Taking carbon out of heat

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If government targets are to be met, by 2062 all London's homes and workplaces will have been virtually zero carbon for twelve years. Currently the energy used by London's buildings is responsible for 80% of the city's carbon dioxide (CO_2) emissions. Almost 50% of these emissions arise from demand for heating and hot water. The majority of this demand is currently met through the national gas network supplying individual gas boilers in homes and workplaces. Taking carbon out of heat is also an immense retrofitting problem as around 80% of the buildings with us now will still be in use in 2050.

Learning how to do policy again

Heat is a relative newcomer to current UK energy policy making, but energy policy making itself had to be relearned after two decades when it was left to the market and a regulator whose only concern was price. It was the growing need to tackle energy security and climate change that led to a return of energy policy at the start of the 21st century. Agreeing the set of high-level objectives was a fairly quick and simple task, these being to secure supplies of energy that are:

- affordable
- secure, from diverse sources
- sustainable and low carbon.

But agreeing how to get there has been neither quick nor simple. UK energy supply is dominated by the centralised, top-down networks for electricity and natural gas supply. In the absence of supplies of 'low carbon' gas, it is easy to see why policy making has focused on mechanisms to get more large-scale, low carbon generation feeding into the grid.

At the other end of the system, policy has tackled demand for heat in new buildings through the Building regulations. For existing buildings, heat policy has been limited to obligations on suppliers to fund insulation and heating system upgrades in dwellings. This funding has been greatly

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reduced with the introduction of the 'Energy Company Obligation' (ECO) alongside the 'Green Deal' (which is a loan not a grant).

The 'all electric' detour

Given the difficulties in influencing how millions of consumers use energy, it is easy to understand why supply-based technical fixes for decarbonising heat would be so seductive. For a number of years the prevailing view among policy makers was that the optimum solution was to:

- move heating from gas to electricity – primarily by installing heat pumps
- decarbonise the electricity grid – using nuclear, carbon capture and storage (CCS) and large-scale wind.

But it gradually became clearer that a major obstacle along this route was the highly seasonal pattern of demand for heat. Around 60% of the extra electricity plant that would be required to meet winter peak heat demand would be idle for six months of the year. In addition, transmission and distribution networks would need upgrading to carry the increased loads, along with all the substations. All of these additional costs would need to be met by electricity bill payers.

It was this seasonality that was highlighted as a key issue in policy documents (in particular 'The Future of Heating' (Department of Energy & Climate Change, 2013)). But there are two further major problems facing the electric heat solution which have been more difficult to admit in policy documents:

- the performance of retrofitted heat pumps
- the rate of grid decarbonisation.

Heat pump performance in retrofits

Heat pump performance (coefficient of performance, COP) decreases with increasing temperature difference between the 'source' (where the pump gets the heat) and the 'sink' (where the pump delivers the heat). So ground source heat pumps can achieve higher efficiencies than air source heat pumps (ASHP) as ground temperature in winter is higher than ambient air. A new build property with under-floor heating supplied at around 45°C will achieve a higher heat pump efficiency than an existing building with standard radiators supplied at 75°C. For urban and suburban retrofits it will be ASHP that would be adopted (due to their smaller space requirements) supplying standard radiators. These installations would need to be accompanied by solid wall insulation (and in some cases oversized radiators) to achieve acceptable COP levels.

With solid wall insulation being too costly to be delivered by the Green Deal mechanism, a large proportion of the ECO was designed to subsidise it. Experience from most community-scale energy efficiency programmes is that take up rates are low even when insulation has been offered for free. The Green Deal has had a very slow start, and the jury is still out on whether it is attractive enough to consumers to deliver the targeted reductions in energy demand. In addition to the economic case, uptake of external cladding may well be limited by conservation areas and homeowners' aesthetics, while internal cladding is thought to involve too much hassle and loss of internal space.

Grid decarbonisation

Perhaps the most serious obstacle is that the policy milestones for grid decarbonisation are effectively being pushed further into the future by 'realpolitik'. All forms of low carbon generation involve some additional cost, and in tough economic times no government wants to be seen as loading additional costs on to consumers' energy bills. The new 'Contracts for Difference' (CfD) mechanism is designed to drive low carbon electricity generation by guaranteeing a minimum price (so called 'strike price') to generators should the market price be lower. Despite lengthy negotiations with potential nuclear developers, at the time of writing a strike price has not been agreed.

Any cost and delivery time estimates for new nuclear need to take into account the evidence from the only two new build projects in Europe. Both are vastly over budget and have been delayed by many years. With CCS yet to prove its large-scale technical and economic viability, UK electricity looks set to continue to rely on gas for many years (whether from domestic 'fracked' shale resources or imported).

Then back to the '70s... sort of

We have to decarbonise electricity, but with electricity demand itself steadily growing, it would be crazy to add to this if there were other ways to remove carbon from heat.

In all of the media and public debates about energy there has been little mention of the fact that our centralised power stations reject around two thirds of their input energy as waste heat – in total, roughly the same amount that is needed to heat all buildings in the UK. This is down to the laws of thermodynamics rather than poor design. The majority of our electricity is produced by burning a fuel to heat water into steam which then drives a turbine generator. The greater the temperature drop between the steam entering and exiting from the turbine, the greater the electricity output. So, UK plants optimise the electricity output by using cooling towers or sea water (in the case of nuclear plants) to cool the exit steam (down to around 35°C).

Following the oil price shocks of the 1970s, Denmark converted their power stations to run as Combined Heat and Power (CHP) plants and to extract the waste heat at a higher temperature (around 110°C) so that it can be used to supply city-scale district heating schemes distributing hot water to buildings. This results in a loss in electricity output from the power station, but the critical point is that you typically get seven kWh of heat for every kWh of electricity lost (a 'virtual' COP of 7). This beats all practical retrofit heat pump installations (which typically achieve a COP between 2 and 3). And this performance can be achieved without first having to insulate all those solid walls.

Over the following decades, the Danes realised further benefits from having installed these heat networks:

> **Fuel flexibility** – Hot water is distributed rather than a specific fuel (like gas), so it has been simple to switch to cheaper or lower carbon fuels. In Copenhagen, district heating covers 98% of the city, and 35% of CHP plant is fuelled by waste and biomass.
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> **Storing peak energy** – Unlike electricity, hot water can be stored easily and cheaply. Excess electricity from wind generation can be converted into stored heat when electricity demand is low.

Responding to the '70s oil crises in the UK, Lord Marshall's 1979 energy paper recommended the adoption of CHP and district heating for a number of key cities. But these initiatives were

Planning policy & regeneration	Developers required to: • connect to any existing network • consider site-wide networks on schemes • be 'network ready' e.g. provide communal wet heating system.	• Only covers new build projects • Connections always subject to viability • For 3rd party heat network developers, planning (Section 106) agreements are not 'bankable' revenues – e.g. heat supply contract not guaranteed.
Providing 'anchor' heat loads	• Offer long term agreements to purchase heat for own buildings and social housing.	• Asset disposal (most local authority portfolios are shrinking) • Transfer and outsourcing (e.g. 3rd parties responsible for energy use – e.g. Academy schools, PFI leisure centres etc).

Table 1: Tools used by local authorities.

soon lost in the flow of cheap gas from the North Sea and in gearing up the energy industry for privatisation. It has taken over thirty years for district heating to return to UK policy. 'The Future of Heating' (Department of Energy & Climate Change, 2013) includes a chapter dedicated to the role of heat networks in decarbonising heat in urban areas. The policy details for delivering these networks are expected for consultation in 2014.

How can we make it work this time?

Local government has been ahead of national government on district heating, particularly in London, where successive Mayoral administrations have strongly supported the development of heat networks. The main tools used by local authorities are set out in **Table 1**, along with some of the constraints. But the biggest threat to further action is that all this activity is optional, at a time when local government has to decide what statutory services to cut back. So there needs to be a strong national framework of support to turn feasibility studies (of which we have plenty) into real networks.

The big carbon prize is in existing buildings, but here there are no incentives or policies to drive the creation of heat networks – and they will also be competing against well established electricity and gas networks with secure regulated revenues for maintenance and replacement.

Fixing the heat off-take risk

Heat networks are capital intensive new infrastructure. In the absence of any incentives to create these networks, new district heating projects have to finance the whole system from generation plant, network and building heat exchangers, from heat and electricity revenues. Hence, most new schemes:

- are based on gas fuelled CHP as the lowest cost form of generation
- require either long-term guaranteed heat revenues (from existing building schemes), or one off connection fees to cover capital investment (in new build development schemes).

Supporting the right infrastructure in the right place

Heat networks will only be the most cost-effective solution for low carbon heat in areas with sufficient heat density. But equally, we should not be incentivising ASHP or gas micro-CHP in those same areas as this will result in higher pass-through distribution costs to customers. The worst case will be where an upgraded electricity cable, gas pipe and heat main all pass down a street but each only supply heat to a third of the buildings.

The government's emerging policies will need to address these issues, but a good start would be:

- Local authorities, together with central government, undertake heat planning and agree to designate zones where heat networks will be pursued.
- CHP/district heating receives incentives within zones identified for heat networks – individual low-carbon installations do not (e.g. heat pumps, solar, biomass, micro-CHP).
- Buildings occupied by publically funded organisations must connect to district heating where it is demonstrated to be economically viable (to compensate for the fragmenting local authority estate).
- Consider a small levy on electricity and gas networks to be used to underwrite new heat networks (the levy being based on the avoided costs of upgrading these networks to carry greater capacity for heat).

Ensuring new gas generation is CHP

It is now almost inevitable that new gas plant will be built to fill the gap between the closure of old plant and the delays in getting the new low carbon plant developed. As policy makers have viewed power stations solely from the point of view of electricity generation, use of the waste heat for district heating has not been properly rewarded because (as highlighted above) this decreases the electricity output and increases the carbon content of the electricity. Hence, this zero carbon district heat has never been on a level playing field with high carbon domestic gas boiler heat (which attracts no carbon taxation at all).

It is therefore encouraging that the government's *Future of Heating* document (Department of Energy & Climate Change, 2013) promises both to develop a new bespoke policy for CHP, and to treat our energy supply systems as an inter-related whole. But we also need to ensure that new plant is developed in proximity to heat demand (this will also reduce the electricity losses). We moved our power stations out of cities because of smog, we now need to bring them back – albeit with cleaner fuels, and technology to clean up the smoke stacks.

While thinking about London's energy future it's worth reminding ourselves what it was like fifty years ago. In 1962, Battersea power station was producing power for London while also operating as a CHP plant providing heat to London's first district heating scheme in Pimlico. Although fuelled by coal, the heat would have had a carbon content just below a condensing gas boiler. It was a great idea then, and it's still a great idea for the future.

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