe. A comparison with heat pumps is required.

Geothermal - this section provides costs and the others don't. For clarity, all sections should use the same approach.

<u>Paper IV - Technologies</u>

Page 1: The footnote doesn’t show the date and we don’t know what technologies are being used to process the bioenergy. Is this estimate of 25GJ per person based on current bioenergy technologies or new ones?

Page 3: domestic hot water tanks **-** in the UK, around half of boilers are combination boilers, so do not have domestic hot water tanks. Furthermore, many showers use direct electricity, rather than hot water from a tank.

Page 4: The study should also consider the cost-effectiveness of variable plant run intermittently to cope with renewable generation. This may not fit a market model.

Page 8: The note mentions EU 2020 and Horizon scanning projects. What are the dates for completion of these projects? What is the TRL of each technology? And the potential market? And the size/barriers? These elements are not included in the table in the Annex.

The size/compactness is a very important issue, particularly in countries where houses do not have basements (like the UK).

Department of Energy & Climate Change
3 Whitehall Place
London SW1A 2AW
www.gov.uk/decc