Subject: Long Term Electricity development of networks.

Stuart,

Scenarios.

I have had your request for responses to the LENS work that Strathclyde are doing thorugh CHPA.
I would be grateful if you could consider running a scenario of the effect of the installation of 500kW of CHP at most local transformers on the network.
This is a small proportion of the 33GW of electrical CHP potential identified by DEFRA as being economic at public sector real rates of return.
We carried out an EST funded study that indicated that CHP connected to the LV system operated actively burning gas, but with a standby stored fuel and black start capability, offered network benefits that looked as though it will be the optimum location for CHP and for developing CHP on a planned basis in UK cities.
The was carried out with input from Edinburgh University and their network team and Ilex.
We currently estimate that 10GW of such capacity could be installed.
The standby fuel would be underground. Possibly LPG or oil.
The most important benefit is local security of heat and power supplies against terrorist attack on transmission systems or other network system failures.
Dependency on gas for the heat sector is removed in this scenario as piped heat supply systems are not fuel specific.
Voltage and power factor control for the LV system and local active management of demand with a synchronous generator are a benefit.
Release of capacity at higher voltage levels to bring in renewables such as wind and reduce reinforcement costs is a benefit.
Back up for wind and faster local load following is a benefit.
Peak load capacity close to load avoiding marginal losses on transmission and distribution of 20% plus (losses rise as square of power carried)
Connection on LV side of transformer for stability effects.
Current developments of cryogenic current limiters is seen as having the potential to deal with faults on the radial LV systems the transformer serves and for the interface between the generator and the 415 to 11kV transformers.
Ease of management of the LV network compared to multiple small asynchronous generation with poor power factor
We bid to ETI for evaluation of this option with Strathclyde, Povry, University College London and Carbon Descent with a package of work was to identify the "low hanging fruit transformers" in London such as the one at the Roupell Park Estate in Lambeth where we are installing a grant aided condensing CHP units and a heat network designed on the same principles as the heat network that was retrofitted to the city of Odense in Denmark.
We understand that ETI consider this is a matter for their strategy team to look at under Andrew Haslett, before considering aspects of our proposal and the demonstration projects and the work packages we offered to evaluate this option. After the holiday period is over we will be discussing this scenario further with ETI and also to see whether the work fits more into the building sector than the DG sector, also what sort of restructured bid would match a later call for DG submissions.
We visited the Roupell Park Estate demonstration 500kW CHP today with Caterpillar to discuss how parasitic loads might be reduced and the overall performance of thier CHP engine installed in Lambeth can be improved for CHP operation i.e. to run for short periods at 10% overload to meet half hour peak demands at the bottom of the system Caterpillar are expert on these engines and will be able to estimate the future technical improvement this size of engine offers.
At this size the engine and generator can be readily unplugged from the heat and electricity system and replaced to give high availability.
A heat network is developed across cities to be fed with heat ultimately from large scale CHP and Nuclear CHP as evaluated in Energy Paper 35 and 53.
The engine based CHP units at each transformer provide peak load power and heat and local standby.
The units would be actively managed backing each other up through the 11kV system and would be interconnected for the heat load as well as the electricity load as the heat network developed.
Current investment in renewing the low pressure gas system could be switched to investment in piped heat supplies and a medium pressure gas system retained.

This piped heat supply scenario ties in with heat from renewable sources and the likely lifetime of natural gas.
The scenario results in a cut in gas consumption of around 40% for areas connected to the system thus extending the lifetime of gas.
I attach a paper Harness this Heat published in the Building Services Journal that outlines this option and evaluates the CO2 footprints for various heat supply options and shows where the 500kW CHP fits into the overall picture from micro CHP to Nuclear CHP. We were surprised how low the capital cost per kWh or heat from Sizewell could be if we used two two metre pipes to transmit 2200MW of heat!
We put a team together to evaluate this option with ETI funding. It is possibly that the work would be more relevant for OFGEM and we would be happy to discuss our proposals with you to link in with the LENS work so I am copying this to them and also David Clarke and Andrew Haslet at ETI.

Markal

I would welcome the opportunity to discuss how your version of Markal models CHP.
From my experience of using it for the Kaliningrad region when carrying out a national energy study with AEA/ETSU/FES for thier CHP we found it could not evaluate the primary energy savings correctly in the respective heat and electricity sectors.
This was because it did not use the marginal actual fuel burn for the respective products of heat and electricity when there was a change in demand for one product when there was no change in demand for the other product.
Markal signalled a reduction in fuel burn for the electricity sector when no savings in practice arose. i.e. the fuel burn did not change in the electricity sector if you used the heat. Bit like the motor car no saving in fuel for the journey if you put your car heater on.
In work done by Neil Strachan for the Nuclear Review it showed fuel savings in the electricity sector from CHP and in the heat sector, this indicates the old Kaliningrad problem and algorithm is still in the model!
PS same problem with WASP.
William Orchard.

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HARNESS THIS HEAT

Waste heat from electricity generation could be a vast source of low- or zero-carbon heating for our cities, argues William Orchard

Is piped reject heat from electricity generation the most sustainable option for the UK? This byproduct is the UK's largest untapped resource of low- and zero-CO_2 heat. It was evaluated by government in the late 1970s and early 80s. But in recent White Papers, including the current Energy White Paper on nuclear power, city-wide combined heat and power (CHP) and piped heat supplies have not been considered.

Instead of these large systems, the government has chosen to focus on small and micro CHP systems such as a 1kW gas-powered domestic CHP unit and industrial CHP systems.

The potential of city-wide CHP systems that give the greatest CO_2 savings have been all but ignored by the government (with one recent exception: the Office of Climate Change's recent call for evidence on renewable sources of heating energy). This is a grave oversight because well-designed piped heat supplies in cities would halve the UK's requirement for gas and hence double the time taken to exhaust the country's gas reserves, reducing our national dependency on imported gas.

To understand the benefits of CHP you must first understand the principle of it. A car is a small CHP power station. In winter waste heat from the engine is piped to the heater to keep the occupants warm. The important thing is that this heat is delivered to the occupants at no extra cost for the journey and without burning any extra fuel, because it would otherwise have been wasted heating the environment.

This waste heat effectively has zero CO_2. And, while it does not reduce the fuel for the journey, it does reduce the cost and CO_2 footprint because the motorist would need to buy something else to keep warm – even if that something was a hot water bottle, some warmer clothes or a miniature boiler!

In the same way that a car's heater utilises waste heat from the engine to provide CO_2-free heat, so cities can use waste heat from major power stations to provide very low- or zero-CO_2 heat to all buildings.

DEFRA, in its October 2007 analysis of the UK potential for clean heat and power, estimates the potential for electricity generation from city-wide CHP systems is 33125MW. By using piped heat from this CHP, DEFRA estimates 159881GWh of energy can be saved a year. This level meets the UK government's CO_2 targets and all the UK electricity generation requirements without the need to build nuclear.

To get an idea of the possible savings in CO_2 per household by using the waste heat from power generation, it is necessary to understand just how much CO_2 households emit using conventional heating. The difference in the CO_2 emissions for a flat is illustrated in **Figure 1**, which compares piped heat supply from three different CHP sources compared with heat from a gas boiler and from electric heating. The impact of insulation is also shown.

The important thing to note from Figure 1 is how the benefit of insulation changes as the heat supply system changes with the CO_2 footprint of the energy source. Heat from electricity has four times the CO_2 of heat from a new gas boiler and over 20 times the CO_2 of waste heat from city-wide gas-fired generators.

An electrically heated flat, insulated to Part L of the Building Regulations, will have a far higher carbon footprint than an old uninsulated flat with an old gas boiler. Orchard and Partners London's work on a project in the London Borough of Southwark showed the insulation of flats would have cost between £2000 and £3000 per kilowatt of heat load displaced for external insulation and double glazing.

Once a building is supplied with city-wide piped heat, the low marginal cost and low CO_2 footprint of the CHP-derived heat will change the economic case for expensive insulation. As a result many conventional insulation measures, such as retrofitting insulation to the walls of pre-war domestic homes, are no longer viable.

There is a strong case to change the Building Regulations to remove requirements for minimum insulation levels and to allow designers to optimise their investment between low CO_2 piped heat and insulation. The actual CO_2 savings from piped heat depend on the fuel used for the CHP and the energy source and fuel for the alternatives (see **Table 1**).

Reduced dependency on gas

Another major benefit for consumers of piped heat is that it removes their dependency on gas (a virtually monopoly supplier to the heat sector) and they avoid costly and disruptive retrofit insulation measures. Orchard Partners London has identified a new, less disruptive and lower cost route to install piped heat supplies in cities by replacing kerb stones. This solution appears to be a practical, more sustainable, less disruptive, and less costly option for consumers than replacing gas pipes deep below the carriageway.

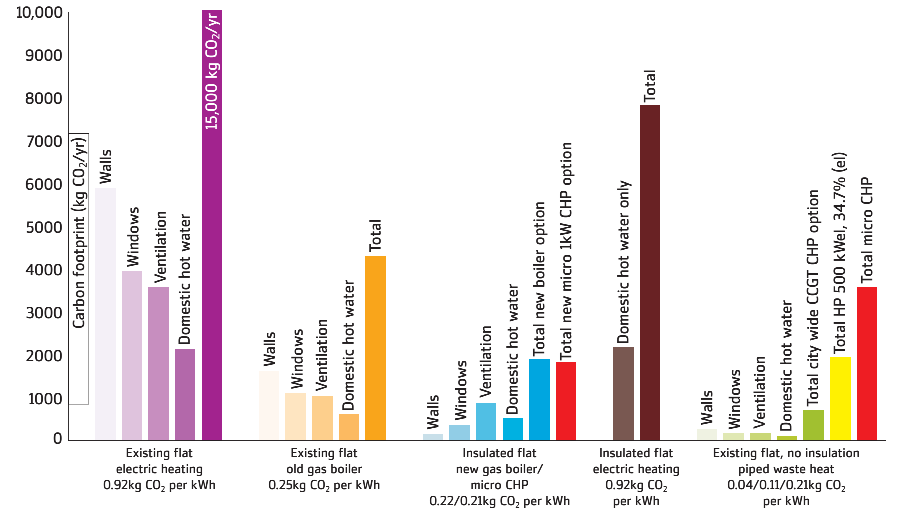
For the government, installation of piped heat could significantly reduce the carbon impact of new coal-fired power stations. On 2 January, the government gave permission for construction of Kingsnorth, the first coal-fired power station to be built in the UK for 24 years. If the waste heat from this power station was piped for use as heat, displacing the current mixture of heating and electricity from central gasfired combined cycle gas turbine and old gas domestic boilers, a city's overall CO_2 footprints would be similar. The CO_2 savings would be even greater if the government chose to make Kingsnorth a nuclear power station. However, piped heat has not been evaluated in the White Paper on nuclear power.

Claus Hojlund Rasmussen, who has designed a number of the largest heat transmission systems in Denmark, has done a back-of-an-envelope calculation for a pipeline to serve London with heat from Sizewell nuclear power station 128km along the coast in Suffolk. A 2m diameter line would carry 2200MW of heat, leaving the power station at 95°C and arriving in London at 95.1°C after picking up pump energy as heat from the pipe friction. Offset against this heat would be the pump load at 54MW and the heat loss of 30MW. The CO_2 footprint for this heat (assuming the electricity for pumping came from coal-fired power) would be 0.026kg CO_2/kWh. Whether the cost of the line would be economic is another matter.

Unfortunately the government's own statistics are compiled in such a way as to mitigate against signalling the benefit of using clean heat for the energy sector. The Digest of United Kingdom Energy Statistics (DUKES), produced for the Department for Business, Enterprise and Regulatory Reform (BERR), provides a detailed and comprehensive picture of energy production and use over the last five years.

Unfortunately, DUKES cannot be considered a sound basis for the analysis of CHP or for signalling the actual CO_2 emissions of CHP on the respective heat and electricity sectors in our national statistics. This is because it considers that any fuel burn in CHP should be shared between the two different products, electricity and the heat, in a ratio of two to one on the basis that roughly one unit of fuel produces heat and roughly two units of fuel produce electricity, as explained in chapter 6.34 of its publication. This defies thermodynamic laws, as any motorist's practical experience of using their car heater will demonstrate.

The result of the government's method of analysis is plotted in **Figure 2**. The difference between the green line and blue line in Figure 2 illustrates the flaw in the DUKES analysis. By selecting the efficiency of your car at, say 25%, you will see that, with the DUKES methodology, simply by using the heater you should halve



Notes to figure 1
The CO_2 footprint for electricity is treated as coming from coal-fired plant as this is the electricity that will be displaced when CO_2 trading becomes a reality. Then high CO_2 emitting coal-fired power stations are affected by changes in demand and may be brought on or off line as necessary. Current government calculation methods undervalue the CO_2 benefit of alternative fuel types by assessing the benefit against gas-generated electricity. The CO_2 footprint for heat from CHP in the table follows the convention that the fuel burnt for electricity consumers, its CO_2 footprint and costs all stay the same when the reject heat is used or wasted. Note: the greater the electrical efficiency of the CHP unit the greater the CO_2 savings for the heat. As you insulate and double-glaze a flat, the fabric heat load illustrated by walls and windows reduces. This does not affect the heat used for domestic hot water and ventilation.

Figure 1: Carbon footprint of the Roupell Park Estate flats in south London

Table 1: CO_2 footprints of different heating systems

Central heat and energy supply options to housing stock electricity, gas, piped heat and hot water [kg/CO_2/kWh] | **Savings in dwellings from piped heat supply compared to different local production [kg/CO_2/kWh] heat sector**

Heat supply options Gross or higher CV basis	kg/CO_2/kWh per unit of energy	Energy Average loss %	CO_2 Average loss kg	kg/CO_2/kWh Energy delivered	Old gas boiler 75%	New gas boiler 86%	Electric heat coal 36%	Electric heat CCGT 48%
Electricity by wire from renewables wind/solar coal fired plant displaced	0.010	10	0.001	0.007	NA	NA	0.914	0.430
Piped urban heat biomass CHP	0.066	20	0.013	0.079	0.175	0.143	0.841	0.358
Piped urban hot water heating from nuclear-fired CHP	0.003	20	0.001	0.004	0.251	0.218	0.917	0.433
Electricity from nuclear	0.010	10	0.001	0.011	NA	NA	0.909	NA
Piped urban hot water heating from gas-fired CCGT CHP	0.033	20	0.007	0.040	0.215	0.182	0.881	0.397
Piped urban hot water heating from coal-fired CHP	0.066	20	0.013	0.079	0.175	0.143	0.841	0.358
Piped heat, CHP 500kWel 34.7% (el) 86% overall efficiency gas	0.103	10	0.010	0.113	0.141	0.109	0.807	0.324
Heat micro CHP 1kWel 6% (el) 86% overall efficiency	NA	NA	NA	0.212	0.043	0.010	0.708	0.225
Wood as a fuel	0.340	NA	NA	0.340	NA	NA	NA	NA
Heat from biomass and wood treated as sustainable (part L)	0.025	20	0.005	0.030	0.225	0.192	0.890	0.407
Gas as fuel	0.191	2	0.004	0.195	NA	NA	NA	NA
Old gas boiler	NA	NA	NA	0.255	NA	NA	0.665	0.182
New condensing gas boiler	NA	NA	NA	0.222	0.033	NA	0.698	0.215
Coal as fuel	0.301	NA	NA	0.301	NA	NA	NA	NA
Electricity from gas 48% & CHP	0.397	10	0.040	0.437	NA	NA	0.483	NA
Electricity from coal 36% & CHP	0.837	10	0.084	0.920	NA	NA	0	NA

Notes to table
The footprint for biomass is treated in two different ways: first using a figure from Part L of the UK Building Regulations (for England and Wales); secondly using a figure based on the actual CO_2 footprint of dry wood, because wood has a CO_2 footprint similar to, or higher than coal. Also, conversion efficiencies of wood to electricity and heat tend to be lower than for coal unless wood is co-fired with coal.
The figures in the table for piped heat from coal and nuclear reflect government figures in Energy Papers 20 35 and 53 but are based on flow and return temperatures for the city wide heating at 90°C /45°C.

the fuel for your journey from 4 units to 2.

DUKES was used as part of the government's energy modelling system in the recent Nuclear White Paper. The BERR carbon abatement curve must have used similar principles, as a saving is shown for micro CHP in both the heat and electricity sectors when in practice CHP can only give a saving in the heat sector.

A further major problem with government information is that it fails to present the savings from CHP, which can mislead decision makers.

The percentage savings of CO_2 or fuel from the use of CHP are very different depending on whether you calculate the savings as a percentage of units of electricity added to units of heat (a combined saving across two quite different sectors), or the percentage saving for electricity and heat as separate entities and sectors.

For example: if a small amount of heat is taken from any power station's cooling towers to heat a greenhouse, this would give a 100% saving in the heat sector because you would not need any fuel for heating. But if this system is presented as a saving for the electricity and heat sectors added together, heating a greenhouse from a 1000MW power station gives such a small percentage saving for the heat and electricity sectors the benefit is negligible.

This comparison of the methods is illustrated in **Figure 3**. The green and blue lines reflect the allocation to each sector in line with thermodynamic principles of the fuel burn for respective products. The orange shows line shows the saving across the two sectors added together.

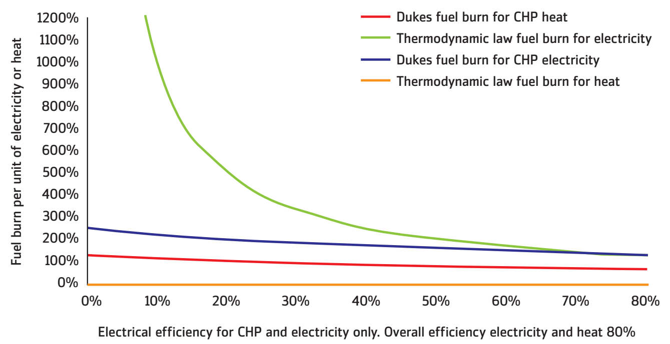
Despite DUKES failings, the government has recognised the benefit of using reject heat and provides incentives to promote CHP. However, these incentives need improvement if potential CO_2 benefits from CHP are to be realised.

The current incentive is on the production of electricity, which becomes exempt from the climate change levy. The incentive reflects the fact that there is an increase in the fuel burnt by a steam turbine serving a large city-wide scheme because the unit's heat needs to be produced at a temperature high enough for space heating. However, since domestic consumers do not pay the climate change levy, suppliers of CHP heat and electricity over their own "pipe and wire systems" get no incentive under this system. This puts local authorities trying to utilise CHP at a severe disadvantage

Opposition to city-wide CHP

Despite its obvious cost, security of supply and environmental advantages, the piped heat supply option is opposed by the gas and electric utilities. Piped heat is not in their commercial interest since current rules mean both suppliers lose sales and revenue when piped heat is installed.

In the city of Odense, Denmark, piped gas supplies have been abandoned after the installation of a piped heat system. The large city-



Notes to figure
The overall common efficiency for heat and electricity production was assumed to be 80%.

Figure 2: Graphic representation of the government's CHP analysis

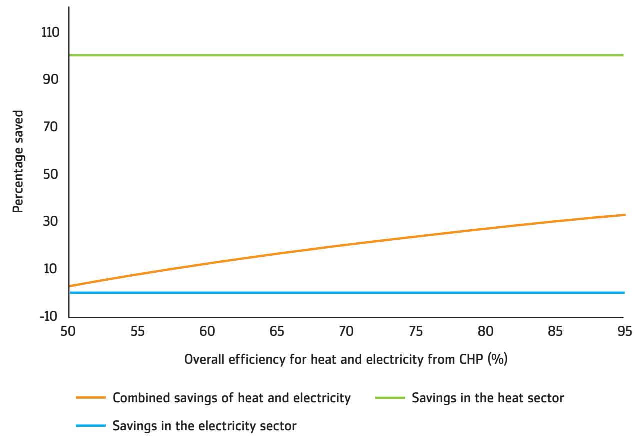


Figure 3: Savings in fuel from use of CHP

wide CHP system uses gas, coal or oil. Most houses and buildings are connected to the piped heat supply and, as a consequence, the buildings have had the lowest cost heat in Denmark for many years.

In a study funded by the Energy Saving Trust a few years ago, Orchard Partners London identified what it considers to be the optimum way to achieve UK CO_2 targets by retrofitting cities with piped heat from local 500kWe electricity generators. These would be sited at each local electricity transformer supplying low voltage electricity and using their waste heat to serve about 500 houses. They could be designed in such a way that they continue to supply electricity and heat to residents even when central gas or electricity supplies fail. The current medium and high pressure gas pipes would be retained to serve the local 500kW CHPs, initially with natural gas and at some future date with biogas.

There is an excellent case now to benefit consumers with piped heat supplies: £5 billion of their money is to be spent replacing dilapidated local gas infrastructures. This money would be better spent if both electricity and gas utilities became city-wide heat supply utilities. This system would allow them to obtain better value from the fuel they import and to enter into interruptible and lower cost electricity and heat supply contracts, because they would have the ability to switch readily from one fuel to another to play the market as they do in Odense. Such a strategy will ensure a continuing role for utilities as heat suppliers when gas is no longer available or cannot be purchased at a reasonable price.

This solution will also be beneficial for all renewable energy generation, particularly wind. Numerous 500kW CHP units at every substation, generating electricity locally, free capacity in the high voltage transmission and distribution system. These local CHPs can change their operation: generating electricity at times when the wind does not blow and, when the wind blows too hard, converting this electricity to heat which can be stored.

Piped heat supplies have an enormous potential. The Office of Climate Change's recent call for evidence is an encouraging sign that at last government is starting to recognise the importance of the heat sector and the role CIBSE can play in the development of piped heat supplies to cities. It is important they act fast – piped heat systems could help the UK meet its electricity and CO_2 commitments, without the need for expensive nuclear power. ■

William Orchard is a director of consulting engineers Orchard Partners London. He was the first chairman of the Combined Heat and Power Association and acted as adviser to the Select Committee on Energy in the 1980s.