Report of the ERP – ETI – RAEng Heat workshop

22 January 2009

Introduction

The Energy Research Partnership, Energy Technologies Institute and Royal Academy of Engineering jointly organised a workshop to examine the role of heat in the UK's energy system. It took place in the afternoon of 22 January 2009 at the home of the RAEng, 3 Carlton House Terrace, London.

The workshop was designed to raise the level of thinking on heat as an issue, help guide ETI's future work on heat, and inform participants' responses to the Government's consultation on the Heat and Energy Savings Strategy, which was subsequently launched on 12 February.

Participants were asked to consider the demand for, and supply of, heat in the UK's energy system, now and under scenarios which put the UK on a path to 80% reduction in CO_2 emissions. An emphasis was on how new technologies and wider innovation in our use of heat can help achieve these emissions targets.

Over fifty energy professionals attended, with almost half from industry, and an even split from academia and the public sector (including policy makers and funders) amongst the rest. A series of presentations set the context, covering whole systems, policy and technology, followed by an interactive panel discussion, with senior figures from private and public sectors.

This report summarises the views of the speakers, and the discussion that followed. The full set of presentations is available on ERP's website at: www.energyresearchpartnership.org.uk/heat.

The organisers thank all those who participated in the workshop, in particular the presenters and members of the discussion panel. Special thanks go to Jim Skea, Research Director of the UK Energy Research Centre, for chairing the event.

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1. Summary

It has become increasingly apparent that managing the demand for heat, and decarbonising its supply, will be crucial in efforts to reduce carbon emissions: half of the UK's total carbon emissions come from the use of heat. Government projections have implied that emissions from heat would have to fall 10% by 2010, and almost 20% by 2020, to reach just a 60% overall reduction in the UK's CO_2 emissions by 2050.

Yet carbon emissions from heat use have been increasing over the last 30 years in the UK. Despite various energy efficiency measures, demand in the domestic sector (which accounts for half the energy demand for heating) has grown steadily as the number of dwellings and internal temperatures have increased. The industrial sector has seen reductions in CO_2 emissions from heating, due to greater sensitivity to fuel prices, and a shift away from energy intensive manufacturing and carbon intensive power generation.

The workshop explored all aspects of heat, and it was clear that to meet the ambitions of an 80% reduction in carbon emissions by 2050, radical reform would be required to both lower the carbon intensity of the supply of heat, and reduce demand especially in the built environment. However, it was accepted that the simplistic notion of addressing supply on the one hand, and demand on the other should be superseded by a more sophisticated approach. Optimisation of the whole energy system to reduce carbon emissions will require a significant change in thinking that must be embraced.

Such an integrated approach is difficult, though, because there is no commonly accepted picture of how the UK's energy system may evolve. How, and how fast, a decarbonised, and possibly distributed, electricity generation system develops will impact on which technologies will deliver the most cost-effective CO_2 reductions from heat.

Participants called for the energy community in the UK to develop a vision of the UK's future energy system to allow a more focused approach to developing and deploying technologies. At the same time, there was a view that the UK could not afford to discard options that could deliver emissions reductions.

A decline in heat generation from non-abated fossil fuel was expected from 2020, but it was not obvious what would follow . The options debated included district heating networks, decarbonised electricity, combined heat and power (from natural gas or biofuels, at a district or household level), and the role of energy storage (electrical or heat). What may be the case is that the UK moves from a reliance on specific, dominant vectors and technologies – gas boilers in the case of the domestic sector – to a more diverse market. This could be accompanied by new business models which sell the provision of thermal comfort and drive up carbon efficiencies, but will need regulatory changes to make viable.

In the near term, current technology must be deployed more extensively and at an increased rate, but this will only take us to somewhere between a 30 – 40% CO_2 reduction in the domestic sector. Over longer time scales, advances will be needed in insulation and window technologies, with improvements in appliance efficiencies, as well as integrating them into a more system wide approach of energy saving and emissions reduction. Research and development programmes are necessary to bring new technologies through to the market, and the specific market challenges for these technologies must be addressed.

Many at the workshop saw a pressing need for large-scale demonstration activities and reliable data. A better understanding of real-world energy usage would be needed to underpin policy and investment decisions on further interventions.

Experience from other countries could also provide valuable lessons. A number of examples were cited by participants, including district heating networks in Scandinavian countries, energy service companies which are common in France, and schemes operating in Canada in which utilities own domestic heating appliances.

A theme common to any discussion on energy was the appeal for consistent policy, with long-term objectives. This is needed to encourage innovation and give investors confidence in the viability of installing new technologies.

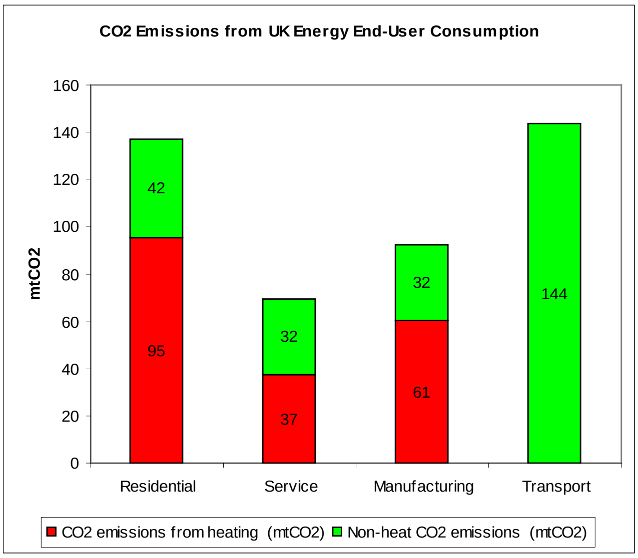
2. Setting the context

Whole systems

(i) Bryan Silletti, Caterpillar & ETI Strategic Advisory Group on Heat

Link to presentation

The annual UK energy consumption to provide heat is 70 Mtoe (814 TWh), and a significant contributor to CO_2 emissions:[1]



The energy use for heating by sector shows the particular importance of residential space heating:[2]

Mtoe (TWh)	Space heating	Water heating	Low temp process	High temp process	Cooling
Residential	26 (302)	11 (128)	1 (12)	0	N/A
Service	9 (105)	2 (23)	2 (23)	0	1 (12)
Manufacturing	6 (70)	N/A	8 (93)	5 (58)	N/A

To put these figures in context, road transport uses 42Mtoe, and electricity production uses 50Mtoe.

System level optimisation will require significant change in terms of how things are done. In the UK, heat and electricity have been effectively. However they are integrally mixed; those links need to be understood to explore how the system can be made more efficient. Can a high-temperature process feed a low-temperature process? Can 'waste' heat from a low-temperature process go to space heating?

For the domestic load, the question is not necessarily about heating or cooling, but how a system can allow people to be comfortable more efficiently. Improvements from new build are coming through, but 70% of 2050's housing stock has already been built. This can be tackled through decarbonising the supply or retrofitting energy saving technologies.

In the near term we should use heat more effectively, such as through integrated controls and insulation. Longer term we can look at how to deliver and use space and water heating more efficiently and with lower CO_2 emissions.

There are many options for decarbonising heat supply. One is to use the large amount of wasted heat from various systems, much from electricity generation. This table looks at how much heat is technically available, not what would be economically viable:[3]

Source	Wasted heat (Mtoe (TWh))
Power stations Approximate technical potential estimated for a generic multi-stage steam turbine power station.	20 (233)
Refineries Available for use as low temperature heat source with a viable heat sink from 60-120°C	2 (23)
Other industry (> 20MW) Technical heat recovery potential at temperatures up to 1500°C with commercial technology	1 – 2 (12 – 23)

The Danish Energy Authority has done a great deal of work on heat networks, utilising heat and making the systems much more efficient. Starting with natural gas a 30% reduction in CO_2 intensity was achieved, which is diversified with the inclusion of biomass and waste heat, then renewable firming to continue decarbonisation. Nine heat networks in the UK are already established or expanding, so there is a financial model by which they can work efficiently.

There are other key enabling technologies which exist to help achieve greater efficiencies, including heat storage and heat pumps. But we need to understand how to integrate those systems to use energy efficiently and integrate into a broader segment to reduce CO_2.

A combination of demand management and decarbonised supply is critical to reach emissions targets. The sequence of deploying technologies and managing demand is a debatable point, but there will be a time element and a capacity element. What we really want is affordable comfort with a low carbon system and secure supply.

[1] "Energy Consumption in the UK", BERR (July 2008); "Digest of United Kingdom Energy Statistics 2007", BERR (2007); "Updated Energy and Carbon Emissions Projections", DECC (2008). Available via http://www.decc.gov.uk/en/content/cms/statistics/.

[2] "Energy consumption in the UK", DECC (2007). Available at: http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx

[3] From "Energy Flow Chart", DECC (2007). Available at http://www.decc.gov.uk/en/content/cms/statistics/publications/flow/.

(ii) Geoff Hammond, University of Bath

Link to presentation

Over the last 30 years, there has been a gradual growth in energy demand in both domestic building services and in the commercial sector. The area that has been the greatest success story has been the reduction in energy use in industry because of greater price sensitivity and a move in the UK from heavy to light industry together with a switch from coal and oil to gas and electricity.

For our whole systems analysis we have used a portfolio of thermodynamic techniques, including ones that just look at the *quantity* of energy but also others that look at the *quality* of energy. In the UK, we have rather lost sight of thermodynamics, when those constraints underpin the whole of the energy system.

The most important point is that there is more than one law of thermodynamics. Just using the first law gives this idea of the quantity of energy, or *enthalpy*. Using the first and second laws comes to a measure of a property which is commonly called *exergy*. Exergy is about the efficient conversion of energy into work, but not into heat. These ideas give different insights into an energy system.

Exergy analysis shows how to optimize the use of energy at different levels of quality – or, different temperature levels. That leads to the idea of energy or heat cascading. We have been looking at how to develop heat networks which optimize the use of this heat cascade at the different temperatures; just to see what would be possible in terms of utilisation of energy, particularly in the industrial sector.

Electricity is a high grade energy source, which should be used for high grade applications. It is inefficient to use it for space and water heating at least with the current network. Despite this, under a series of projections of energy scenarios to 2050, we find that roughly 50% of electricity will be used for power applications in the home and roughly 50% will still be used for heating applications. This is at least partly due to these same scenarios including significant proportions of future energy supply from electricity generation in renewable and/or nuclear plant.

There are a number of barriers to improving energy productivity in industry. Though the thermodynamics might suggest 80% of existing energy use could be saved, in practice, about 50% is technically achievable. Economic factors further reduces this to about 30%.

Recent work for the ETI has estimated that the technical potential for heat recovery in industry (excluding the power sector and refineries) to be in the range 10 to 20 TWh per annum with commercially available technologies.

These ‘whole systems’ approaches encapsulate the idea of sustainability assessment, which should be used more widely, though with a proper understanding. Thermodynamic concepts are very instructive but have to be used in the right way. There are some cases where they can lead to the wrong conclusions being drawn – using exergy analysis to analyse heat networks, for example, can sometimes be misleading. We need to take account of both the quantity and the quality of energy when trying to optimise an energy system.

We also need to test to what extent we have lower hanging fruit, particularly in industry. If industry has been so successful already in reducing its energy consumption and it is price sensitive, then how much is there left to do?

Policy

(iii) Hergen Haye, Department of Energy and Climate Change

Link to presentation

In energy policy, electricity always had centre stage and heat has been the Cinderella of policy making. However there has been a shift within government departments and ministers, to note the importance of heat and therefore which policy levers to consider putting in place to enable carbon savings from heat where possible.

Energy saving and heat have been brought together as policy drivers in the Department of Energy and Climate Change. We believe that the best heat is the heat that you do not need to generate and so energy saving and energy efficiency policies are an important component of any over-arching heat policy.

What is certain is that to meet the 2050 targets in renewable energy and 80% CO_2 reduction, then we need radical reforms: incremental step changes will not ensure that these targets are met.

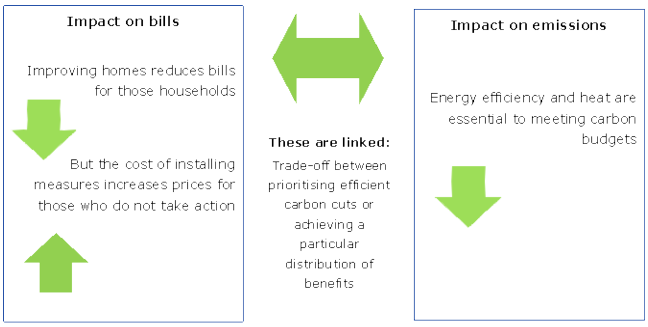
What we really want to see is a ‘whole-house’, rather than piecemeal, approach. An issue is whether there is a need for a more co-ordinated, holistic, and expert service, to advise the home owner on a range of solutions from energy efficiency to the installation of heating or micro-electricity technologies. Also, we have to ask whether the range of instruments for financial support - obligations and incentives - works effectively together; and whether our ambitious targets require more direction through regulation in the future.

One of the areas we are considering is the role of district heat networks, and whether there is a place for more such schemes in the UK. Overseas they are more widespread, but for different reasons. In Denmark, for example, there was no gas system in place and they used heating oil. The local government decided that three-quarters of Copenhagen should have district heating, while one-quarter was connected to the gas mains. It was a very directional approach and one that was very much facilitated by the oil crisis in the 1970s.

Urban areas in the UK are now mainly on a gas grid, but do we want a further heat network installed, with all the prices and capital investment that is required? There could potentially be 5.5 million household (a quarter of the current housing stock) within the UK that could be connected, sensibly, to a district heating network, compared to about 2% currently.[4]

In terms of industrial heat and CHP, there is again a set of policies already largely in place. The question for us is whether there are too many, should we streamline them, and are they the right policy instruments?

Our policies will have to consider bills and carbon emissions – and these impacts are related:



Improving energy efficiency or installing heat technology will reduce residential or business bills, but someone has to pay for that.

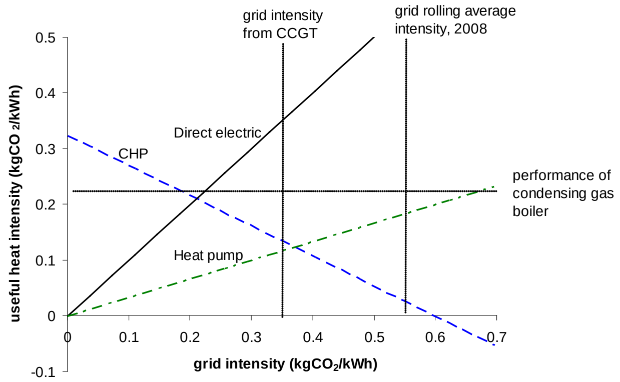
There is also an issue of distribution, and distributional impact, for policy makers to consider: whether some policies are targeted to ensure that these new technologies and the energy efficiency measures do not reach just a certain strata of society.

(iv) Nick Eyre, University of Oxford

Link to presentation

Meeting energy security and carbon goals with respect to heat in the UK can now only be achieved by using less energy or shifting to renewables. The constraints for heat are the competitiveness and affordability goals. Heat is a low-value energy demand which people are not prepared to pay for in the way they pay for electricity or transport fuels.

There are three scales to think of low carbon heat. The large scale is to decarbonise electricity and use electric heating. This graph looks at how the carbon intensity of heat from typical CHP and heat pump units depends upon the carbon intensity of the electricity grid:



Heat pumps can improve on direct electric heating, with lower carbon intensities. CHP technologies have negative slopes (dependent on the electrical efficiency) because the more carbon intensive the grid is, the bigger the benefit of generating electricity from gas-fired CHP.

Grid intensity is currently about 0.54 kgCO_2/kWh, and a gas boiler produces about 0.22 kgCO_2/kWh. At the moment, both heat pumps and gas fired CHP are therefore good for carbon, compared to a boiler and direct electric heating. However, when the grid intensity of marginal plant on the system (likely to be gas or coal with the current configuration), at the time when heat is required, reaches about half the current grid intensity, heat pumps are very good and CHP becomes bad. That, however, is quite a long time away, and there is a generation of CHP technology that can be put in before there is a risk of damaging the overall carbon economy.

On the medium scale, district heating is only low carbon if it is CHP or fuelled by biomass. It remains an open question whether it makes sense to put in a heat system in low carbon developments. However, it is not a general panacea.

The micro scale, where fuel is turned into heat at the point of use, or close to it, will go on being important, and the most important for the foreseeable future, so we should be focusing on those technologies.

Is current policy working for heat? The price for carbon in current policy instruments is about £10/tCO_2 (see table below), about an order of magnitude lower than the market price for carbon in gas. So the instruments are probably not affecting behaviour and the fuel mix. That is not to say they are bad – they can be effective if the money raised is used in a sensible way.

Sector	Carbon price
Energy intensive industry – EUETS	~£12/tCO_2
Other large organisations – CRC	£12/tCO_2
All business and public sector – CCL	~£8/tCO_2
Household suppliers – CERT	~£16/tCO_2

Carbon prices for heat. This compares with the current gas market price of £100-£200/tCO_2 depending on sector.

[4] "The UK Potential for Community Heating with Combined Heat & Power" (2003) BRE report for the Carbon Trust. Available at http://www.energysavingtrust.org.uk/business/content/download/180001/441477/version/2/file/UK+CH+potential+report_CTFinal.pdf

To support innovation, a consistent policy is required, with something like a feed-in tariff or a renewable heat incentive which operates when there is a consistent price, and people know they can get it. Support from the Low Carbon Building Programme has not been consistent enough to be fully effective.

On buildings and behaviour there is a better story to tell, and the Government is doing quite a lot in this area. The regulations that made condensing boilers mandatory were excellent, and CERT has done its job well. However, for the future, policy instruments may only deliver 30% reductions in emissions; reaching 80% will mean a fundamental reconstruction of the building stock.

To conclude, in the short term the priority is to use less heat, and remember that the second law of thermodynamics exists. Longer term, the struggle will be to use more renewable fuel, requiring significant incentives to develop the supply chain.

Technology

(v) Dennis Loveday, Loughborough University

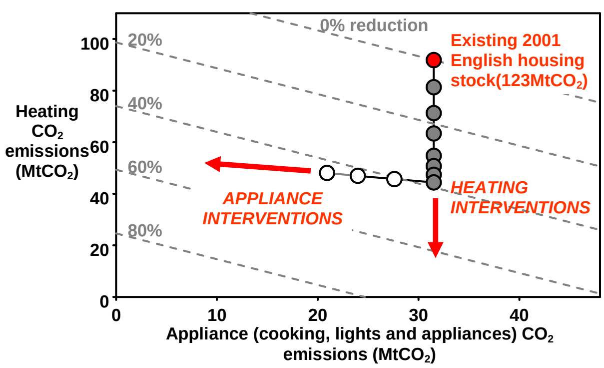
[Link to presentation]

There has been a growth in the demand for heat in the domestic sector over the last 30 years despite better efficiency measures on insulation and heating technologies. It may well be because people have more disposable income and wish to spend it on being warmer: there has been a general increase in indoor temperatures, and the number of rooms being heated. There has also been a 40% increase in the number of households.

It is interesting to consider the market penetration of home energy efficiency measures over this period. To reach saturation has taken quite a long time – several decades in some cases which implies that some form of stronger promotion or encouragement will be needed for future energy efficiency refurbishments.

The following graph shows that even with 100% interventions in insulation and other energy saving technologies to the existing English housing stock would deliver about 40% carbon reductions:[5]

Energy efficiency predictions: 2001 English housing stock



So there needs to be other radical interventions to get to 80% emissions reductions for the built sector. Given a cost of further fabric interventions to be around £20k per house, that is an investment of £400bn across the UK.

Some of the more advanced demand reduction technologies in various stages of development include advanced window systems (triple or vacuum glazing and aerogel replacements), vacuum insulation panels (which can improve standard by a factor of 10 on the performance of standard building insulation, though there are currently issues with effective lifespan) and super insulation (which allows internal gains to be sufficient to keep people thermally comfortable).

A particularly interesting issue is the technology/human interface, with significant scope for self-learning, predictive/optimal-based control systems to give better control of heating systems. Advanced controls have been reported to be capable of offering up to about 20% savings, and they have good retrofit potential.

Human thermal comfort will be important to consider in a changing climate: will warmer conditions be acceptable, or will there be a demand for air conditioning in the home, as it is at work and in cars?

There is no magic-bullet technical solution, and we should not lose sight of the fact that many of the challenges revolve around socio-technical/socio-economic factors, together with issues related to the skills base, supply chain and infrastructure required to deliver future solutions.

[5] Steven K. Firth and Kevin J. Lomas. Investigating CO2 emission reductions in existing urban housing using a community domestic energy model, Building Simulation 2009, Glasgow, July 2009. Available at http://www.ibpsa.org/proceedings/BS2009/BS09_2098_2105.pdf.

(vi) Garry Staunton, Carbon Trust

Link to presentation

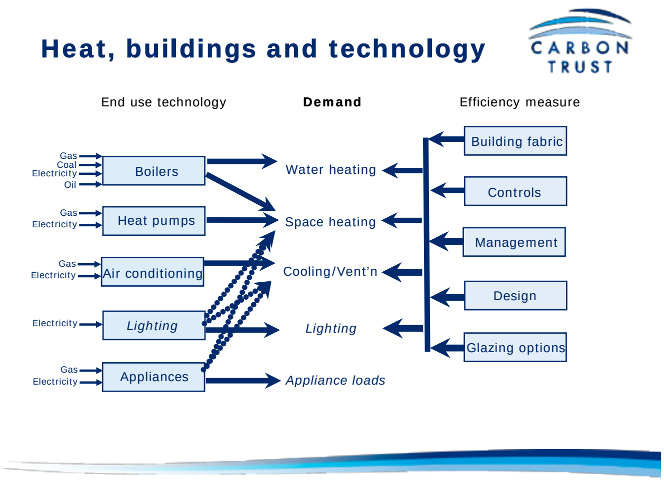
Though heat accounts for approaching half the UK carbon emissions, DUKES[6] shows that in the UK the amount of traded heat – heat for which money changed hands – is tiny:

Final energy consumption (kToe)	**Coal**	**Gas**	**Elec.**	**Heat**
Industry	1,173	11,760	10,123	692
Domestic	487	30,090	9,893	52
Public Admin	5	3,834	1,879	376
Commercial	4	3,091	6,469	9
Other	4	1,662	329	0

Behind the figures is a complex set of interlinked markets where the cost and value of heat can vary substantially. Heat can be expensive to buy or produce in financial and carbon terms, but it may also be difficult and expensive to get rid of. In considering heat technologies we should consider how to open up new markets for technologies, either to deliver what is wanted at a lower cost, or to utilise or upgrade heat which someone else does not want, which will require innovation.

One of the key elements that makes electricity different from heat is that electricity is the ultimate undifferentiated commodity at point of use. All electricity is the same, but not all heat is the same: from cooling at -25ºC through to industrial processes at 800ºC. So in considering support options it is important to consider this diffuse market structure: segmentation and targeting the technology are very important.

This diagram shows a simplified schematic illustrating how heat demand arises in the buildings sector, how this demand may be met and those 'energy efficient technologies' that could reduce demand without reducing delivered service:



That said we should not overlook wider factors. For example in the domestic sector the actual efficiency of condensing boilers, in service, can be hugely influenced by design and integration at all sorts of levels. The work that the Carbon Trust has carried out as part of its small CHP field trials shows that what can really cripple device performance, from condensing boilers through to CHP, is the return temperature. Technology performance can be at least in part a function of the plumbing in the building.

Similarly, commercial building spaces are being designed with very light thermal mass and very high solar gain which can lead to overheating, and with a rise in temperature from climate change, this will get worse and not better. The current answer to this appears to be to add air conditioning. However, in principle it is possible to better utilise what thermal mass there is and this coupled with passive design features in those structures could lead to substantial reductions in air conditioning load without loss of comfort. This is a technology challenge, but will also require a change in the market.

Lighting and appliances are not heat technologies *per se* but they generate a good deal of heat and have an impact. So one of the questions about a super-insulated house is, with just the right lighting, is a heating system required for space heating? Or does the house tend to overheat simply because it is over-lit and over-stocked with appliances?

We need to bear in mind that process development normally delivers an efficiency gain, but the efficiency goal is not always an explicit one. If this aim is made more explicit then we should be able to find more cases where designing a system efficiently does do things like finding uses for heat that are nearby.

We also need to look at how to remove heat efficiently. Perverse as it might sound, managing away high temperature heat is easier than low temperature heat. Cooling something at 80ºC can be more difficult (and expensive in terms of money and carbon) than cooling from 200ºC. A huge challenge lies in the fact that much of the available waste heat is below 100ºC.

To summarise, heat can be expensive to obtain and any you do not need can be difficult utilise, sell or dispose of. Thus there are significant innovation challenges around how we can open up new markets in addition to reducing the direct and indirect disposal costs. There many different heat-efficient technologies available, and many more are coming through. But to come through and to succeed, they have to enter a complex market which has very high entry barriers to it. Therefore, when we look at how we incentivise and develop the effective use of heat, we need to think about how to address the market challenges and the company challenges, as well as the technology challenges.

[6] "Digest for UK Energy Statistics", DECC (2007). Available at http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

3. Discussion

The discussion period was wide-ranging and provoked much debate on how heat would fit into the UK's future energy system, the role of different technologies in that system, and what policies would be required to bring about the necessary changes to meet carbon emissions targets.

The purpose was not to reach consensus positions on issues, rather to articulate what the key issues were, and the range of views that existed. A number of themes emerged which particularly engaged the workshop:

- Establishing a better understanding of how heat will be part of a future energy system, to guide development of appropriate technologies.
- There was a lack of consensus on which vectors or technologies would dominate the supply of heat in 2050, which may reflect a growing diversification away from fossil fuels after 2020.
- Implementing large scale demonstration trials of retrofit energy saving technologies to inform policy decisions.
- A general lack of high-quality data available on energy use at household level, which could be used to improve understanding of consumer behaviour, and allow the development of innovative business models and policies.
- Developing new business models, which value services (such as providing thermal comfort) rather than selling commodities, as a mechanism for delivering CO_2 savings.

The summary of the discussion below is divided into:

- *Whole energy systems*
- *District heating and CHP*
- *Business models*
- *Consumer behaviour and available data*
- *Technology development and demonstration*
- Policy

The discussion was held under Chatham House rules, so speakers are not identified.

Whole energy systems

There were views that a more centrally guided, rather than purely market-driven, approach will be necessary to deliver emissions targets.

Key points raised:

- **A clearer view of how the UK's energy system will develop is needed to deploy the appropriate technologies and stimulate innovation.**
- **It is critical to understand how heat will be managed as part of the system.**
- **More systematic thinking is needed on energy storage.**

Summary of views expressed:

- To deliver 80% CO_2 reductions in the UK, a more systematic and ambitious view as to how the future will unroll is needed. Understanding how heat will be managed as part of this system is absolutely central to all other decisions because of the interlinkages that are implied. This is particularly important in consideration of the strategy on combined heat and power, targets for the penetration of district heating, and whether to utilise heat from electricity generation. Until then, judgements on locations of power stations, and how to integrate them into the heat system, cannot be made. Furthermore, innovation will happen around a vision of a future energy system.
- Storage is an incredibly important property of any system where there is variability of demand, and variability of supply. The systematic thinking about storage in the UK has been very weak because we accepted the model of building the capacity to supply demand. As a consequence, and with very cheap energy, we have opted for the lowest possible capital conversion prices.
- To illustrate the options for storage in the system, storing close to the point of supply is good if the connection from the point of supply through the transmission system is very expensive, because then that connection can be optimised. But storage close to the point of demand is often a better solution – it allows the whole system to be used to match supply and demand and allows the overall use of storage on the system to be optimised The form of energy storage should be considered when the supply of electricity and the supply of heat are cross-connecting at different places in the system. The more expensive parts of the system should be running all the time, with some rapid load following parts to take energy from the store and turn it into a service, like a gas boiler.

District heating and CHP

The UK has a relatively low level of district heating installed. The extent to which it can have an impact in the future was much debated during the workshop, with diverse views from participants.

Key points raised:

- **Current viability of district heating schemes is limited.**
- **Though not technically difficult, large scale deployment of district heating is a challenge because of high costs and non-fiscal barriers.**
- **Gas-fired CHP still has a role to play in the short to medium term.**

Summary of views expressed:

- District heating is not a panacea, and may not be viable in low-rise buildings where too much heat is lost. Even in multi-rise, if installed incorrectly, losses can be as much as 25%. However, a heat distribution system can be an important part of what is done. Cultural barriers to heat distribution in the UK may be down to a lack of awareness.

- District heating may be expensive but is reasonable when compared to the alternatives such as solar thermal, ground source heat pumps or biomass boilers. Retrofitting existing homes with energy efficiency improvements for £20,000 to £30,000 per household is much more expensive than a district heating solution for most buildings. A renewable heat incentive would be required to stimulate deployment.
- The real issue is the cost of building heat networks in the UK due to the lack of competent contractors to install the pipe. Installation costs about £1500 a metre, of which £300 is pipe supply, £200 is pipe installing, and £1000 is to open and close the road. There is significant potemtial for cost reduction here.
- Nordic cities use heat pumps to extract heat from the waste water system into the heat distribution system. The district heating system in Copenhagen is about 30 kilometres across, and in Gothenburg heating pipes cross a major river – one of the biggest in Northern Europe – to apartments with heat losses from distribution of about 4%.
- Though gas-fired CHP may not be the long-term future, it is an enabler that is available now. Even if the grid was decarbonised through CCS, there would still be an important role for CHP by reducing the amount of electricity capacity needed for heating. Electricity for heating will be much more expensive than people are used to, perhaps by a factor of three or four by the time decarbonisation costs are added in.

Business models

Radical changes to business models in the provision of heat were seen by some at the workshop as a mechanism of delivering cuts in emissions. There was some scepticism, though, that such changes would take place, despite examples from overseas.

Key points raised

- **A business model in which the consumer buys thermal comfort as a service, rather than fuel as a commodity, could lead to a cut in emissions.**
- **However, persuading utilities to operate like this has been tried and failed in the UK. For it to succeed the whole framework would need changing.**
- **Positive returns from energy efficiency measures may not be enough to change investment priorities.**

Summary of views expressed:

- There is almost a fundamental misalignment between the societal need to cut emissions and the revenue model where gas or electricity suppliers make more money by selling more. If the model can be flipped, from having service-backed commodity suppliers to commodity-backed service suppliers, then interests between society, energy suppliers, and consumers can be aligned. This can be done by having the product in the home owned and operated by the utility, such that gas is a cost to the operation of that highly efficient device. The utility then sells a service of thermal comfort and lighting and has a direct incentive to maximise the efficiency of the device.
- Consumers hate capital expenditure, typically discounting to zero any operating cost savings. The cost of deployment needs to be done by big companies with big balance sheets, who give a proportion of the energy saving to the consumer in terms of lower overall energy bills, with the cost of the device amortised over a set period.
- A desire to change the culture of utilities to make them operate more in terms of delivering service is being expressed by policy-makers, but there is scepticism that this will actually be delivered. Government policy has been trying to turn utilities into energy service companies but they do not fit the requirement at all. They have fallen back to being essentially an efficient wholesale purchaser and a call centre.
- However, it is not clear that a different business model would emerge, even with a change in culture of utilities to providing services,and a cap on the energy or carbon emissions from supplied electricity and gas. We need to develop a new framework, and admit that we cannot decouple in a system that has no price regulation.
- There have been many business model changes in history, but time is running out to be waiting for first movers. We need to create the environment and policies that will push industries and players in the direction to think seriously about what they are actually doing for customers. Industry innovators will not do this on their own.
- There may be lessons to be learnt from other countries. In the UK, the energy services business is about 5% of the size that it is in France, where completely different organisations exist: utility companies are utility companies, and they are involved in retailing massive amounts of energy; while energy services companies run hundreds and thousands of little schemes delivering localised energy. In Ontario, almost every single gas appliance is rented to the consumer, and owned and operated by the utility.
- Even though part of the abatement curve shows positive returns from energy efficiency measures, it is giving a return which is lower than that of customary, moderate risk industries. It is not clear that society will be ready to pick up lower returns for such investment.

Consumer behaviour and available data

There was general agreement from participants in the workshop that lack of data on energy use and consumer behaviour was a barrier to making effective policy and investments in technology.

Key points raised:

- **There is a lack of reliable data on energy usage at the individual household level.**
- **Better information on household energy consumption will become more important, and provision of it will be a growth area in the future.**
- **Despite sophisticated heating controls, consumer behaviour shows high variability of energy use.**

Summary of views expressed:

- A lot of models are based on incredibly incorrect energy data. It is a systematic problem that either the data is not available, or it is not validated, or it is not available in the right form, or it costs large sums of money to access. Some available data on individual electricity consumption for a two-bedroom flat in the UK have been wildly out when compared to actual measured values. Large utility companies do not really look at the household level, it is smaller companies selling to 300, 400 or 1,000 houses that are motivated about individual house usage. In a more distributed world, with lots more transactions and smaller bits of data, then suddenly the data becomes a valuable resource. The whole system of data management, and transactional bit of energy, which historically has been pretty irrelevant, will become massively relevant, and a major opportunity for growth for the future.
- The kind of accurate, rich, granular, highly segmented data store that could be trusted would be a gold mine for many companies. The level of granularity is particularly important, because it matters whether your house faces north/south or east/west, as to whether solar thermal on the roof is possible, and it matters not per postcode but per building. A group from the Carbon Trust, the Technology Strategy Board, the Department of Communities and Local Government, the Energy Saving Trust Board, have got together and agreed that lack of data is a problem and to do something about it.
- Despite standards required in building a sustainable community such as the Greenwich Millennium Village (GMV) which has sophisticated heating controls, a lot of windows are open simply because people like fresh air. There are 1,100 homes in GMV with a heat-take average around 7,000 KWh but ranging from 4,000 to 20,000 KWh/year. We need to know what people at the high end are doing, how they are using their systems, and whether more restrictive controls are necessary.
- The energy sector needs to get more expertise in understanding customer requirements. One of the reasons why companies may provide a poor service is simply because they do not know what consumers want, and fail to measure the enormous amount of value that is being given away.

Technology development and demonstration

In this area there was general consensus on measures that needed to be taken with similar points being made by many participants.

Key points raised:

- **Large scale trials are urgently needed to demonstrate how effective technologies can be.**
- **Existing technologies will not be enough to meet emissions targets, R&D must deliver new technologies.**

Summary of views expressed:

- Serious, large scale trial applications on existing houses are needed urgently to test how far established technologies can deliver CO_2 reductions. Some believe quite strongly that existing technology will actually be nowhere near enough and that more R&D is needed to produce some new ideas and technologies, but we are still not sure which is the best way and where are the areas to put serious money. The Energy Technologies Institute, Carbon Trust, Research Councils and Technology Strategy Board must all encourage the development and deployment of new technologies in heat supply and demand.
- Housing associations could be a fantastic test bed for technologies, but Government needs to make changes to allow this to happen. We need a 'Decent Homes' mark 2 to upgrade social housing to a much higher standard. The rigid rent policy on funding for upgrading properties prevents this happening now. Demonstration pieces should be put in on the ground, so that industry and customers can become comfortable with what they see.
- The system that provides the comfortable environment for us to live in comprises of the structure of the building, the insulation, the glazing, devices to provide and distribute the heat, the ventilation, and the system to control all of the components. On the whole, each one of those technologies is supplied by a different organisation which is very keen to promote the performance of their component. There is very little information on the performance of the various components interacting with each other. There needs to be far more monitoring of existing retrofitted houses.
- There is no silver bullet: there cannot be a major technology that is not deployed, and renewables must go forward and become commercially viable.

Policy

Much of the preceding areas cover policy issues, but some other general points were raised during the workshop.

Key points raised:

- **A shared view of the best way forward is needed to reach a cost-effective solution.**
- **Long-term investment needs to be encouraged.**

Summary of views expressed:

- It is probably not a good idea just to start doing things now and assume the market will deliver, because the assets are expensive and very long-lived. The challenge is to develop a shared view about the best way forward, and to think about the implementation issues. We will not get to a cost-effective solution without having such a shared view which is based on evidence concerning economics, technology and business models.
- This is a complex scene and there is no single instrument that works in all circumstances. An interesting example is the recent decision to put a large sum of European money in place for CCS and new technology, which may be a good way to help technologies along the cost curve.
- Looking to 2050, the policies should encourage long-term investment, so that long-term investment is the current business model.

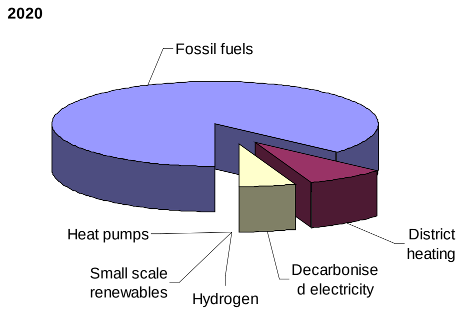
It is not economically optimal for each piece of the energy system to get to 80% reduction. With the efficiency savings alone, getting to 80% or even 60% reduction in heating on the total housing population may not be economic or practical – we are also going to need to address supply emissions.

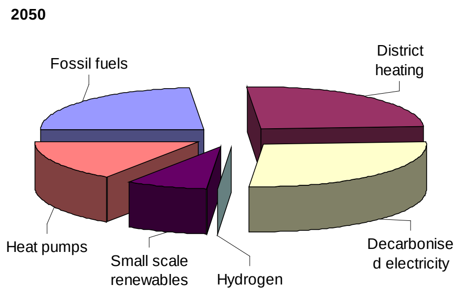
4. Questionnaire responses

Participants were asked to respond to a number of questions on heat, put at the start of the workshop, then again during the panel discussion. Though not a robust survey, it is interesting at least to note the views of more than 50 energy professionals. A selection of the responses is described below.

- The majority believed greatest improvements in the way we use heat (and to reduce associated CO_2 emissions) would come from the demand side, specifically from existing buildings (with insulation a priority). A significant minority thought that heat networks, and the use of waste heat, would deliver the greatest improvement.
- There was a consensus that fossil fuels (and boilers as the technology) would dominate heat provision in 2020. There was no such consensus on the 2050 timescale at the beginning of the workshop:

Q. What will be the dominant source of heat in the future?

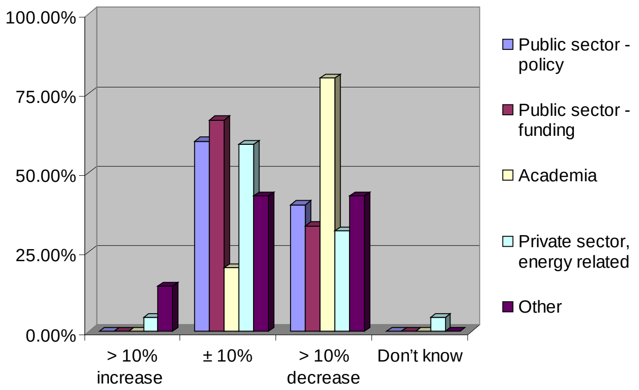




- Over the course of the workshop, opinions did change on what the dominant future source of heat would be. Those thinking that heat networks would dominate in 2050 increased from 25% to 56%. Those thinking it would be fossil fuel fell from 24% to 7%.
- Asked to prioritise areas for RDD&D funding, half voted for domestic buildings, one-third said heat networks.
- When asked what the barriers to deployment of new approaches to supplying heat were, half thought capital

expenditure, though significant minorities thought regulation and social inertia. Availability of technical solutions was not seen to be a barrier.

- There was an even split between those who believed residential emissions of CO_2 would either not change significantly by 2020, or be reduced by greater than 10%. This was strongly influenced by academics who voted overwhelmingly that there would be large reductions. Participants from the private and public sector thought (by a slim majority) there would be no change in these emissions.



5. Chair's conclusions

There is a good deal of consensus about what needs to be done in the short term with a strong focus on energy efficiency. For the existing residential housing stock there was a great deal of emphasis on the 2020 timescale.

For 2050, there was a rather different perspective. We think that things will be different, and ought to be very different, in technological terms by 2050, but there is not a consensus about what the future will look like. The weight of opinion shifted somewhat as a result of the discussion, with heat networks coming more to the fore, but there were still people who were interested in decarbonised electricity, and microgeneration was still in there.

Interestingly, that slightly contrasted with a point made by Shell in relation to their *Blueprint* scenario. Coming together to decide where you want to go has a value in itself. The trouble is that while we want a consensus we do not know which option we want to reach consensus on. That has interesting implications for organisations such as ETI, thinking about R&D portfolios.

Another theme that came through was the importance of enhancing knowledge. There is clearly a view that the heat network issue would be helped if there were more analytical thinking about what the future might hold. That type of thinking, at a systems level, is something we need to do.

In terms of knowledge, there were two further points. We clearly identified the need for better data, and to bring different types of data together. Another interesting point, which will affect people's lives over the coming decades, is that communicating that knowledge and information to wider society will be important, to get buy-in for the changes that are possible in the future.

The final point relates to regulatory frameworks, business models and institutional design and capabilities. There was a strong view that what we have at the moment is not fit for purpose if we have big ambitions for the long-term future. We may need to change the regulatory frameworks and, if they are changed, this may allow different business and service models to emerge, which was seen to be very important.

We have also identified a number of barriers that need to be dismantled. Some of the institutions and capabilities that we have are really not up for that kind of change yet. We need new skills and capabilities, and we need institutions to interact with each other in different ways. That is where there is a role for bodies like the professional institutions, such as the Royal Academy of Engineering, to take these discussions forwards.