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Assessment of Combined Heat and Power Opportunities at Wylfa Newydd Power Station

Horizon Nuclear Power Ltd

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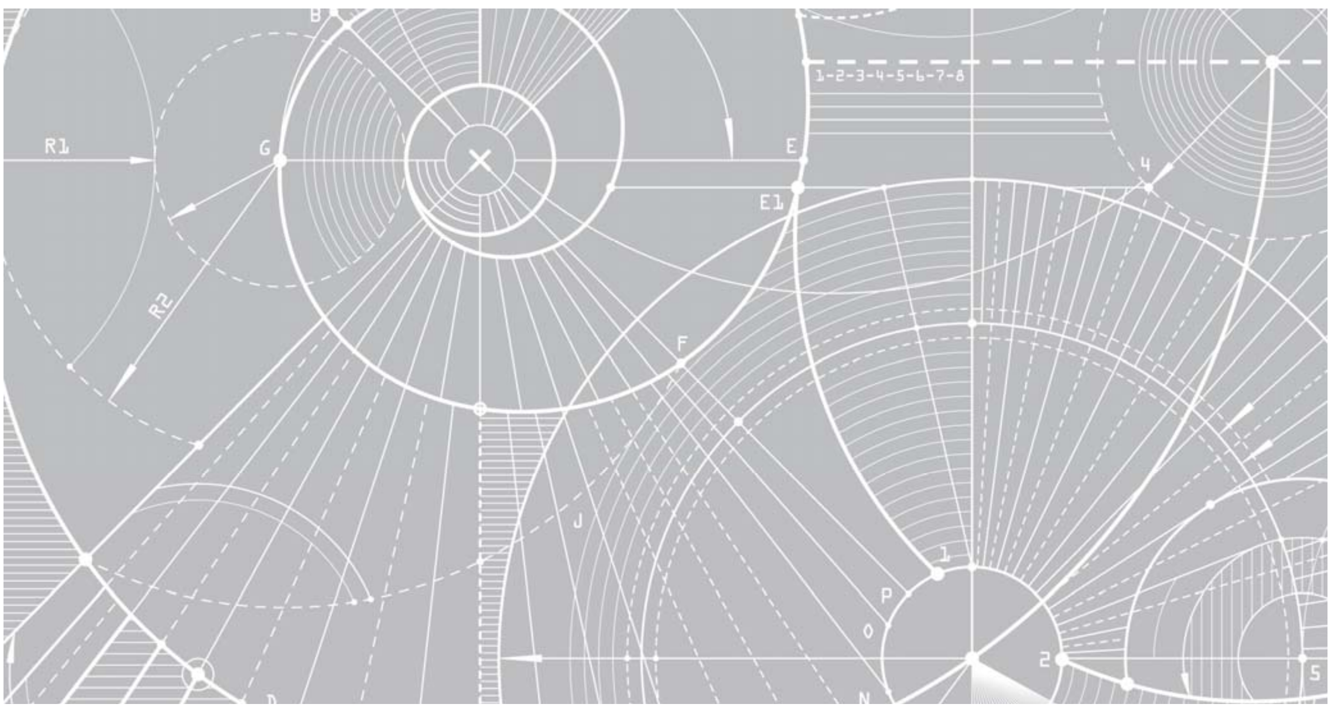

Assessment of Combined Heat and Power Opportunities at Wylfa Newydd Power Station

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Contents

Executive summary

The UK Government wishes to promote combined heat and power (CHP) wherever it is practical to do so. The National Policy Statement (NPS) for Energy EN-1 (Department for Energy and Climate Change (DECC), 2011a) and EN-6 (DECC, 2011b) both require an assessment to be made of the potential for CHP for all power plants, including nuclear.

A high-level assessment of the potential for CHP has been conducted by:

- Making an initial assessment, from mapping of where the most significant heat load is located and developing a potential pipeline route. The largest heat load has been identified as the area of Holyhead, which is by far the most significant settlement and has commercial heat load.
- Assessing the likely heat load existing in Holyhead and along a pipeline route.
- Reviewing the relevant local development plans for the area to determine the potential increase in heat load demand in the foreseeable future, and consulting the Isle of Anglesey County Council to provide greater insight into the plans and the likely take-up of development opportunities.
- Developing an initial cost estimate for the installation and operation of a CHP system that can be compared with the alternative cost of natural gas, which is the most common heating fuel.
- Making an initial assessment of the potential carbon dioxide abatement benefits of the project and the approximate cost of abatement.

Considering alternative options, which may offer similar CO_2 abatement benefits at lower cost, the assessment has concluded that a CHP system connected to the Wylfa Newydd Power Station is not viable. A further assessment was made to evaluate what would be necessary to make the system viable and it was found that the reductions in capital cost or increases in heat load which would be necessary, are unachievable. The proposal is not viable by a considerable margin and this high-level analysis is sufficient to demonstrate this.

Consideration was also given to the potential CO_2 abatement benefits of the potential CHP scheme and these were found to be poor. The maximum potential CO_2 abatement would be around 32,770 t/yr of CO_2. This is expected to cost a minimum of £315 per tonne of CO_2 abated. Potential alternatives to the Wylfa Newydd CHP system were considered and it was found that wood pellet boilers would be capable of achieving abatement for around 83% of the cost per tonne of CO_2 abated which can be achieved by the proposed CHP scheme.

This conclusion is consistent with similar studies, which have also indicated that a much greater heat load would be required to create a viable CHP system.

1 Background

1.1 Introduction

1.1.1 Wylfa Newydd Power Station would operate two reactors that could function as a potential heat source to provide low carbon heat as well as electricity. The practical opportunities to additionally supply heat to settlements and businesses in the area have been assessed in this report.

1.1.2 In order to assess the economic viability of the options for the supply of heat, the following approach has been taken:

- Assess the potential for the Wylfa Newydd Power Station to supply heat to a pipeline system, which could transmit the heat to off-site heat loads.
- Undertake an initial heat demand survey to assess the potential heat demand that exists in 2017 as an initial basis for the calculation.
- Review the current local development plans to assess the potential for increases in heat demand in the foreseeable future, when the station would be operating.
- Consult with the Isle of Anglesey County Council and other interested parties to determine if there is a realistic potential for future increases in heat demand.
- Produce an outline scheme to utilise the maximum potential heat load and establish indicative costs for heat delivered by the potential heating scheme compared to other available heat sources.
- Compare the indicative costs of reducing CO_2 emissions with other options to achieve the same goal.

1.1.3 This report is intended to provide an initial assessment using indicative estimates to establish whether combined heat and power (CHP) could be practical and economically viable. This initial assessment is necessarily simplistic and will be subject to significant uncertainties, but its objective is only to indicate the potential for a viable CHP option. If this initial study indicates that a viable system is possible then the proposal would require assessment in greater detail.

1.1.4 Similarly, the commercial assessment has mainly considered current costs to indicate whether viability is likely before conducting a highly complex analysis involving forward cost projections and net present value calculations. If the initial assessment shows that the system is potentially viable then a more complex assessment would be carried out.

1.1.5 In order to ensure that the inevitable uncertainty of this first assessment does not preclude further development of a potentially viable system, the following approach has been taken.

- The initial assessment has sought to develop a system cost which is at the lower end of the expected range.
- The cost of heat from the Power Station has been assessed at the minimum value for which it could be achieved.

- The assessment has not sought to generate any significant internal rate of return for the operating company, but to cover the necessary costs.
- The heat load has been assessed at the upper end of the expected range in order to maximise potential revenues.
- The take-up by potential customers and their heat utilisation has been considered to be 100% as an initial calculation. This will minimise the cost per MWh of heat supplied. A second calculation for a more realistic 70% utilisation has also been included.

1.1.6 By taking the above approach the assessment should indicate if a CHP scheme is potentially viable, even if it were marginal. As a second stage the assessment estimates the order of magnitude of the changes necessary in order to make the scheme break even, to see if these changes are potentially achievable.

1.1.7 This Assessment of CHP has been prepared in order to comply with Section 4.6 of the *Overarching National Policy Statement for Energy (EN-1)* (DECC, 2011a) and Section 2.9 of *National Policy Statement for Nuclear Power Generation (EN-6)* (DECC, 2011b), which require developers advancing thermal generating stations, including nuclear, to consider the opportunities for CHP.

1.1.8 For the basis of this assessment it has been assumed that the CHP scheme would be developed, owned and operated by a Heat Service Company independent of Horizon. The operating company would need to commercially justify its investment and obtain commercial finance. Horizon would need to modify the reactor system to provide a heat connection and would own and operate this equipment. It is assumed that the Heat Service Company would be provided with a metered supply of heated water at an agreed point at the station boundary.

2 CHP policy and guidance

2.1 Introduction

2.1.1 The UK Government's commitment to promoting the installation of CHP wherever economical, is set out in national policy, in particular NPS EN-1 and NPS EN-6, and guidance relating to energy infrastructure.

2.2 National Policy Statements for Energy, EN-1 and EN-6

2.2.1 The National Policy Statements for energy infrastructure form the policy framework for applications for new generating stations of greater than 50MWe capacity in England and Wales. Consideration of CHP is contained in Section 4.6 of NPS EN-1. Paragraph 4.6.2 states that CHP is technically feasible for all types of thermal generating stations, including nuclear, although the majority of CHP plants in the UK are fuelled by gas.

2.2.2 Paragraph 4.6.5 states:

> "*To be economically viable as a CHP plant, a generating station needs to be located close to industrial or domestic customers with heat demands. The distance will vary according to the size of the generating station and the nature of the heat demand. For industrial purposes, customers are likely to be intensive heat users such as chemical plants, refineries or paper mills. CHP can also be used to provide lower grade heat for light industrial users such as commercial greenhouses, or more commonly for hot water and space heating, including supply through district heating networks. A 2009 report for DECC* [Pöyry and Faber Maunsell, 2009] *on district heating networks suggested that, for example, a district heating network using waste heat from a generating station would be cost-effective where there was a demand for 200* MW_{th} *of heat* [load] *within 15km. Additionally, the provision of CHP is most likely to be cost-effective and practical where it is included as part of the initial design and is part of a mixed-use development. For example, retrofitting a district heating network to an existing housing estate may not be efficient.*"

2.2.3 Paragraph 4.6.6 highlights that under guidelines issued by the former Department of Trade and Industry in 2006:

> "*any application to develop a thermal generating station under Section 36 of the Electricity Act 1989 must either include CHP or contain evidence that the possibilities for CHP have been fully explored to inform the IPC's consideration of the application. This should be through an audit trail of dialogue between the applicant and prospective customers. The same principle applies to any thermal generating station, which is the subject of an application for development consent under the Planning Act 2008. The IPC should have regard to DECC's guidance, or any successor to it, when considering the CHP aspects of applications for thermal generating stations*."

2.2.4 Paragraph 4.6.7 states that:

"*In developing proposals for new thermal generating stations, developers should consider the opportunities for CHP from the very earliest point and it should be adopted as a criterion when considering locations for a project. Given how important liaison with potential customers for heat is, applicants should not only consult those potential customers they have identified themselves, but also bodies such as the Homes and Communities Agency (HCA), Local Enterprise Partnerships (LEPs) and Local Authorities and obtain their advice on opportunities for CHP. Further advice is contained in the 2006 DECC guidelines and applicants should also consider relevant information in regional and local energy and heat demand mapping*."

2.2.5 Paragraph 4.6.8 states that to encourage proper consideration of CHP, substantial additional positive weight should be given to applications incorporating CHP. Proposals for thermal generation without CHP should:

- "explain why CHP is not economically or practically feasible for example if there is a more energy efficient means of satisfying a nearby domestic heat demand;
- provide details of any potential future heat requirements in the area that the station could meet; and
- detail the provisions in the proposed scheme for ensuring any potential heat demand in the future can be exploited."

2.3 Department of Trade and Industry 2006 CHP Guidance

2.3.1 Further guidance on CHP is set out in the Guidance on background information to accompany Notifications under Section 14(1) of the Energy Act 1976 and Applications under Section 36 of the Electricity Act 1989 (Department of Trade and Industry, 2006).

2.3.2 Paragraph 11 of the guidance states that:

"*Developers should therefore provide evidence to show the steps that they have taken to assess the viability of CHP opportunities within the vicinity of their proposed location for the plant. Their application or notification should contain:*

- an explanation of their choice of location, including the potential viability of the site for CHP;
- a report on the exploration carried out to identify and consider the economic feasibility of local heat opportunities and how to maximise the benefits from CHP;
- the results of that exploration; and,
- a list of organisations contacted."

2.3.3 Paragraph 12 of the guidance lists what must be included with generating station applications where CHP is not proposed:

- "the basis for the developer's conclusion that it is not economically feasible to exploit existing regional heat markets;
- a description of potential future heat requirements in the area; and
- the provisions in the proposed scheme for exploiting any potential heat demand in the future."

3 The Potential Heat Supply from the Wylfa Newydd Power Station

3.1 Introduction

3.1.1 This section outlines the technical basis for the Wylfa Newydd Power Station to supply heat since the technical characteristics of the heat supply will determine the potential range of applications that can be considered for the heat supply.

3.2 Options for CHP

3.2.1 There are two main options for heat supply:

1. to supply process steam to industrial concerns; and
2. to supply lower-grade heat to district heating networks.

3.3 Supply of process steam

3.3.1 The supply of process steam or heat to industrial concerns is not considered feasible at the Power Station for many reasons, including:

- The steam supply could only be used adjacent to the plant because of the cost of steam pipework and the heat losses in heat transmission. There is no industrial concern in the area and it is most unlikely that such a development would be proposed, or permitted.
- The direct use of steam from an Advanced Boiling Water Reactor (ABWR) in an industrial process would not be economic or practical because of constraints to the heat supply and the site. The reactor steam cannot be exported directly and so would need to be used to evaporate water in a secondary circuit, which would supply the steam to the heat customer. The need for this heat exchanger would make the heat supply complicated and reduce the maximum steam supply temperature to around 270ºC which will preclude its use in many processes which require higher temperature.
- The steam has its greatest value in generating electricity in the steam turbine cycle, which has been designed to use it. Abstracting steam at the turbine inlet would reduce electricity generation by 1MWe for around $3MW_{th}$ of heat abstracted. This means that the heat abstraction would substantially reduce the power output of the steam turbine generator.
- The value of the extracted steam is calculated on the basis of the reduction in turbine power that results from the abstraction of the steam. This is the power penalty from using this steam for the CHP system and means that the value of the steam is based on a third of the selling price of the power. This is likely to lead to a cost of the order of £25 to £30 per MWh of heat compared to a mean cost of large volumes of industrial

gas of less than £16 per MWh[1] in 2016, which if used in efficient boilers, would give a current steam heat cost of less than £18 per MWh. When the cost of the installation, system operation and maintenance is added to the ABWR heat cost, it increases significantly to mid-£30s per MWh. The cost of gas will therefore be of the order of half the cost of using ABWR steam. Although the relative costs of gas and other fuels are bound to change, it is likely that as the cost of gas rises, the cost of electricity and all other commodities will also increase, but possibly at a lower rate. It is most unlikely that such a large gap will ever be closed. In any event, the cost of heat from the Power Station CHP scheme would have to be guaranteed to be significantly cheaper than other heat sources before a commercial enterprise will invest. With a current heat cost of double the price of alternatives, this is not considered a realistic possibility.

- Using 'waste heat' from the turbine condensers would apparently provide a source of heat with no heat cost. Unfortunately, the temperature supplied by this source will be a maximum of 12ºC above seawater temperature, making a maximum of 28ºC in summer and 19ºC in winter. The use of heat exchangers will mean that the process concerned could expect temperatures between say 17ºC and 26ºC. We are not aware of any coastally sited power station which supplies industrial process heat at these temperatures. The very low temperatures will make the long-range transmission of heat impractical. Where such heat is supplied it is from stations with cooling towers or air-cooled condensers which operate at higher temperatures supplying greenhouses or similar installations alongside the plant.

3.3.2 Although gas is not available at the Power Station, an industrial developer in the Anglesey area would seek out a site with a cheaper energy source and better prospects for obtaining a planning consent. The topography of the area, the presence of protected sites, poor transport logistics and the fact that the area is not designated for industrial development make the development of a site adjacent to the Power Station unrealistic.

3.4 Heat supply to district heating networks

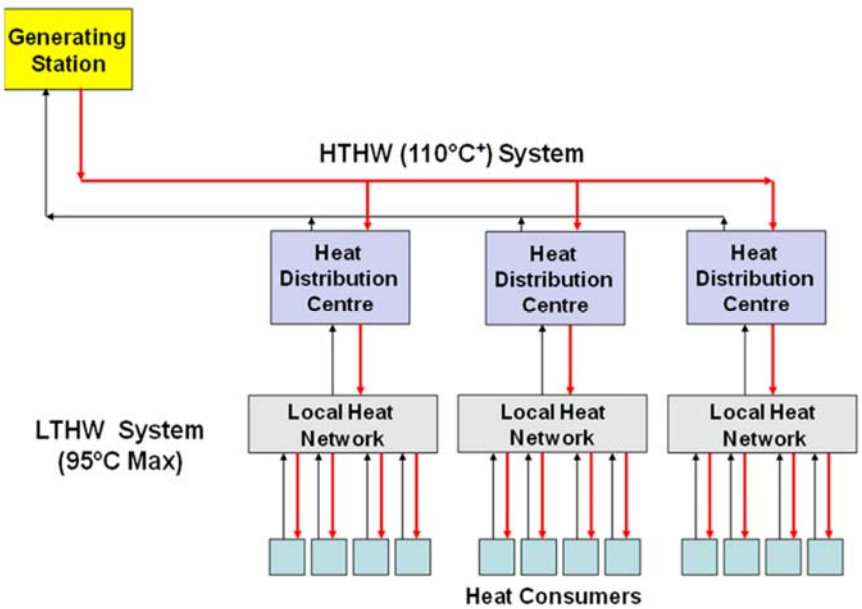
3.4.1 District heating involves the supply of heated water to buildings using conventional heating systems involving water-filled radiators and convector heaters. The heat supply can also be used to heat domestic hot water.

3.4.2 Existing heating systems are based on a hot water supply from a boiler at around 80°C - 85°C giving a typical radiator inlet temperature of 75°C and an outlet temperature of 65°C to give a room temperature of around 20°C.

[1] *Gov.UK Website* Prices of fuels purchased by manufacturing industry in Great Britain (QEP 3.1.1)

3.4.3 A typical district heating system (see Figure 3.1) would probably employ a primary high temperature hot water (HTHW) system to connect the heat load centres to the Power Station. This primary HTHW system would have to operate at relatively high pressure (4 to 5 bar) to prevent the water in the circuit from boiling. The heat would be distributed from heat distribution centres through secondary low temperature hot water (LTHW) systems, which can operate at lower pressure with the water at less than 95°C so that boiling cannot occur at atmospheric pressure.

Figure 3.1: HTHW and LTHW Heat Systems



3.4.4 Using these parameters, it is possible to work backwards from the temperatures required for an existing central heating system to give an indication of the temperatures required of the supply at the Power Station, as shown in Table 3.1.

Table 3.1: Indicative heating system water temperatures

Location in heating system	Indicative water inlet temp (°C)	Indicative water outlet temp (°C)
Customer-side of heat exchanger in the customer's premises	63	85
LTHW side of heat exchanger at distribution centre	70	94
HTHW side of heat exchanger at distribution centre	105	80
HTHW heat exchanger at Power Station	75	112

3.4.5 The ABWR power plant steam cycle requires extremely high quality water in its steam and water systems. The water in the heating network would be of much lower quality and could be contaminated by work on the pipework system. It would also need to be treated with corrosion-inhibiting chemicals. The ABWR system water must therefore be kept separate from the water in the HTHW network.

3.4.6 This separation can be achieved by using a tube-type heat exchanger system. To avoid the risk of direct contamination of the ABWR it may be prudent to use a two-stage system in which the ABWR circuit water is used to heat a water circuit, which then provides water to heat the HTHW water in a second heat exchanger. This arrangement would require steam to be withdrawn from the turbine at a point where the pressure and saturation temperature are adequate to provide around 135°C at a pressure of around 3.5 bar.

3.4.7 The heat exchangers would need to be specially designed high-integrity tube-type heat exchangers. The initial heat exchanger would need to have sophisticated leak detection to isolate the turbine steam cycle side if contamination is detected. It would also need protective devices to prevent flooding of the heat exchanger on the steam side leading to potential water ingress into the turbine. This is a much more sophisticated installation than standard district heating systems and so the installation at the Power Station would be extremely expensive.

3.4.8 No design work has been undertaken for such a system and so only provisional estimates can be made of its cost. It is also not possible to say precisely what the steam extraction temperature and pressure would be at this stage and therefore the value of the steam abstracted. However, it is likely that the steam would be abstracted from a point that would mean that around 7 or $8MW_{th}$ of heat could be supplied for the loss of 1MWh of electricity generation. This would lead to a heat cost of between £10/MWh and £13/MWh. At this stage a cost of £10/MWh has been used in the initial calculations since it is likely to be the minimum value of heat that is likely to facilitate the economics of CHP for the initial assessment.

3.4.9 If the initial assessment indicates that a CHP scheme may be viable, a detailed assessment will need to be conducted of the steam connection to the Power Station. This will need to consider:

- The most appropriate method of abstracting steam from the turbine. Hopefully, without a significant re-design of the turbine or the feed water heating systems.
- The actual reduction in sent out power from the turbine generator and its commercial value.
- The nuclear safety and permitting implications.
- The necessary high integrity heat exchange equipment to prevent ABWR steam cycle water from contacting water from the heating system.
- The necessary control systems, heat flow metering etc.
- Health physics monitoring of the system and exported water.

3.4.10 This detailed assessment would allow an accurate cost to be fixed for the heat supplied to the CHP scheme.

4 Initial Heat Demand Study – Existing Heat Loads

4.1 Introduction

4.1.1 The existing heat demands have been assessed by considering the size and layout of existing centres of population and potential commercial/industrial load from mapping, and government data sources.

4.2 Potential pipeline route

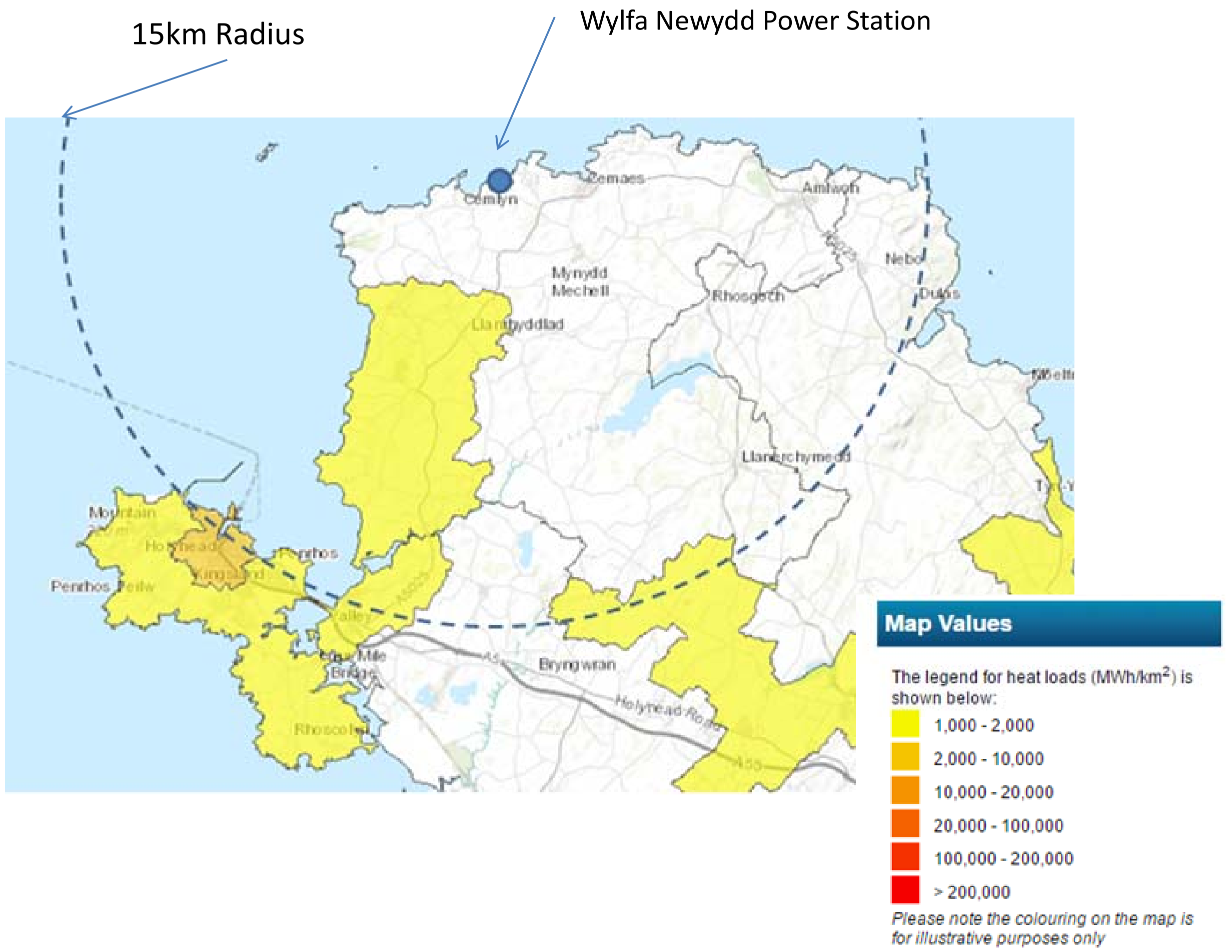
4.2.1 The first issue to be decided is how far from the Power Station to consider for potential heat demand by end users. The report (Pöyry and Faber, 2009) referenced by NPS EN-1 provides an indicative study on the potential for CHP in the UK. This report indicated that viable schemes are likely to have 200MW_{th} of heat load within 15km of the site. The study was initiated by using the UK CHP Development Map website (refer to Figure 4.1), which shows heat demand for all areas of the UK. Figure 4.1 shows that the heat load potential is much greater to the southwest of the site in the direction of Holyhead than it is towards the east and southeast where the settlements are much smaller. The UK CHP Development Map also indicates that there are no significant industrial heat loads in the immediate area around the Power Station.

4.2.2 The15km radius just reaches Holyhead, which is the largest centre of population in the area. As a basis for this analysis, it was therefore decided that a pipeline to Holyhead should be considered as the most likely feasible option. The direct route requires a pipeline crossing under the strait to reach Holyhead, which is highly likely to be prohibitively expensive. Hence a longer route has been assumed that crosses to Holy Island by the road bridge. This route also passes reasonably close to Valley, which is a moderate-sized settlement with an active Royal Air Force base.

4.2.3 A potential direct route from the Power Station to the Holy Island road bridge is constrained by undulating topography. This is particularly pertinent between Cemaes and Llanfaethlu, where the ground level fluctuates between 20m AOD to 90m AOD. This changing ground level would add cost and engineering difficulties to delivering a CHP pipeline to Holyhead, connecting other settlements en route. Between Llanfaethlu and Holyhead the ground becomes less undulating, with changes in levels less severe and more gradual, between 50m AOD and 10m AOD. Therefore, a potential pipeline route has been developed that broadly follows existing roads, avoids the high ground between Cemaes and Llanfaethlu, whilst using straight sections wherever possible. This results in an estimated pipeline distance of 22km. The potential pipeline route is shown in Figure 4.2.

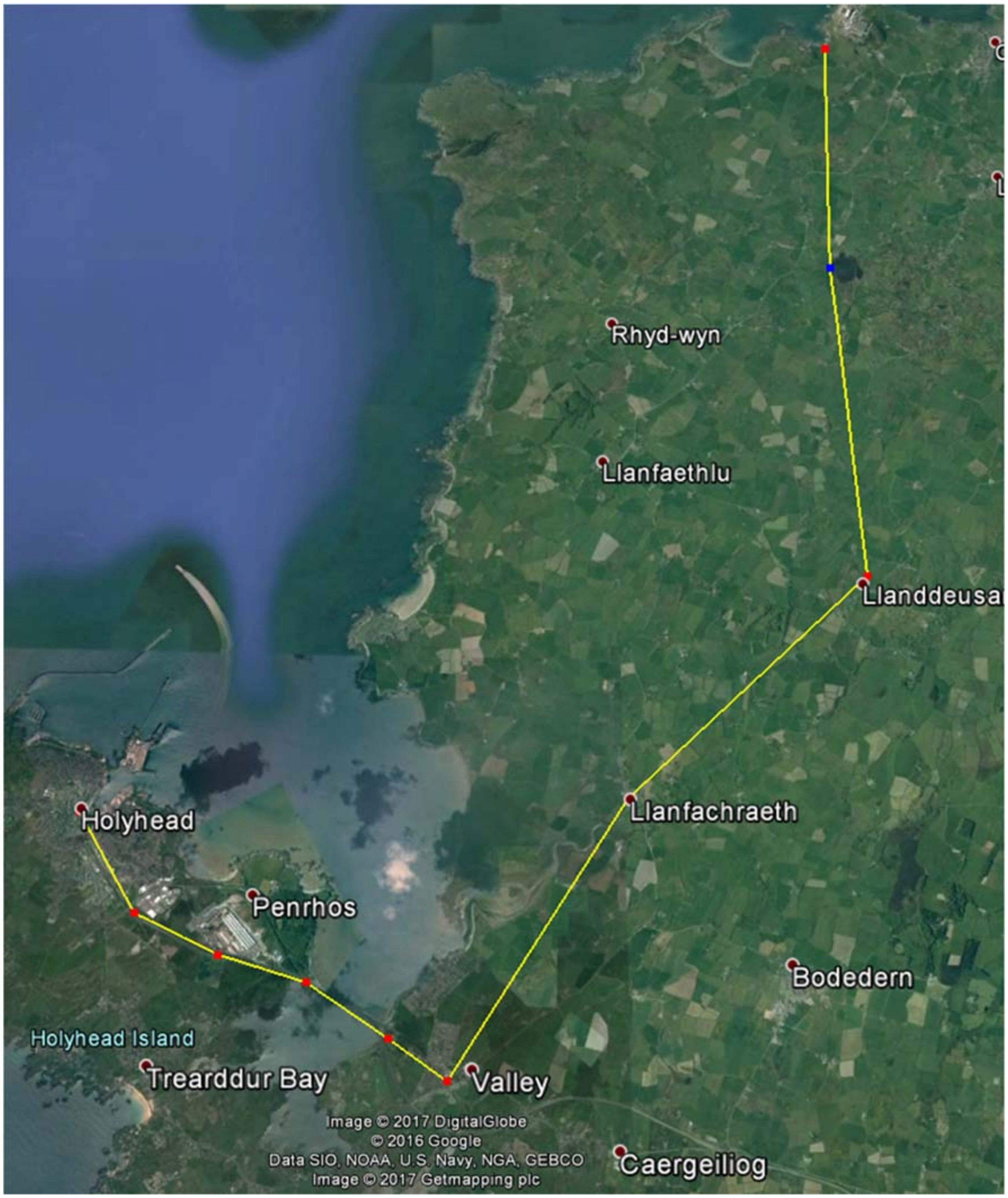
4.2.4 It is noted that the development of such a pipeline would involve a number of constraints, including the Anglesey Area of Outstanding Natural Beauty and other receptors, including Sites of Special Scientific Interest and Scheduled Monuments close to the proposed route. A clear land use planning justification for impacts on these designations would therefore be necessary, and why alternatives are not considered possible.

Figure 4.1: UK CHP Development Map showing heat loads on Anglesey



Note: Published by the DECC which is now the Department for Business, Energy and Industrial Strategy (BEIS)* **http://chptools.decc.gov.uk/developmentmap/.

Figure 4.2: Potential pipeline route to Holyhead and area of interest for heat connection



4.3 Assessment of potential existing heat demand

4.3.1 Heat loads have been assessed using a variety of sources to estimate typical annual utilisation. In general, the heat load has been assessed at the higher end of potential range to seek to promote a CHP scheme, if it is possible. As a first stage assessment it has also been assumed that the maximum possible heat load would be available, i.e. 100% of the heat load will be required, 100% of the heat demand will be connected by the owners and that 100% of the potential heat load could be connected economically.

4.3.2 The results of this initial heat load assessment are summarised in Table 4.1. This assessment is intended to provide a first indication of the likely heat load.

Table 4.1: Heat load from existing buildings in the area of the potential pipeline

Potential heat user	No. of units	Estimate of heat demand MWh/year
Housing		
Houses and flats	Approx. 7,400	133,200
Education		
Primary schools	11	4,010
Secondary schools	1	950
Health		
NHS clinics	5	2,960
Hotels		
Hotels	15	25,700
Commercial		
Industrial estates	2	1,360
Business/retail parks	1	1,995
Supermarkets (including nearby retail outlets)	7	11,870
Dock buildings	6	1,100
Agricultural facilities	35	6,460
Small businesses, small shops, offices, other public buildings etc. (35% of commercial heat load)		8,000
TOTAL		197,605

4.3.3 The data sources used to derive the estimates in Table 4.1 are outlined below.

JACOBS

Main data source

4.3.4 The Chartered Institution of Building Services Engineers (CIBSE) has published data on the typical annual heat consumption per m^2 floor area for categories of buildings. Typical floor area is in Table 5.1 of *Review of Energy Benchmarks for Display of Energy Certificates* (CIBSE, 2011) and typical heat consumption in *Energy Benchmarks, TM46* (CIBSE, 2008).

4.3.5 These data have been used as outlined in the following sections.

Housing

4.3.6 The housing calculations were based on the population of settlements within the proposed route corridor. The population for each settlement was divided by 2.3 to give an estimate of the number of houses. The total population for Holyhead and other settlements on the route corridor based on data within the 2011 Census is 16,690. This figure was rounded up to 17,000 and was then divided by 2.3 (a mean average figure of people per dwelling). This gave a housing figure of 7,391, which was rounded up to 7,400.

4.3.7 The heat demand for each house was estimated from the Typical Domestic Consumption Values published by the Office of Gas and Electricity Markets (OfGEM). The value chosen (18 MWh/year) was in the high range because much of the housing is old and poorly insulated and many of the properties are relatively large.

Education

4.3.8 The heat demand calculations for education facilities in the region were based upon the number of primary and secondary schools on the Isle of Anglesey. This information was obtained from the Isle of Anglesey County Council's website, where local school data have been gathered to form part of the evidence base for the emerging Anglesey and Gwynedd Joint Local Development Plan, between the Isle of Anglesey County Council and Gwynedd Council. It was also established that there are no college sites within the potential pipeline corridor between the Power Station and Holyhead. The only college campus site on Anglesey is in Llangefni, forming part of the Coleg Menai campus.

4.3.9 CIBSE data were used, thus assuming that the primary and secondary schools had typical floor area and heat consumption.

Health establishments

4.3.10 The data on health establishments were obtained from NHS websites. There is no major hospital on Anglesey. There is a Minor Accidents and Emergency Centre (Ysbyty Penrhos Stanley Hospital) in Holyhead. There are smaller clinics however, based in Holyhead, Valley and Cemaes.

4.3.11 The heat consumption was based on the average floor area and heat consumption data from CIBSE. It was assumed the Minor Accident and Emergency Centre may be somewhat larger than a clinic, but that the other establishments were smaller and so overall the average data were appropriate.

Hotels

4.3.12 An indication of the number of hotels was found from booking websites. The hotels were presumed to be of typical size and heat consumption as indicated by the CIBSE data.

Commercial, Industrial, Agricultural

4.3.13 This assessment was made by the following assessment methods.

- Agricultural facilities were identified along the pipeline corridor using Ordnance Survey maps and geographic information systems. Many of these facilities will be barns that will be unheated or partially heated. Each facility was assumed to be the equivalent of 10 households in terms of heat demand.
- The docks buildings were measured from satellite imagery and assumed to be equivalent to the warehouse heat load.
- Holyhead industrial buildings were measured from satellite imagery and assumed to be equivalent to the warehouse heat load. The major unoccupied units close to the docks and at Anglesey Aluminium Metal Ltd have been discounted, but considered as potential sites for industrial development.
- Retail units at Holyhead business parks were measured from satellite imagery and assumed to be equivalent to the general retail heat load. The area of the supermarkets was estimated at the large food store rate.
- There will be a number of smaller commercial and local government buildings, which are difficult to assess. It has been assumed that an allowance of 35% of the commercial/industrial and agricultural estimate will cover these loads.

4.4 Comparison with Government heat load website data

4.4.1 The DECC website referenced in Figure 4.1 also has a feature which allows a first estimate to be made of the heat load in an area. The data are now around 10 years old, but it does allow a useful comparison to be made, which will indicate if the above assessment is producing results of the correct order of magnitude.

4.4.2 The website has a tool that enables an area on a map to be enclosed, which then calculates from its database an indicative heat load. This process was found to give good results for urban and semi-urban areas, but did not work well for elongated shapes like pipeline corridors.

4.4.3 An assessment was made considering the area from Valley, on the mainland side of the bridge to Holyhead and the town of Holyhead itself. This area includes an estimated 85% which would be served by the proposed pipeline from the Power Station. The result from the DECC website was 118,500 MWh/y. If this was 85% of the total heat load of the system then the total heat load would be of the order of 140,000 MWh/y, which compares with the 197,605 MWh/y calculated by this study.

4.4.4 The heat load estimation in this study is greater, however the higher number is based on assuming that all housing uses the maximum consumption from the OfGEM assessment and housing is the main portion of the heat load. If the domestic consumption is assumed to be around 70% of the OfGEM maximum, then both methods produce similar results. This comparison improves the confidence that the results are reasonably indicative of the heat load. The heat load for this stage of the study has been deliberately estimated to be an upper bound in order to favour further investigation of CHP if there is any possibility of the scheme being viable.

5 Potential Future Developments

5.1 Review of development plans

5.1.1 The adopted *Anglesey and Gwynedd Joint Local Development Plan 2011 – 2026 Written Statement* (July 2017), was prepared to understand future housing and employment projections. The Plan makes provision for a requirement for 7,184 housing units between 2011 and 2026 and allocates sites for housing in Holyhead (Caergybi), which will provide 430 housing units. In addition, the Plan states that there is potential for a further 332 units identified on unallocated sites in Holyhead.

5.1.2 In the Plan, Strategic Policy (PS) 13 – Providing Opportunity for a Flourishing Economy, safeguards 642.9ha of current land and units for employment and business, and allocates 55.1ha of land for employment and business purposes on Anglesey and Gwynedd. Those areas have been divided into:

- Primary sites – allocated at Holyhead are Parc Cybi, Holyhead (109.2ha) and Penrhos Industrial Estate, Holyhead (5.8ha);
- Secondary sites – allocated at Holyhead are Anglesey Aluminium Metal Ltd, Holyhead (90.5ha), Former site of Eaton Electrical, Holyhead (2ha), Kingsland site, Holyhead (0.8ha); and
- Reserve employment site – allocated at Holyhead Port, Holyhead (41.9ha).

5.2 Assessment of potential future heat demand

5.2.1 It is difficult to assess heat load growth, because it is not certain what development will actually take place in the designated areas and the energy demand they will represent. However, the following has been assumed as an upper bound scenario of 10% increase in the next 10 years for development in the area of interest along the route to Holyhead.

5.2.2 700 new houses, which will be energy-efficient, are built in estates where the heat connection could be designed-in. This would mean that the majority of the housing units identified in the plan would actually be built. It is assumed that the 700 units will be for additional residents somewhere in the chain of house sales.

5.2.3 The business parks and light industrial load is doubled by using the designated development areas in the former Anglesey Aluminium Metal Ltd site. This reflects the policy to promote employment in the area. The following increases are likewise assumed.

- 10% increase in schools, clinics etc. thermal load to keep pace with housing development.
- 10% increase in new supermarket load, assumed to keep pace with housing development.
- Hotel capacity and heat load increased by 10%.
- Agricultural facilities heat load increased by 10%.
- Dock buildings and heat load increased by 25%.

5.2.4 In addition, an allowance of approximately 5,000 MWh/yr has been included which would be sufficient for substantial further projects to be developed. This would allow for projects such as the combination of a further doubling of industrial estate capacity, 200 further houses, 50% further expansion of docks facilities and a further 10% increase in agricultural facilities. It is considered that this should allow for any additional development which is significantly beyond current expectations.

5.2.5 There are many planning constraints along a pipeline route such as the Anglesey Area of Outstanding Natural Beauty, Sites of Special Scientific Interest and Scheduled Monuments. These planning constraints, the topography and the sparse population mean that it is most unlikely that a major heat load would be developed between the Power Station and Valley at the Anglesey end of the bridge to Holyhead.

5.2.6 The potential exists for a development on the former Anglesey Aluminium Metal Ltd site using biomass fuel to power a CHP to produce electricity and use the heat to produce both farmed seafood and vegetables. At this stage however, this project has not been consented or confirmed. If it goes ahead, it will mean that the most likely major development in the target area will not provide any heat load for the CHP. At this early stage, the effect on the potential Wylfa Newydd CHP project has been discounted. However, if the CHP scheme were to be investigated further, the effect of this potential competition must also be considered.

6 Economic Assessment

6.1 Introduction

6.1.1 As with the heat assessment, a full costing exercise for CHP infrastructure would be complex and expensive. It would only be justified if this approximate assessment shows the proposal to develop a CHP system would have a reasonable chance of proving viable.

6.1.2 At this stage a simple assessment of capital cost has been carried out using indicative costs. This capital cost has been used to develop an outline model for the costs of repaying the capital and operating the system. The costs are based on 2017 values.

6.2 Initial cost assessment

6.2.1 Table 7.1 provides a cost assessment on supplying hot water to premises. It is assumed that the owner of the property would provide a suitable heating system to use the heat within the property as they would do if a gas or oil-fired boiler was used.

Table 7.1: Indicative capital cost of heating system

Cost item	Unit cost	No. of units	Total cost
HTHW system			
Connection to Wylfa Newydd Power Station, turbines, heat exchangers and infrastructure	£1,000,000	2	£2,000,000
HTHW insulated heat mains flow and return in the same trench – £ per km	£1,250,000*	22 km	£27,500,000
HTHW pumping station	£1,500,000	1	£1,500,000
LTHW system			
Distribution centres	£500,000	3	£1,500,000
Distribution centres and secondary connections to HTHW	£100,000	5	£500,000
Standby boiler plant			£500,000
Control system and control room			£500,000
Connection of houses and the local LTHW network	£8,200**	7,400	£60,680,000
Commercial scale connections	£65,000	30	£1,950,000
Small business connections agriculture offices and business units	£10,000	50	£500,000
Plant base cost			**£97,130,000**
Planning, consents and wayleaves (10% of base plant cost)			£9,713,000
Project management commissioning and testing (10% of base plant cost)			£9,713,000
Total CHP plant cost			**£116,556,000**

** Based on cost of installing gas mains in similar circumstances from a North West Gas Networks report that is consistent with other internet sources. This was increased by 25% to cover the cost of pre-insulated flow and return mains in the same trench. It is highly likely that the cost of installation close to Holyhead would be considerably greater than the typical cost.*
*** Mean connection cost per house –an average of terraced and semi-detached house connections in Table 35 of Pöyry and Faber Maunsell, April 2009 The Potential and Costs of District Heating Networks. The cost has been updated to 2017 using RPI.*

6.2.2 Table 7.2 provides an indication that the minimum cost of the development and operation of a CHP system to supply the heat loads would be around £60/MWh of heat delivered.

Table 7.2: Initial assessment of cost per MWh for 100% connection of heat load

Item	Value of item	Annual cost
Total capital cost from Table 7.1	£116,556,000	
Interest rate %	3.5%	
Payback period years	25 years	
Annual repayment of capital and interest on a reducing balance basis		£6,701,970
Pumping power, approximately 1.5% of energy MWh/yr	1,976 MWh/yr	
Power price £/MWh*	£70.00	
Pumping power cost		£138,324
Maintenance costs 1% of plant capex		£971,300
Operating company costs		
Five staff @ £60,000 (salaries, pensions and immediate overheads)		£300,000
Staff buildings and overheads +50% of salaries		£150,000
Heat energy cost at Power Station £/MWh	£10.00	£1,976,050
Increase by 5% to cover heat losses in the system		£98,803
Total annual cost £/Yr		£10,336,446
Cost +15% for business rates, wayleave charges, miscellaneous business costs and contingency**		£11,886,915
Mean cost per MWh assumes 100% heat take-up and heat sales, low margin for operating company and no unplanned expenses £/MWh	**£60.15**	

** An indicative estimate consistent with BEIS current commercial power price forecasts for Central and High price scenarios for 2018. Transmission costs for rural Anglesey make power more expensive.*

*** At this stage the detail of the full costs of the operation of the heat Supply Company cannot be calculated. This includes significant items such as business rates and wayleave charges plus a large number of smaller expenses such as vehicles and transport, producing audited accounts, safety compliance costs, professional fees, marketing etc. This allowance is intended to cover these inevitable underestimated costs plus any underestimates in the listed costs which have been estimated at the lower end of the expected range, there is also a contingency. This is not intended to represent a commercial margin.*

6.2.3 In practice, it would not be possible to connect all of the heat loads, because agreement with all homeowners is unlikely and/or the connection cost would be unrealistically high. A similar calculation was undertaken for the connection of 70% of the estimated heat load, which would be a more likely outcome. For this scenario, the capital cost was reduced to allow for the fewer connections. On this basis, the cost per MWh is expected to be of the order of £83 per MWh, which is more likely to be realistic.

6.2.4 The assessments have been made on the basis of a flat rate energy cost. In practice, domestic customers would pay more to justify their higher per MWh infrastructure costs and commercial enterprises would pay less, as is the case with electricity and gas. Tables 7.3 and 7.4 show the comparison against a flat rate cost for all heat and with the domestic selling price increased to reduce the commercial heat sales price.

Table 7.3: Initial assessment of cost per MWh for 100% and 70% connection of heat load – flat rate cost for both domestic and commercial

Heat user	2017 gas cost in 90% efficient boiler £/MWh	Estimate for CHP system with 100% take-up £/MWh	Estimate for CHP system with 70% take-up £/MWh
Domestic heat	£47	£60	£70
Commercial heat	£28.8	£60	£70

Note: Gas prices have been based on UK Government (Department for Business, Energy and Industrial Strategy) Data Table 5 updated March 2017. The value for 2017 High scenario has been used because gas prices tend to be higher in this relatively remote region where the supply companies' costs are higher.

Table 7.4: Assessment of cost per MWh with commercial heat price reduced

Heat user	2017 gas cost in 90% efficient boiler £/MWh	Estimate for CHP system with 100% take-up £/MWh	Estimate for CHP system with 70% take-up £/MWh
Domestic heat	£47	£71	£83
Commercial heat	£28.8	£33	£38.5

6.2.5 Gas is understood to be available in the Holyhead area and along the main A5 road, but not in the remainder of Anglesey. Nonetheless, the cost of mains gas is a good indicator of heat energy prices for most of the connectable heat load. In order to be successful, the CHP system will have to persuade most of its customers to switch from mains gas. The users of higher-priced fuels may have more incentive to switch but it would be the comparison against gas prices that would influence the decision for most people whether to switch energy suppliers. The CHP system could certainly not be successful if it targeted the relatively few users of higher priced energy in the area. The non-gas users are probably more remote premises which will also cost more to connect to the CHP scheme.

6.2.6 This assessment has been conservative by assuming that people will switch for a comparable price when, in fact, it would be necessary for the CHP scheme to be significantly cheaper to promote a switch of supplier. There would need to be a significant incentive to encourage a change which would involve disruption to make the connections and fit heat exchangers and metering.

6.2.7 Clearly, the comparison with current gas costs in tables 7.3 and 7.4 all show that the cost of supplying heat due to costs of the CHP infrastructure and operation would be considerably greater than the cost of using mains gas, for all the scenarios considered. In practice, the assumption of a 70% take-up and utilisation of the system is probably more realistic and offering a reduced commercial gas rate would also be necessary. This means that a domestic heat cost is likely to be more than double the equivalent cost of gas.

6.3 Future development

6.3.1 The heat load offered by future development is difficult to predict for two reasons. Firstly, it is difficult to predict the number and nature of the developments that will take place and secondly it is difficult to predict the heat load it will represent.

6.3.2 As an indication, it has been assumed that a 10% growth in heat demand could be achieved over the next 10 years. The 10% growth in heat demand was assumed together with the likely costs of connection of the additional heat load. As expected, this reduces the cost per MWh, but the effect is very small. It is likely that a 10% increase in heat demand with an increase in capital cost of 10% of the housing connection cost would only reduce the cost of the 100% take-up scenario from £60/MWh to £58/MWh.

6.4 Sensitivity assessment

6.4.1 Since it is not possible to be accurate in this type of assessment, it is useful to assess the extent of the change that would be necessary to the estimates to have the potential to alter the outcome. All the sensitivity assessments are compared to the base case assessment.

Capital cost

6.4.2 A sensitivity assessment was carried out to see the magnitude of a change in capital cost to enable the proposed CHP to match current gas prices.

- To match the price of domestic gas for the 100% take-up scenario for the heating system and the full predicted heat demand, the installation cost would have to reduce from £116 million to £78 million.
- To match the price of domestic gas at 70% connection to the CHP, the installation cost would have to reduce from £116 million to £47 million.

6.4.3 The capital cost has been developed based on estimates from a variety of sources. The core elements of the cost are the main pipelines and the cost of connection of each house would have to be halved to reduce the capital cost to £63 million. There is a reasonable basis for these core costs and halving them would not be realistic. A capital cost of £78 million is not considered to be a viable assumption; in fact, the £116 million estimate is quite likely to be low, rather than high.

6.4.4 The cost of connection to the Power Station has not been the subject of a detailed study and supposes relatively simple connections and heat exchangers, similar to connection of a conventional plant, but with some allowance for higher integrity equipment. These costs must be regarded as an absolute minimum and could well increase substantially once a detailed assessment has been carried out. The basis for the cost of the connection of houses assumes a reasonable average complexity and length of connection. It is highly likely that the connection cost will prove to be above average because of the preponderance of older housing in Holyhead with highly complex and aging local infrastructure and for longer than average connections.

6.4.5 Assuming 70% heat utilisation is a more realistic assumption, this would be made up of a reduction in connected premises, which would reduce capex perhaps by £18 million to £95 million, but heat demand from the connected customers would also fall. An overall capex of £47 million is not credible because it would mean that complete installation would cost around £4.5 Million more than the cost of the connection of the houses alone as assessed by Pöyry and Faber Maunsell (2009). This would be totally inadequate to pay for the heat mains, pumping station, connections to the power plant etc.

6.4.6 The capital cost sensitivity assessments were carried out using the most optimistic method of calculating the heat cost per MWh, which is to assume that all heat users pay the same rate. However, around 40% of the load is commercial and these customers would expect a reduced rate to be competitive with commercial gas. To achieve parity with both commercial and domestic gas prices would require these unrealistic capital costs to be reduced still further.

6.4.7 In conclusion it is unrealistic to consider that the capital cost can be reduced sufficiently to make the scheme viable. Overall the capital cost estimates are much more likely to increase than decrease, particularly because the existing housing stock would be difficult to connect.

Heat load sensitivity

6.4.8 An assessment has been made assuming that the capital cost remains the same, but that the combined heat load could be increased without further infrastructure costs. In practice, this means that all the individual consumers hypothetically increase their demand without adding new end users. Increasing the heat demand of users already assumed to be connected to the system is much more effective at making the system economically viable than connecting more heat loads due to the zero incremental investment cost. To match the cost of domestic gas at 100% take-up and uniform domestic and commercial cost, the heat load would have to be 280,000MWh per year instead of 197,000MWh per year.

6.4.9 This appears to be a relatively small increase. However, for an increase in heat demand that would make the proposal viable, all the homes and businesses would be required to permanently use 40% more heat than estimated for the next 25 years. This is not credible for the following reasons:

- This scenario assumes 100% take-up which is most unlikely especially since the base assessment assumes that commercial consumers would pay the same rate as domestic consumers, which is not realistic. If domestic heat prices are increased to reduce commercial prices, then the heat usage increase has to be even greater.
- The domestic usage represents around 60% of the heat load and it has already been estimated at the upper end of expectations. The assumption of the highest value quoted by the Office of Gas and Electricity Markets probably overestimates consumption as the base case. It is most unlikely to achieve the estimated demand which has been quoted. Increasing this demand by 40% over the upper bound of typical results is not a credible proposition.
- Even if it occurred, an increase of 40% over the upper bound of typical usage would be unlikely to be sustained. The high consumption would make energy efficiency measures highly economic, which would be expected to reduce the demand at least to the typical levels assumed in the calculation.

6.4.10 For the more realistic 70% heat take-up scenario, the base heat demand needs to increase by almost 70% to 330,000MWh per year to match gas prices with equal heat prices – to both domestic and commercial customers (note: only 70% would be sold to the heat network customers). For this more realistic scenario it can be seen that increasing the heat load is not credible, because it requires each connected consumer to increase their demand by 70% above the upper bound OfGEM heat consumption for the next 25 years

Sensitivity to Commercial Assumptions

6.4.11 The assessment has made a series of assumptions of gas prices and interest rates which will be subject to change over the life of the potential system. In order to test this a few key examples have been conducted to indicate whether changes in interest rates or gas prices are likely to make the system viable.

Interest Rates

6.4.12 A change of long-term interest rates to a very low rate of 1% would have a beneficial effect, but it would not be sufficient to make the domestic MWh costs comparable with gas as shown below. Commercial gas may approach parity for the unrealistic 100% take up scenario, even then there is no meaningful differential to make it attractive to switch. Domestic gas users would have to effectively subsidise commercial customers and the domestic customers would not switch to a significantly higher price and so the scenario is not realistic.

6.4.13 As expected for the more realistic 70% heat take-up scenario the heat costs are even less favourable.

Table 7.5: Assessment of cost per MWh on the basis of Table 7.4 with a low 1% Mean Long-term Interest Rate

Heat user	2017 gas cost in 90% efficient boiler £/MWh	Estimate for CHP system with 100% take-up £/MWh	Estimate for CHP system with 70% take-up £/MWh
Domestic heat	£47	£61	£71
Commercial heat	£28.8	£28.5	£33

6.4.14 An increase in long-term mean interest rates to 5% would have a substantial detrimental effect which would increase the MWh costs significantly. Historically 5% is not a high interest rate and rates of 5% or more are much more likely than a sustained rate of 1%.

Table 7.6: Assessment of cost per MWh on the basis of Table 7.4 with an increased 5% Mean Long-term Interest Rate

Heat user	2017 gas cost in 90% efficient boiler £/MWh	Estimate for CHP system with 100% take-up £/MWh	Estimate for CHP system with 70% take-up £/MWh
Domestic heat	£47	£77	£90
Commercial heat	£28.8	£36	£42

Gas Prices

6.4.15 It is possible that gas prices will increase ahead of general inflation. The 2017 BEIS fuel price projections estimates anticipate that gas prices will double by 2040. In this period the escalation of the other costs of operating the system would have to be 32% or less if the gas price was to make the system just break even for the 100% heat take-up scenario. A 32% rise over the period to 2040 is only an annual inflation rate of around 1.2%. As a comparison for a similar period in the immediate past (August 1994 to August 2017) the Retail Prices Index has increased by almost 84% which is almost 2.8 times the break-even rise required over the next 23 years. It is most unlikely that the rate of general inflation will be low enough to allow the system to break even for the optimistic 100% heat take-up scenario.

6.4.16 At 70% heat utilisation the doubling of gas prices breaks even in 2040 at an annual inflation rate of 0.55%. Inflation is almost certain to occur at a significantly greater rate and so under the 70% use scenario the system will always make a loss.

6.4.17 In over 20 years there will further insulation and developments in heating control systems which are likely to reduce the heat demand below its current levels, increasing the losses. Increasing energy prices will make these changes more likely.

6.4.18 This is a simplified calculation to illustrate the effect of rising gas prices. The calculation ignores the fact that it would take many years of the system making losses whilst waiting for gas prices to rise. In this period substantial losses will be made which will increase the debt and thus increase the loan payments. This will mean that the break-even point will be raised and the system will continue to make substantial losses. Even for the 100% heat take-up scenario the increase in the debt may well be sufficient to nullify the benefit of the increased gas prices and the system will make an increasing loss every year.

6.4.19 It is inconceivable that any credible rise in gas prices will make the system approach a break-even situation.

Conclusion of sensitivity assessment

6.4.20 The sensitivity assessment shows that the CHP system proposal is not viable by a significant margin. The 100% heat take-up is effectively impossible, but even with this optimistic assumption, allowing for commercial heat to be cheaper, requires a capital cost of around half the base estimate, which is not credible. To match current gas prices with 70% utilisation is even worse because this would require a capital cost of around £47 million, around 40% of the base estimate. The conclusion is similar for the increase in heat load by existing customers; to make the system viable requires a minimum increase of 40% for the 100% heat take-up scenario and the more realistic 70% take up scenario requires the heat load per consumer to increase by 70%.

6.4.21 Gas prices are low at present and will probably increase in the coming years. However, the cost of the CHP scheme is heavily dependent on interest rates and the value of nuclear electricity, both of which are also likely to rise, possibly ahead of gas prices. The sensitivity assessment shows that if long-term mean interest rates fall to as low as 1%, the proposed system still does not break even. If interest rates increase the costs of the system escalate rapidly.

6.4.22 The projected increase in gas prices will not make the system economic as outlined above. It is not practical to initiate a loss-making project and wait for prices to rise to achieve a break-even condition many years in the future. Gas price projections of this nature for over 20 years must be regarded as highly speculative. There is a considerable possibility that unexpected developments in renewables and other technologies mean that there is an oversupply of gas and that the expected price rise does not materialise.

6.4.23 These sensitivity estimates seek to match the price of gas whereas in practice it would be necessary for the CHP network to be significantly cheaper than gas to encourage people to switch. It is also known that the heat cost from the Power Station and many other aspects are at the lower end of expectations and are quite likely to increase in a more detailed and accurate assessment.

6.4.24 In order to actually develop such a system, the business plan of the heat supply company would have to show a rate of return on the investment and so breaking even would not be sufficient. The sensitivity assessment shows that the proposed CHP system must make a substantial loss and could never be considered a realistic commercial investment capable of making a realistic return.

6.5 What additional heat demand would make the system economic?

6.5.1 Since the economic appraisal does not appear viable, it is worth assessing what heat loads would need to be added to the system to make it economic, compared to the base case assessment.

6.5.2 It is possible to provide a first order estimate to indicate how much additional heat load would be required to enable the heating scheme to match current gas prices. This is based on considering the contribution towards the capital cost of the system, which can be made by additional connections. The contribution is the difference between the cost of energy from gas and the irreducible minimum costs of the CHP scheme, i.e. the purchase of the energy plus the operation of the heating network. The number of additional connections necessary to match the energy sales price to the price of gas has been assumed to be a good indication of the order of magnitude of the task necessary to make a CHP system viable.

Connect more existing homes

6.5.3 Connecting more existing houses at the same connection cost as the main assessment, with a system life of 25 years, requires the connection of almost 72,000 additional houses to break even with current gas prices. This is over around 10 times the number of homes to be connected using the proposed pipeline route and twice the total number of houses in Anglesey. The pipeline route was selected because of the relatively high population density. This is very sensitive to gas price at the time the connection is made; if prices rise by say £3/MWh, the number of houses reduces to fewer than 30,000.

6.5.4 This calculation only considers the house connection cost. The intention is to investigate whether CHP system revenues could be increased without appreciably increasing the main infrastructure and overhead costs. However, the calculation shows that a very large number of houses need to be connected which would require long additional heat mains running to different locations with lower heat loads than Holyhead. The economics of longer heat mains feeding smaller load centres must be worse than the system investigated and so connecting large numbers of additional existing houses is not a viable option.

Connect more new homes

6.5.5 If new houses could be constructed close to the proposed route this may increase revenues without a major increase in infrastructure costs.

6.5.6 Unfortunately, the energy demand of new houses is very much less because of modern insulation standards. The benefit of connecting each house to the economics of the CHP system is very small because the capital cost of the connection can only just be recovered from the revenues from the low energy sales to a well-insulated home. An estimate has been made of the number of new homes required to make the CHP system viable using the estimated cost for connection of new houses from the guideline values reported by Pöyry and Faber Maunsell (2009) and escalated to 2017 prices by RPI and with an assumed connection life of 40 years. This estimate indicates that to create a viable CHP system would require around 47,500 additional new houses to be built, which would house up to 110,000 people, over 1.5 times the current population of Anglesey. Again, this is very sensitive to the price of gas, but nonetheless it is unrealistic to consider that building new homes could make the system economic.

Connect more commercial load

6.5.7 Additional commercial load is also not attractive, because the differential between the minimum cost of heat and the commercial cost of gas is only around £10/MWh (this is the heat cost at the Power Station plus the costs of operating the system plus the cost of commercial gas used in a 90% efficient boiler). The following is an approximate indicative calculation.

6.5.8 If commercial loads were to be proposed and connected to the proposed system, the amount of additional commercial load would be of the order of 345,000MWh per year to reduce costs to the same order as current commercial gas prices. This assumes that the system infrastructure does not appreciably increase in capital cost. 345,000MWh per year is a continuous demand of 40MW and probably 50MW at a reasonable load factor. The annual load is of the order of 1.75 times the current total projected heat load and over five times the expected commercial heat load. The existing development areas are highly unlikely to produce a heat load of this magnitude, which would require developments of the following order of magnitude:

- 2 million m^2 of food retailing, which is around 90 major supermarket complexes of 150m x 150m;
- 2.6 million m^2 of warehousing and distribution centres which is around 120 major 150m x 150m warehouses;
- 650,000m^2 of glasshouses, which would be around 12 times the area of the Wissington glasshouse complex in Norfolk, the largest producer of tomatoes in the UK. Whilst such a development would be a possibility, it is not realistic to consider projects of this scale; also, such development is better suited to a plant that can provide both heat and CO_2 to stimulate growth rather than heat alone. The glasshouse projects use waste heat, which has a very much lower cost than heat produced from gas and so matching the price of gas would not be sufficiently commercially attractive anyway.

Connect industrial load

6.5.9 A large industrial load would be impractical for two reasons; firstly it is unlikely to require hot water and secondly industrial gas is currently cheaper than the marginal cost of supplying heat.

Heat Demand at the Wylfa Newydd Power Station

6.5.10 There will be a heat demand to heat the buildings within the WNDA Development. However, this demand would be fed directly from the hot water heat exchangers and would not use the expensive heat mains and distribution system. Thus the heat demand would only need to make a contribution to the cost of the connections to the turbines and the associated heat exchangers. The proportion of heat used would only be a few percent, less than 5%, of the total and the cost of the heat exchangers is only around 2% of the overall system cost. Therefore, the heat use at site would probably make a contribution of around 5% x 2% of the capital cost which is only around 0.1% of the total capex.

6.5.11 This calculation is approximate and is only intended to show the order of magnitude of the benefit to the CHP project of using heat within the WNDA Development. The use of heat would be a good idea if the system was viable but it makes a negligible difference to the overall economics of the project.

6.6 Could Government subsidy schemes make the system economic?

6.6.1 The UK Government has been helping local authorities in England and Wales to plan and develop heat networks, through a specialised unit called the Heat Networks Delivery Unit (HNDU). HNDU was set up to provide support (grant funding and guidance) to these local authorities to progress the development stages of heat networks projects – from heat mapping through to early commercialisation. By providing funding for project development and their own expertise and support, HNDU has built up a pipeline of over 200 projects across more than 130 local authorities.

6.6.2 The £320 million Heat Networks Investment Project (HNIP) capital investment programme, announced in the November 2015 Spending Review, is expected to support up to 200 projects by 2021 through grants and loans and other mechanisms and to lever in up to £2 billion of wider investment, reducing bills, cutting carbon and forming a key part of wider urban regeneration in many locations. The HNIP Pilot Scheme (administered by Salix Finance with a budget of £39 million and open to local authorities and other public sector bodies) ran from October 2016 to March 2017. Learning from the pilot is shaping the design and delivery of the main HNIP funding scheme, which BEIS aimed to launch by the end of 2017.

6.6.3 BEIS has identified three classes of projects (noting that the internal rate of return (IRR) ranges shown below reflect BEIS's current thinking and the definition and ranges are still to be confirmed):

- 'sub economic' with a project equity IRR of less than 5%;
- 'economic' with a project equity IRR between 5% and 12%; and
- 'commercial' with a project equity IRR greater than 12%.

6.6.4 A key driver for BEIS is the principle of 'additionality'. In practice, this means supporting projects with merit which would not go ahead without the BEIS funding, as the project financials (such as IRR), whilst positive, are not attractive enough to secure funding. The 'funding gap' in this case is the contribution required to take the IRR without HNIP funding up to the hurdle rate of the equity investors. Applicants for HNIP funding need to demonstrate that all other reasonable sources of funding have been explored prior to application.

6.6.5 The assessment of CHP opportunities undertaken in this report indicates that the potential economics of this CHP scheme and associated heat network are very poor. No achievable scenario can be advanced which breaks even and therefore this would not be sufficient to warrant further evaluation, or future consideration for HNIP funding.

6.7 Could a more limited scheme be economic?

6.7.1 It may appear that if a large system is uneconomic then a limited scheme just to supply the local town at Cemaes may be economic. Unfortunately, this cannot be the case because there are only 1,300 people in Cemaes and approximately 550 houses. Most of the costs per MWh of heat supplied, increase for a smaller system.

6.7.2 The costs and complexity of making a connection to supply heat from the Power Station will not be significantly less than for a larger system. The design costs, safety assessment costs, health physics monitoring costs, metering costs etc. are estimated to be a similar order of magnitude regardless of system size. All the same plant items will be required and their installation costs will be similar but there may be some savings in the plant items themselves, because they will be smaller. Unfortunately, this saving is relatively small.

6.7.3 The connection to power plant alone will cost a minimum of £3,600 per house. Once a full study of the connection has been made this is quite likely to increase substantially. The heat connections to 550 houses will be more expensive per unit than the 7,400 or more houses to be connected to the large system, most of the connections will be made in the relatively high housing density of Holyhead.

6.7.4 Although the pipelines will be much shorter they will cost almost the same per metre to install because the excavation, installation, planning, consenting and wayleave costs must be higher per metre and this will not be offset by a relatively small saving in material costs. Therefore, the cost component of the heat mains will not reduce per MWh.

6.7.5 The operation of the CHP becomes very expensive per customer and the cost of billing, metering, maintenance and repair will all be greater per MWh supplied. In addition, there will have to be a standby boiler plant which will also be relatively more expensive per customer. There will be savings in pumping power.

6.7.6 An indicative calculation indicates that a small system to connect Cemaes would have a capital cost of around 12% of the Holyhead System for only around 6% of the heat load. The increased operating costs per unit of heat supplied are also significant. The result will be a minimum energy cost to the consumer of around £110/MWh which is much higher than for the proposed CHP system to connect Holyhead, even for the optimistic 100% heat connection scenario.

6.7.7 The report by Pöyry and Faber Maunsell, April 2009, indicates that successful CHP schemes require much larger heat loads than that available at Cemaes.

6.7.8 There is no gas in Cemaes and so the comparison could be made with oil. Current oil prices are around 38p/l (Ref BEIS Data 2017 High scenario). Each litre provides around 10 kWh of hot water in a 90% efficient boiler which means that each KWh from oil is less than 3.8p (£38/MWh) compared to £100 to £140/MWh as the minimum cost for the CHP scheme. The price of oil is currently low but even doubling the oil price would be nowhere near breaking even with the minimum likely CHP scheme costs.

6.7.9 Since the costs of the small-scale CHP system are so high, it will always be more expensive than existing fuels.

7 Consultation

7.1 Introduction

7.1.1 It became clear during the study that the rural nature of the area around the Wylfa Newydd Power Station means that the CHP system is highly unlikely to be viable. The heat loads are relatively small and the distances to be traversed by the heat mains are long. Furthermore, the crossing to Holyhead Island would add complexity and cost.

7.1.2 Before conducting any consultation, it was decided to complete some initial estimates of the magnitude of the additional heat loads which would be necessary to allow a viable system to be developed. It became clear that the development required was very much greater than anything expected in the plans reviewed in Section 5. Consultation was undertaken with the Isle of Anglesey County Council (IACC) in 2018 to discuss the potential for large-scale development and the viability of a CHP system.

7.2 Consultation with Isle of Anglesey County Council

7.2.1 A draft of this report was sent to the IACC as a consultation document together with a list of key questions on the extent of likely development which could affect the growth in heat demand.

7.2.2 The response from the IACC made some observations on the content of the report which have been incorporated within this report. The IACC agrees that the development of the additional heat loads required to make the CHP scheme viable is considered unrealistic.

7.2.3 However, the IACC identified that Parc Cybi, the Orthios Project, Port Regeneration and Menter Mon should be contacted to ensure that there were no reasonably foreseeable opportunities for heat loads of the magnitude required. These bodies have been contacted to confirm that any projected development would produce much less heat demand than that required to make the CHP scheme viable.

7.2.4 From this consultation exercise, it was concluded that it is unrealistic to expect the very large expansion of heat load required to make the Wylfa Newydd CHP scheme viable. This means that the proposed CHP scheme could not form the basis for a commercial opportunity which would be worth either further investigation, or further consultation.

8 Assessment of the Effects on Greenhouse Gas Emissions

8.1 Amount of greenhouse gas abated due to the CHP System

8.1.1 The objective of the CHP system is to reduce the emissions of CO_2 caused by the combustion of fossil fuels for heating. Most of this fuel in the Holyhead area would be natural gas, which has a relatively low carbon dioxide emission per unit energy. To provide an indication of the benefit of the system in reducing CO_2 emissions, it would be a reasonable first approximation to assume that the entire heat load (197,600MWh/yr) is currently supplied by natural gas-fired boilers with an efficiency of 90%. The remaining heat load away from Holyhead could include both LPG and oil. The LPG emissions will be similar to natural gas and oil will be greater but it is a small proportion of the total.

8.1.2 Using the current UK Government factor of 0.184 kg/kWh for UK gas, means that the avoided CO_2 emissions would be 36,358 t/year (BEIS, 2017). This is probably an over-estimate for two reasons; firstly, the heat load is known to be an over-estimate and secondly the operation of the CHP is not free from the creation of carbon dioxide emissions. These emissions result from the following sources.

8.1.3 The extraction of steam from the turbine generators at the Power Station means that the output of the Power Station would be reduced by up to one MWh for every 7.5 MWh of heat extracted. This would mean the loss of 26,350 MWh of electricity, which would lead to CO_2 emissions in the replacement power generation. The amount of CO_2 emitted will reduce as the amount of nuclear and renewable generation increases, but nonetheless there will be a resultant emission for many years to come. If 25% of this energy was generated from natural gas at 50% efficiency, this would lead to around 2,210 t/yr of emissions.

8.1.4 A similar effect occurs with the pumping power, which would also reduce the effective generation from the Power Station. This is likely to be of the order of 1,976 MWh per year and lead to an emission of a further 165t/yr.

8.1.5 There would need to be some use of gas firing in peak load/standby boilers because:

a. there would be a need to shut down the heat mains for maintenance and repair;
b. standby boilers may be run to assist with short-term peak demands if the system capacity were fully utilised; and
c. the reactors have refuelling outages and there would also be maintenance shutdowns of the nuclear plant. Therefore, a standby heat supply would be necessary to maintain supplies to the district-heating scheme.

8.1.6 It would be reasonable to assume that 3% of the heat to the district-heating scheme would be fed from gas-fired back-up boilers at times when the heating system was not operating or the demand was very high or the reactors were shut down. This leads to a further reduction in CO_2 benefit of around 1215t/yr.

8.1.7 This means that the maximum benefit the CHP scheme could generate (if there was 100% take-up and 100% of the estimated heat load is utilised) is around 32,770 t/yr of CO_2. Based on the costs for this scenario in the commercial assessment, this is £315 per tonne of CO_2 abated. It must be emphasised that this is for the most optimistic CHP scenario and so £315 per tonne of CO_2 is the minimum cost and it is likely it would be significantly greater.

8.2 Comparison with the cost of alternatives, e.g. wood pellet fired boilers

8.2.1 Alternative technologies should be considered to provide a cost comparison with the proposed CHP scheme. This assessment is not intended to be an exhaustive consideration of potential options. The objective is only to consider a typical technology to see if the cost of CO_2 abated is likely to be lower, ignoring any subsidies.

8.2.2 Wood pellet fired boilers can be provided for all the potential heat loads in the Holyhead area. The boilers come in a range of outputs to meet the needs of homes and businesses. They could also supply shared systems for flats or new housing developments. The boilers can be retrofitted to replace existing gas and oil boilers. The boilers can also be fitted over a wider area than the CHP scheme and target replacement of oil boilers to increase the CO_2 abatement.

8.2.3 As a basis for comparison, domestic boilers have been considered since they would form the biggest single element of the heat load. If the domestic boiler was cost-effective, then commercial boilers would also likely be cost-effective since they would benefit from economies of scale.

8.2.4 If it is presumed that the boilers have a life of 20 years, then the indicative cost of fuel and the boiler installation is as indicated in Table 8.1.

Table 8.1: Indicative cost of wood pellet boilers

Description	For domestic installations
Wood pellet cost per tonne (bulk blown delivery)	£160
Fuel pellet net CV GJ/t	17.5 GJ/t
Heat cost per MWh from 88% efficient boiler	£37.40
Boiler installation cost per MWh	£16.00*
Total cost per MWh of boiler and fuel	£53.40
CO_2 emissions from producing the equivalent amount of energy from natural gas in a 90% efficient boiler (0.184 kg/kWh /0.9 using the CO2 emissions for UK gas referenced above). t/MWh. As a first approximation this is assumed to be equivalent to the net CO_2 emission reduction from using wood pellets.	0.2044 t/MWh

Description	For domestic installations
Cost of abatement of CO_2 per tonne by domestic biomass boilers	£261

** Boiler of £5,750 lasting 20 years with 18 MWh/year heat input*

8.2.5 This indicative assessment of domestic biomass boilers leads to an unsubsidised cost of CO_2 abated of around £261 per tonne, which is of the order of 17% less than the minimum cost of the CHP scheme per tonne of CO_2. This magnitude of difference means that the simplifying assumptions should not affect the outcome, particularly since the CHP estimate is the minimum and this cost is certain to be greater. This comparison is based on domestic scale pellet boiler installations. Commercial scale installations would be considerably cheaper which would reduce the overall average cost per tonne.

8.2.6 The economics of wood pellets are greatly affected by the fuel price, which depends on the delivery method. For a large-scale take-up of wood pellet boilers in a particular area, fuel could be purchased in large quantities for many users by a cooperative. This form of purchasing has been organised by oil users in areas where oil use is common because of a lack of gas. The concentration of wood pellet users would be a reasonable comparison with a CHP scheme which must concentrate users in a restricted area.

8.2.7 From the above it would be reasonable to conclude that biomass boilers could produce cheaper overall CO_2 removal costs than the Wylfa Newydd CHP scheme, without any subsidy. The fact that there are subsidy schemes available makes the take-up much easier for consumers.

8.2.8 Since connection to the CHP heating system would be certain to be less than 100%, the costs of the CHP are likely to be an under-estimate whereas the average cost of wood pellet boilers at a similar scale are likely to reduce. The margin between the cost of biomass boilers and the CHP scheme would be likely to be significantly greater than shown in this initial assessment.

8.2.9 The biomass boiler installations have the following major advantages.

- They can be tailored to the circumstances and adjusted to all sizes of installation;
- There is much lower risk than for the CHP scheme, which requires the Wylfa Newydd Project to proceed, to obtain planning consents for the pipelines and installations and, most importantly, to obtain financing.

8.2.10 The CHP system is an integrated and complex system requiring a complex process to bring it about. There are many issues which could stop or delay all or part of the Wylfa Newydd Project. The biomass boiler installations are quick to plan and execute with very low risk.

8.2.11 This assessment has deliberately ignored subsidies for either the CHP system or the alternative technology because subsidies are only a mechanism of transferring part of the cost. The purpose of this assessment is to assess whether the CHP system is a viable overall investment, whoever pays the final cost. However, there are established subsides such as the Renewable Heat Incentive for wood pellet, which would make the use of this technology much more attractive to end users than the CHP scheme.

8.2.12 Wood pellet fired boilers were used as an example with wide application. There are many other technology options available including solar thermal, improved insulation and energy efficiency technologies, ground source and air source heat pumps. These technologies could be used anywhere and do not have to be tied to a geographical location to connect a CHP scheme to a particular heat source.

8.3 Industrial alternatives

8.3.1 There are potential industrial opportunities, which could lead to wealth creation as well as greenhouse gas emission reductions. North Wales produces forestry residues and woodchip that is already processed in the region. There are proposals to re-use the former Anglesey Aluminium Metal Ltd site to provide an innovative and complementary process based on a woodchip-fired CHP to provide 299 MW of electricity and use the heat, which would be lost to the steam turbine condensers, to heat water to grow prawns and then use the waste from prawn production to fertilise vegetable production. The prawns would also be processed and frozen on-site.

8.3.2 The details of this particular project are not the issue; it merely illustrates that innovative projects could be developed. It is not clear whether this proposal will finally achieve the necessary investment. However, such innovations would be much more productive for the local economy than the Wylfa Newydd CHP scheme. The use of biomass fuels allows steam to be produced and electricity to be generated, making the system a CHP scheme with much greater flexibility than a hot water based CHP scheme, intended for district heating, which is very limited for use in industry.

9 Discussion and Conclusions

9.1 Assessment summary

9.1.1 This assessment shows that the use of heat from the Wylfa Newydd Power Station in a CHP scheme is not considered to be a viable proposition. This outcome is consistent with other CHP studies and results from the remote location of the Power Station, meaning that the nearest significant head load for any CHP scheme is a long distance away. However, the following practical aspects make the proposal even less viable.

- The source energy at the Power Station has a significant commercial value (at least £10/MWh and probably significantly more), which reduces the revenue available to pay for the CHP infrastructure. The cost is high because of the high cost of nuclear power plants and the high value of nuclear electricity as an almost carbon-free technology. Successful district heating schemes use very low value heat.

- The available heat load is space heating, which has very poor overall utilisation of the CHP system. because the demand is only around 30% of the maximum heat transmission. This can be derived as follows:
  - 100% duty for 14 hours per day for four months of the year (mid-winter);
  - 70% duty for 10 hours per day for four months of the year (autumn and spring); and
  - 20% duty for six hours per day for four months of the year (summer).

  The poor utilisation means that there is a very poor return on the heating network infrastructure costs.

- There is no energy-intensive commercial user available who could use hot water. Such a user would be very helpful if their business could be located close to the Power Station. Unfortunately, the low population and restrictive planning designations, relatively difficult transport etc., mean that it is most unlikely that the development of a large commercial user would be possible close enough to the Power Station to be beneficial to the economics of the CHP scheme.

- The housing stock of the area is relatively old and a lot of dwellings in Holyhead are Victorian terraces. This means that connection pipework would need to be installed under roads which would be congested with other infrastructure, which is likely to make the installation more difficult and expensive than average. There are also several heat loads which will require long connections because this is not an urban area. This feature is also likely to make the connections more costly than average.

- The Wylfa plant site was selected in the Strategic Siting Review because of its excellent cooling which allows highly efficient turbine/generators to be used. Unless there is a compelling commercial or environmental case for abstracting steam, it is better for it to be used in the turbines to produce carbon-free electricity as designed.

- The development of the CHP scheme would be difficult to interface with the Power Station programme and to provide a reliable source of heat for the system customers. It is likely that the system would have to be developed using the standby gas boilers and then connect to the fully commissioned nuclear plant. In any event the practical establishment of the system would be complicated and costly.

9.1.2 The assessment conducted was intended to be high level and incorporates significant simplifying assumptions. However, the potential heat loads are so small and the pipeline lengths so long that the proposal for a district heating system is uneconomic by such a large margin that the uncertainties resulting from the simplifying assumptions cannot affect the result.

9.1.3 In summary, alternative power sources are more practical because of the following points:

- The CHP project would take many years to come to fruition because it is dependent on the operation of the Wylfa Newydd Power Station. This will prevent CO_2 abatement occurring when wood pellet boilers and similar technologies can be installed in the immediate future.
- It has been shown that there are other technologies that can abate CO_2 emissions at lower cost and with much less risk. A large number of alternative and more cost-effective CO_2 abatement technologies, such as wood pellet boilers, could be operating many years before the CHP scheme, and across a much wider area.
- There are potential innovative projects such as the CHP scheme proposed for the former Anglesey Aluminum Metal Ltd site. Such projects can make beneficial use of the opportunities of the area to create employment and abate greenhouse gas emissions.

9.2 Comparison of the Wylfa Newydd study with other assessments

9.2.1 The Wylfa Newydd CHP assessment can be compared to the report on the similar assessment submitted for the Hinkley Point C Generating Station application for development consent. The assessment also concluded that a Hinkley Point CHP scheme would not be viable by a significant margin. It can be seen in Table 9.1 that the potential Wylfa Newydd CHP Project has 12% of the heat load and around 10% of the houses in the area close to Hinkley Point, whilst the Wylfa Newydd Power Station heat distribution mains are also considerably longer.

Table 9.1: Proposed CHP scheme comparison

Issue	Hinkley Point C CHP assessment	Wylfa Newydd CHP assessment
Total heat load MWh/year	1,284,000	197,600
No. of houses	47,500	7,400
Approximate commercial heat load MWh/year	138,000	64,000
Main pipeline length	15 km	22 km

9.2.2 It is also reasonable to compare the findings of *The Potential and Costs of District Heating Network* (Pöyry and Faber Maunsell, 2009) with the results of this study. The report indicated that systems with a heat load of around 200MW within 15km of the site would be viable. The high winter heat load for the pipeline from the Power Station would be around 70MW within 22km of the site. Therefore, the heat load is around a third of that indicated by Pöyry and the pipeline length is almost 50% greater. Furthermore, the Pöyry report does not consider the additional costs of connecting to a nuclear plant which will increase the supply costs but without any corresponding increase in the value of the heat sales.

9.2.3 The sensitivity assessment included a calculation indicating that a minimum heat load of around 400,000MWh per year would be required to produce a system which breaks even with gas prices for 70% heat utilisation and a differential between domestic and commercial gas prices. This produces a peak heat load of around 180MW and so a system which could sensibly compete with gas would have a load of around 200MW, which is similar to the conclusion reached by the Pöyry report. This indicates that the assessments are producing results of the same order.

9.3 Conclusions

9.3.1 In line with the requirements of NPS EN-1 and NPS EN-6, this Assessment of the development of a combined heat and power system has been undertaken to support the application for a development consent order for the Wylfa Newydd Power Station.

9.3.2 This assessment shows that the use of heat from the Wylfa Newydd Power Station in a CHP scheme is not considered to be viable. This is principally because:

- The original value of the energy from the nuclear power plant is quite high because the heat could be used to provide high value carbon-free electricity in the highly efficient turbo generators, which benefit from low temperature cooling water at this location.
- The CHP system requires a long and expensive pipeline network in order to supply a very small heat load.
- The use of hot water, mainly for space heating, only uses about 30% of the total installed capacity of the system, giving very poor return on the investment.
- The cost of connecting premises is high compared to the revenue which can be raised from the heat sales.

- The costs and complexity of abstracting heat from a nuclear plant are much greater than for conventional sources of heat.

9.3.3 The CO_2 savings would also be modest and the cost per tonne of CO_2 abated would be higher than alternative options such as wood pellet boilers. The fact that there are more cost-effective means of achieving CO_2 reductions means that the option to use subsidies to make the system economic would be inappropriate.

9.3.4 This conclusion is considered to be in line with NPS EN-6, which acknowledges at paragraph 2.9.3 that "the economic viability of CHP opportunities… may be more limited for new nuclear power stations because the application of a demographic criterion for new nuclear power stations can result in stations being located away from major population centres and industrial heat demand".

9.3.5 The findings of the Wylfa Newydd CHP assessment are consistent with other reports on this subject, which show that much greater heat load is required to develop a commercially viable system. The commercial assessment has been subjected to a number of sensitivity assessments to demonstrate that the conclusions are robust and that no further evaluation is necessary.

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