OPTIONS FOR DELIVERING CARBON REDUCTIONS IN THE HEAT SECTOR IN SCOTLAND

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ClimateXChange commissioned this brief early in the preparation of the second Report on Proposals and Policies. Its purpose was to help frame questions and lines of enquiry. The brief was produced to very tight deadlines as an input to thinking in this initial phase.

Introduction

This analysis was provided by the Fraser of Allander Economic Research Institute at the University of Strathclyde in 2012 to assist development of the Scottish Government's second Report on Policies and Proposals - specifically in relation to opportunities to reduce emissions from the heat sector in the period 2023 to 2027.

Achieving reductions in carbon emissions in the heating sector will depend on the following:

- the production of low carbon heat
- infrastructure that allows the efficient delivery of renewable heat to customers;
- improved efficiency in heat use
- decarbonising existing heating systems;
- significant customer take up of lower carbon heating options.

All these aspects need to develop in parallel, in ways that support each other, in order to achieve a balanced and effective low carbon heat market.

The report below analyses some of the main opportunities in Scotland. In the time available this review is high level and further work is suggested in a number of areas.

The Fraser of Allander report for the Economy, Energy and Tourism Committee's Inquiry into the Scottish Government's Renewable Energy Targets has already analysed potential for renewable heat production under a number of scenarios (see Annex A). It concluded that the most likely outcome under current market conditions was 6% to 7% renewable heat production by 2020. Key constraints on renewable heat production are the current subsidy regime for renewable energy which acts to favour electricity over heat production, a policy in favour of indigenous biomass, and low gas prices relative to electricity prices.

In addition to the opportunities listed in Annex A the main additional opportunities assessed for reducing Scottish heating related carbon emissions are:

Opportunity	**Million Tonnes CO2 reduction**	**Percentage reduction in total Scottish carbon emissions at 2022**	**Cost**
Waste heat from power stations and Grangemouth	3.2	8.5%	£hundreds of millions
Gas fired district heating in urban areas (56% of Scotland's population – 1.3 million households)	2	5%	£7billion to £8.5 billion
Improve the efficiency of the gas grid	0.2	0.5%	Not assessed
Waste to gas	0.6	1.6%	~£1 billion

It should be noted that care is needed not to "double-count" some of the carbon savings – for example –waste heat savings overlap with those counted for urban district heating.

This report has not analysed carbon saving opportunities linked to improving building energy efficiency. This would be expected to offer very significant energy savings – but at substantial cost in many of Scotland's buildings. The report has also not analysed the opportunity to recover and reuse heat from large numbers of smaller public, commercial, and industrial facilities across Scotland as acquiring the data for this analysis would require a much larger research project.

Scottish targets

The Scottish targets for reducing carbon emissions from heat are formulated in ways that do not necessarily help the development of joined-up policy in this area. The first is an 11% renewable heat target, the second a target to reduce emissions from non-electrical heating. These targets tend to push policy makers to see heat demand and possible solutions in a fragmented way – leading to exclusion from consideration of the electrically heated sector, and pushing policy away from low carbon heat solutions and towards renewable heat solutions. Examinations of successful strategies in other countries suggest that a holistic approach to the heating sector is more likely to support significant low carbon transition – as different technologies and shared infrastructure act to support each other, so a move to a low carbon solution (eg gas-fired CHP based district heating) can act to support a longer term shift to very low carbon solutions in the future.

Existing UK policies

The current assessment of the impact of UK energy policies in Scotland supplied by Scottish government is based on a simple pro-rata calculation to produce projected carbon savings in Scotland. Differences in the composition of housing stock, patterns and types of energy consumption, social and economic structures, could lead to this projection being inaccurate to some degree. Assessment of whether these inaccuracies are likely to be significant would require a detailed review of the UK model and its underlying assumptions.

Market Take-Up

Gas can be expected to continue to dominate the heating market in the areas of Scotland on gas-grid for the foreseeable future as for most consumers it will remain cheaper and more convenient than alternatives. Domestic and commercial consumers are unlikely to choose to switch from natural gas to electricity, or other sources of heating, unless it is cheaper and more convenient. These are important factors to consider in the design of low carbon heat policy and systems.

Main opportunities

A number of opportunities have been identified below and potential carbon savings calculated for these. These calculations should be treated as broad estimates at this stage.

Waste heat from power stations and Grangemouth

Thermal power stations typically operate at efficiencies ranging from 33% to 50% - rejecting very large amounts of heat as warm water. Three power stations are sufficiently close to large urban areas to be of interest as potential low carbon heat sources (Hunterston, Longannet, and Cockenzie). Peterhead has much lower heat demand in the surrounding area and has therefore been excluded. The Scottish Government already commissioned a study from AEA "A study into the recovery of heat from power generation in Scotland" which examined these opportunities. The assumptions used in the AEA report are unambitious in some aspects – for example, the maximum distance for a district heating pipe is assumed to be 30km. Longer distances are possible (with higher costs and reduced efficiency) and this is important in a Scottish context as slightly longer distances bring Longannet, and Grangemouth within reach of all Scotland's major central belt urban communities, including Glasgow. Cockenzie has the most favourable location due to its proximity to Edinburgh. The estimated amount of waste heat available from these facilities is estimated below.

Site	Estimated recoverable heat per annum[1] GWh	Estimated heat deliverable to customers GWh	Carbon emission reduction (Million Tonnes) vs gas-fired central heating[2]
Longannet	12,000	10,200	2.2
Cockenzie	3,200	2,720	0.6
Grangemouth	2,000 [3]	1,700	0.4

[1] Assumes 60% of waste heat is recoverable
[2] Assumes 0.19Kg CO2/KWh and 85% efficient gas-fired central heating = 0.22Kg/KWh heat or 220 tonnes CO2/GWh
[3] This a rough estimate based on Grangemouth's carbon emissions – but a more detailed study is required to assess this opportunity in reality.

Total	17,200	14,620	3.2 Million tonnes

Assuming that this heat could be delivered and would be consumed by customers, and assuming district heating system losses at 15%, the waste heat supplied from these 3 facilities could potentially meet around 25% of Scotland's heating needs. The total carbon reductions are estimated at 3.2 Million tonnes (assuming that gas-fired central heating is the heating method replaced, and that waste industrial heat is considered to be zero carbon). This equates to a reduction of around 8.5% (as compared to Scotland's 2022 CO_2 emission target of 38.2 million tonnes CO2 emissions).

In reality the key issues will not be the production of waste industrial heat – but ensuring delivery of heat to customers and ensuring market take-up. Achieving this level of heat delivery will require a pervasive, large scale heat delivery system across the central belt of Scotland. Delivering such a system would require major long-term political support – and given the opportunity to deliver lower cost and lower carbon heat to millions of individuals, businesses, and public organisations this may be achievable. We recommend that in order to achieve political and public support the price of heat delivered is pegged below the price of gas. Justifying this major investment also assumes that large scale thermal power stations will be based in these locations for at least 25 years ahead – but given the investment plans of power generators this appears to be entirely realistic.

The AEA study estimates the costs of restricted networks to deliver heat to key anchor loads within a 30km radius as below.

Table 24 Summary of Capital Costs

Power Station Site	Capital for Scenario 1 (100% heat load)	Capital for Scenario 5 (25% heat load)
Peterhead	£21,553,652	£14,556,094
Hunterston	£71,620,175	£42,617,061
Cockenzie	£168,955,127	£66,146,610
Longannet	£99,948,433	£52,531,952
Total	**£362,077,387**	**£175,851,717**

It is important to note that AEA's costs are not based on the costs of delivering a district heating network that would be capable of delivering to all the necessary customers the full waste heat potential of Longannet, Cockenzie and Grangemouth. A new study would be needed to calculate the costs of the different system proposed – but it should expected that the costs of the system would run to several hundred million pounds.

We do not suggest that the full costs of connecting every customer required to the district heating system are met centrally – rather that the Scottish Government underwrites the costs of creating the backbone of a central belt district heating system that would be capable of delivering heat from the three facilities identified to the central belt's main urban settlements, and core district heating systems in these main settlements.

The AEA study notes that without the equivalent of a Danish heat law, or major public subsidy/financing (such as waste industrial heat qualifying for the equivalent of the RHI); the proposed systems are unlikely to be successful in attracting interest from private investors. In our view this is an accurate assessment.

A further issue that should be noted is the technical/commercial risk created by systems that are reliant on a small number of suppliers and customers. Larger systems offer greater technical efficiency, reliability, and reduced financial risk. We would therefore suggest that district heating systems are created that link multiple heat suppliers and consumers in order to reduce risk. This is effectively the model used successfully in Denmark – which uses waste heat from power stations as one element of a wider range of heat suppliers.

Based on analysis of successful district heating systems we recommend the following measures to support the development of district heating and use of waste industrial heat in Scotland:

- Allocate up to £5 million for detailed technical and financial feasibility studies for large scale strategic heat pipes and district heating systems
- Create a national expert team to drive forward a small number of strategic district heating projects in the central belt. These projects are too large and too novel (in Scotland) to be developed by individual local authorities.
- Create the equivalent of a Danish Heat Law to guarantee revenues and enable private investment to be raised.
- Ensure the Heat Law is implemented in the required areas
- Allocate around 10% of project costs (say £50 million) as risk capital from public funds to promote heat pipe construction in urban communities
- Create a district heating financing mechanism to provide the remaining funds required – potentially around £600 million (seeking to raise 90% of costs from private finance, EIB, public bonds, pension funds, sovereign wealth funds etc)
- Make designated large scale industrial waste heat projects eligible for a support mechanism similar to the Renewable Heat Incentive
- Reduce financial risk and build customer and supplier trust by creating a district heating authority that will operate the main district heating pipes, buy and sell heat, guarantee quality of service and ensure good governance/sound regulation for customers and suppliers

The table below indicates a potential timeline for delivery – with the potential costs and carbon savings associated with each phase of delivery. The assumed phasing of the project is as follows:

- 3 years feasibility study and project design
- 4 years procurement, planning, and consents
- 4 years construction of main heat pipes

- 3 years connection of heat consumers.

It would be possible to run some of the construction and connection phases of work in parallel and compress overall timescales if necessary.

Projected Carbon Savings by year for waste heat from Longannet, Cockenzie and Grangemouth

Year	2012 2015	2016 2019	2020 2023	2024	2025	2026	202 7	2028	2029	2030
Phase	Study and design	Procurement and planning	Main heat pipe delivery	Customer connection	Customer connection	Customer connection				
Cost £m	5	25	250	150	150	100	0	0	0	0
Annual CO2 saving M Tonnes	0	0	0	1.1	2.2	3.2	3.2	3.2	3.2	3.2

District Heating in Urban Areas

District heating tends to have lower capital and operating costs and produce better technical and financial performance in dense urban areas with high heat demand. In order to give a rough estimate of the potential carbon saving that could be delivered from implementing gas fired CHP in urban areas we have examined the option of delivering district heating to all urban settlements in Scotland with a population over 40,000 (see list at Annex B). These settlements make up 56% of Scotland's population.

District heating can allow a broader mix of low carbon heating options to be adopted and low carbon heat to be distributed effectively to a much larger proportion of buildings. Initially we would expect these district heating networks to be fuelled using a mix of gas-fired central heating; industrial waste heat; and waste to energy facilities. Post-2023 (or thereabouts) a gradual shift phasing out gas-fired CHP in favour of large scale heat pump facilities can be expected to deliver greater carbon savings. However the economics of this shift will depend on the relative pricing of gas and electricity; the performance of heat pumps; and consumer attitudes to heat prices. We have not conducted a sophisticated analysis at this stage which would cover a number of fuel supply and district heating scenarios (we would recommend this for a future stage of activity).

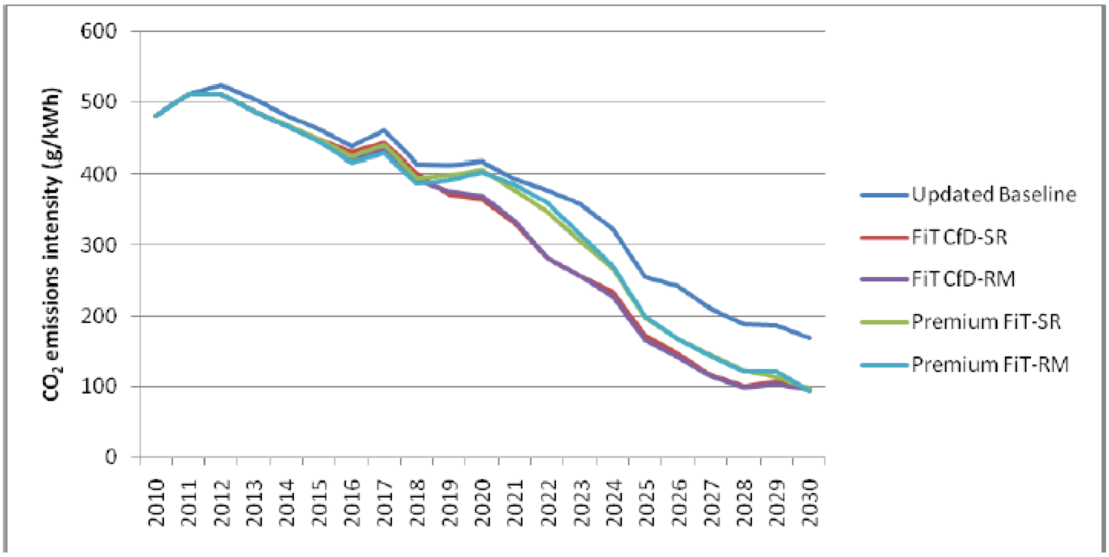
We estimate carbon savings in the region of 2 Million tonnes CO2 in 2022 – however this assumes all heating is provided from gas-fired CHP units and that all consumers are currently using high efficiency gas-fired central heating boilers. In reality we would expect other low carbon heat sources to contribute to supplying such an extensive district heating system and this will tend to produce higher carbon savings. It is also true that a proportion of these consumers are using higher carbon electrical heating – this will also tend to mean higher carbon savings. We would recommend a more in depth analysis of potential carbon savings. Based on a number of previous major district heating projects we estimate the costs of delivering district heating to all buildings in the urban settlements identified as lying in the range £7 billion to £8.5 billion.

The carbon savings estimated will overlap with the option above of using waste heat from power stations in the central belt. Around 25% of the households that we have defined as urban are in communities we believe are unlikely to be served by waste heat from power stations (due to lower population concentrations more distant from the main pipe runs).

Extension of Gas grid

Around one third of Scotland is not on the gas grid. Consumers off the gas grid in Scotland are predominantly reliant on electricity for heating, with some use of LPG, fuel, oil, and biomass. As result these consumers incur much higher costs for heating and have much higher carbon footprints at around 0.5kg CO_2/KWh for electricity consumed as against 0.19 kg $CO_{2/}$ KWh for gas consumers. In theory therefore a significant carbon saving can be made moving electricity consumers to gas. However the figure below shows that by 2027 UK government expects the carbon intensity of electricity to be comparable to gas (or lower). If these estimates are correct significant extension of the gas grid to reduce carbon emissions in the longer term does not appear to be a viable option (though significant carbon savings are available out to around 2025, and the need to tackle fuel poverty is likely to act as a continuing driver for gas grid extension). We have therefore not considered this option further.

Figure 25: Decarbonisation trajectory to 2030 - central price assumptions



Source: EMR Redpoint analysis

Heat Pumps

Studies[4] suggest that many heat pump installations do not currently offer significant carbon savings over conventional gas central heating. There are significant carbon gains for consumers using electrical heating in areas off-gas grid but high capital costs act as a major barrier to widespread adoption.

Adoption of heat pumps in relation to gas becomes significantly more attractive in carbon reduction terms once the carbon emission factor drops below around 0.37 kg CO2/KWh (DECC suggests this will be achieved post 2023) as this starts to offer reasonable carbon reductions (ie CO2 savings in excess of 10%) even at the relatively poor performance experienced by many heat pump users (a COP of around 2.2). However the current

[4] Getting warmer: a field trial of heat pumps – Energy Saving Trust – September 2010

relatively high capital and running costs of heat pumps are unlikely to make them an attractive proposition for consumers in locations where gas is available (unless significant subsidies are available for heat pumps). Adoption of heat pumps in areas off gas grid is also likely to remain poor unless capital costs come down. Given performance issues with heat pumps we suggest establishment of an independent facility that will assess heat pump performance in realistic scenarios. Should significantly improved heat pump performances be identified this might provide a case for greater and earlier public support for heat pump adoption.

It is important in this context to note that low temperature geothermal energy in Scotland (eg use of mine water) relies on heat pumps to deliver temperatures useful for heating buildings and water for washing. Given the generally poor performance of heat pumps in practice careful assessment is needed of these opportunities before any expectation of large scale low carbon heat from geothermal energy is created. We would recommend that a small scale test facility for testing this type of opportunity should be created as a part of the testing facility proposed above – allowing different heat pumps to be tested side-by-side, over time, with realistic demand variation and environmental conditions. Efficient and reliable heat pumps could have a major role in Scotland's low carbon future – but the case for their adoption is likely to be much stronger in 10 years time – when lower carbon electricity could make the case for their wide spread adoption far more attractive, and district heating systems could significantly increase the ability to deliver low carbon heat to a much wider range of buildings.

Decarbonisation of the gas grid

Electricity to Hydrogen Gas Grid Injection

Where surplus renewable electricity is available (ie "surplus" in the sense that it cannot be consumed locally and cannot be supplied to the grid due to constraint issues) conversion to hydrogen, and then injecting that hydrogen into the gas grid, could be used as a means of reducing carbon emissions. Note: there is no point in converting electricity to hydrogen for gas grid injection in circumstances where the electricity can be consumed directly as electricity as this delivers higher carbon gains (or alternatively use of hydrogen as a transport fuel). The gas grid will normally tolerate up to 20% hydrogen in the gas mix without any adjustment of devices consuming or handling the gas mix.

Analysis of constraint payments in 2011 shows windfarms in Scotland were paid by the National Grid not to generate 58,708 MWh. If this amount of electricity were converted to hydrogen at 70% efficiency and injected to the grid this would produce a carbon reduction of around 0.02%. If significantly higher amounts of renewable electricity were available (and that electricity had no better use displacing higher carbon fuels) then this option might be worth reassessing but appears unlikely to make much impact in the near term.

Reduce methane leakage from the gas grid

DECC estimates that the UK gas grid is responsible for methane leakage that is the equivalent of around 4.2 million tonnes CO2 per annum. At the time of writing we do not have separate figures for Scotland but will assume a pro-rata basis that in 2022 leakage will represent around 1% of Scottish carbon emissions. A programme to reduce gas leakage by 30% would therefore deliver a 0.3% reduction in total Scottish carbon emissions. Given the relatively small reduction we have not analysed this option further – but this is a rough estimate and given the significant gas infrastructure in Scotland opportunities might be rather larger than this.

Improve the efficiency of gas grid performance

Operation of the gas grid consumes a significant amount of energy (perhaps equivalent to 4% to 6% of gas transmitted) for compression and pumping. If we assume 30% improvement in the performance of the grid this would perhaps equate to a reduction in CO2 emissions of around 0.2 Million tonnes CO2 per annum – or a reduction in total Scottish emissions of around 0.5%. However this a rough estimate and the amount of significant gas infrastructure in Scotland could mean that opportunities are rather larger than this. We recommend discussions with National Grid to examine whether a more significant opportunity is available.

Production of low carbon methane from waste for gas grid injection

The National Grid estimates that methane produced from anaerobic digestion of waste could deliver between 5% and 18% of UK gas needs [5] at a cost £30 billion to achieve the upper end of this range (so a cost of £3 billion might be estimated for Scotland). Achieving the higher figure would require a significant transformation of Scottish waste handling infrastructure and behaviour (eg every household and business would need to sort its waste appropriately). The 5% figure should therefore perhaps be seen as a more realistic prospect (and a cost of £1 billion for infrastructure assumed). This would equate to a reduction of around 0.6 Million tonnes CO2 emissions – or around a 1.6% reduction in total Scottish CO2 emissions against the 2022 target.

Achieving commercial investment in biogas would require significant public subsidy (estimated as comparable to around 1.5 ROCs per MWh). At the moment the significantly higher subsidies available for renewable electricity tend to result in almost all biogas being used for electricity generation. The relative levels of incentives for heat and electricity would need to change if there is to be significant market adoption of this technology.

[5] The potential for Renewable Gas in the UK – National Grid – January 2009

ANNEX A: SCENARIOS FOR FUTURE RENEWABLE HEAT PRODUCTION IN SCOTLAND

	Existing biomass energy facilities	Heat yield from new industrial biomass facilities	Heat yield from domestic biomass facilities	Heat yield from waste facilities	Existing heat pumps	Assumed additional heat pump penetration	Imported biomass energy facilities	Total
Scenario 1 all new biomass used for heat, 25% municipal waste used for heat only	2.56%	6.51%	0.69%	1.53%	0.12%	0.58%	0%	**12.0%**
Scenario 2a 80% electricity production in large (over 1MW) biomass facilities using indigenous biomass. 65% electricity production in waste facilities	2.56%	1.30%	0.69%	0.77%	0.12%	0.58%	0%	**5.8%**
Scenario 2b 60% electricity production in large (over 1MW) biomass facilities using indigenous biomass.	2.56%	2.60%	0.69%	0.77%	0.12%	0.58%	0%	**6.9%**
Scenario 3a An additional 3 energy plants using imported biomass with 56% electricity production and 80% electricity production in other large (over 1 MW) energy facilitiesusing indigenous biomass.	2.56%	1.30%	0.69%	0.77%	0.12%	0.58%	3.4%	**9.2%**

Scenario 3b An additional 3 energy plants using imported biomass. 60% electricity production in large (over 1 MW) energy facilities using indigenous biomass.	2.56%	2.60%	0.69%	0.77%	0.12%	0.58%	3.4%	**10.2%**
Scenario 4a An additional 5 energy plants using imported biomass. 80% electricity production in large (over 1 MW) energy facilities using indigenous biomass.	2.56%	1.30%	0.69%	0.77%	0.12%	0.58%	4.1%	**9.9%**
Scenario 4b An additional 5 energy plants using imported biomass. 60% electricity production in large (over 1 MW) energy facilities using indigenous biomass .	2.56%	2.60%	0.69%	0.77%	0.12%	0.58%	4.1%	**11.0%**
Scenario 5a 0.8 million odt net additional wood fuel. 80% electricity production in large (over 1 MW) energy facilities using indigenous biomass. 3 energy plants using imported biomass	2.56%	0.87%	0.46%	0.77%	0.12%	0.58%	3.4%	**8.5%**
Scenario 5b 0.8 million odt net additional wood fuel. 60% electricity production in large (over 1 MW) energy facilities using indigenous biomass. 3 energy plants using imported biomass	2.56%	1.74%	0.46%	0.54%	0.12%	0.58%	3.4%	**9.4%**

Scenario 6a An additional 5 energy plants using imported biomass. 0.8 million odt net additional wood fuel. 80% electricity production in large (over 1 MW) energy facilities using indigenous biomass.	2.56%	0.87%	0.46%	0.54%	0.12%	0.58%	4.1%	**9.2%**
Scenario 6b An additional 5 energy plants using imported biomass. 0.8 million odt net additional wood fuel. 60% electricity production in large energy facilities (over 1 MW) using indigenous biomass.	2.56%	0.87%	0.46%	0.54%	0.12%	0.58%	4.1%	**10.1%**
Scenario 7 Net additional indigenous wood fuel 0.6 ODT. Lower take-up of biomass heating in the domestic sector (90% industrial: 10% domestic). Low take-up of heat pumps in areas where gas is available. 80% electricity production in large (over 1 MW) energy facilities using indigenous biomass.	2.56%	0.73%	0.17%	0.54%	0.12%	0.12%	0%	**4.2%**
Scenario 8 As scenario 7 – but with an additional 5 imported biomass energy facilities.	2.56%	0.73%	0.17%	0.54%	0.12%	0.12%	4.1%	**8.3%**

ANNEX B: URBAN SETTLEMENTS

Name	2008 Population Estimate
Glasgow, Settlement of	1,184,350
Edinburgh, Settlement of	476,660
Aberdeen, Settlement of	195,530
Dundee, Settlement of	152,320
Falkirk, Settlement of	98,940
Dunfermline, Settlement of	78,550
East Kilbride	73,200
Greenock, Settlement of	69,800
Hamilton, Settlement of	68,770
Livingston, Settlement of	63,160
Ayr, Settlement of	60,880
Inverness, Settlement of	56,660
Cumbernauld	50,480
Kirkcaldy	48,630
Glenrothes, Settlement of	47,280
Stirling, Settlement of	45,750
Perth	44,820
Dumbarton, Settlement of	44,650
Kilmarnock	44,390

From an initial assessment the urban settlements high-lighted in yellow are those we believe are most likely to offer the best possibility of being supplied from waste heat from power stations.