SECURING POWER

POTENTIAL FOR CCGT CHP GENERATION AT INDUSTRIAL SITES IN THE UK

A report to Greenpeace

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EXECUTIVE SUMMARY

In this study we provide an analysis of the technical potential for combined heat and power (CHP), utilising the European Union Greenhouse Gas Emission Trading Scheme National Allocation Plan (EU ETS NAP) Phase II data for CO_2 to identify the potential heat loads across key industrial sectors of the UK economy. We then use this information to identify clusters (one site or greater) of industrial premises across the United Kingdom where there is significant potential for large scale CHP.

Traditionally the development of CHP has tended to be on a small scale and has generally been connected to the local distribution network rather than the national transmission system. Therefore although CHP has provided benefits in meeting energy demand, such as increased efficiency and reduced electrical losses, it has not been considered a viable option for the development of new large scale power stations.

Through clustering the heat loads at adjacent industrial sites, the development of large scale combined cycle gas turbine (CCGT) CHP could provide a number of advantages to both industrial customers, electricity producers and the environment. The clustering of industrial sites means that the size of heat demand will allow CCGT CHP deployment, which in turn produces a power to heat ratio of up to about 1.5:1, which means the efficiency of any development will be greater than a larger number of small scale plants.

Through the methodology we outline in Section 3, we derive a heat and electrical capacity for industrial sites across the United Kingdom. Table 1 presents the high level results for our optimistic and pessimistic case; this indicates that there is significant potential for CCGT CHP to meet the heat load of UK industry.

Table 1 – Potential heat and electrical capacity[1]

	Thermal (GWth)	Electrical (GWe)
Optimistic	11.9	16.3
Pessimistic	8.4	11.4

Source: Pöyry Energy Consulting

Our best estimate for the technical potential for additional CHP in UK industry is therefore 13.9GWe +/- 2.5GWe. We would re-emphasise that this is a technical potential; our analysis does not address the economies of large scale CHP compared with the alternative option of separate heat and power provision, or with industrial CHP at a smaller scale.

In the final Section (5) of this report we outline 9 case studies of clusters where we believe there is significant potential for CCGT CHP to meet local heat demand, as well as providing electrical capacity to the grid. The list of sites for the case studies is shown in Table 2.

[1] In this document all heat and electrical capacities are based on the technical potential.

Table 2 – Clusters with greatest potential for new or additional CCGT CHP technology

	Thermal (MWth)	Electrical (MWe)
Coryton	960	1,440
Ellesmere Port	905	1,358
Fawley	876	1,315
Grangemouth	1,375	2,064
Immingham	1,701	2,552
Pembroke	1,406	2,110
St Fergus	537	805
Teesside (Seal Sands)	432	627
Teesside (Wilton)	611	916
Total Capacity		**13,187**

Source: Pöyry Energy Consulting

1. INTRODUCTION

1.1 Background

During the summer of 2007 Pöyry Energy Consulting undertook a project for Greenpeace UK to examine the likely potential for industrial CHP in the UK, based on data from the AEA Heatmap website. Following this piece of work, Pöyry and Greenpeace have continued to discuss the potential for CHP and have also spoken with a number of industry representatives and the Combined Heat and Power Association (CHPA).

At a meeting between Greenpeace, Pöyry, the CHPA and industry participants on 18 December 2007, it became apparent that the group had concerns over the completeness and consistency of the AEA data, and that further analysis could be undertaken using the European Union Emissions Trading Scheme Phase II National Allocation Plan (EU ETS NAP II) allocations. This latter source contains primary data, which is more exhaustive than the secondary data in the Heatmap.

This project takes forward this analysis utilising the EU ETS NAP II data for CO_2 emissions to identify the technical potential[2] for CHP across key industrial sectors of the UK economy. We then use this information to identify clusters (one site or greater) of industrial premises across the United Kingdom where there is significant potential to build large scale CCGT CHP.

1.2 About Pöyry Energy Consulting

Pöyry Energy Consulting is Europe's leading energy consultancy providing strategic, commercial, regulatory and policy advice to Europe's energy markets. Part of Pöyry Plc, the global engineering and consulting firm, Pöyry Energy Consulting merges the expertise of ILEX Energy Consulting, ECON and Convergence Utility Consultants with the management consulting arms of Electrowatt-Ekono and Verbundplan. Our team of 250 energy specialists, located across 14 European offices in 12 countries, offers unparalleled expertise in the rapidly changing energy sector.

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2 In this document all heat and electrical capacities are based on the technical potential.

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2. A NEW APPROACH TO INDUSTRIAL CHP

There is potential for the development of large scale CCGT CHP in the United Kingdom. Traditionally CHP has been developed on a small scale (with the notable exception of Immingham) by industrial companies and electricity producers, to meet the heat demand at their own specific site. This approach may have neglected economies of scale and scope that could exist through companies being able to share risks and costs and the subsequent benefits of CHP development. One exception to this has been the highly successful Wilton International SembCorp facility in Teesside which provides heat and power to onsite industrial facilities; however our analysis indicates that even here there is technical potential for further expansion of CHP.

Because the development of CHP has traditionally been on a small scale and has generally been connected to low voltage distribution networks,, CHP has not generally been considered a viable option for the development of the new power stations needed to replace the retiring generation (eg due to the LCPD[3]) or to fill the generation gap that may be created by rising electricity demand. However, CHP has provided great benefits in meeting energy demand such as increased efficiency and reduced losses.

The implication of large scale CCGT CHP is that it will allow electricity customers and generators to utilise the increased efficiency of CHP (through delivery of heat to industrial demand), while at the same time ensuring that existing generation capacity is large enough to be considered a serious and economic alternative to other types of generation.

Through the clustering of neighbouring heat loads, the development of large scale CCGT CHP can provide a number of advantages to industrial customers, electricity producers and the environment. The clustering of industrial sites means that the size of heat demand will allow CCGT CHP deployment, which produces a power to heat ratio of up to about 1.5:1, which means the efficiency of any development will be greater than having a larger number of small scale plants (with a ratio of typically 1:1).

This clustering approach means that electricity producers will have more security with regard to the sale of heat produced. If electricity producers have the additional security of more than one customer or a single large site (such as a refinery) they are more likely to inject the additional finance needed to build a CCGT CHP station rather than a traditional electricity only power station. The benefits of increased demand for the heat output can be combined with the avoidance of the Climate Change Levy (CCL). (Rules relating to CHP LECs and the trading of LECs arising from both renewables and CHP are set out in HM Revenues and Customs Notice CCL 1/2[4]).

Finally, with regard to environmental impact, CCGT CHP could meet a substantial proportion of industrial heat demand with corresponding carbon emission savings.

The calculation of carbon emissions savings from CHP is important, given the substantial contribution that CHP can make to the government's climate change targets. In general, working out the savings is complex because CHP displaces a variety of fuels,

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3 Large Combustion Plant Directive which will require that several coal fired power stations retire before 2016.

4 HM Revenues & Customs Notice CCL 1/2: Combined heat and power schemes, August 2005 available on the website www.hmrc.gov.uk . LECs are Levy Exempt Certificates, where the levy is the CCL.

technologies and sizes of plant. According to the Department of Business and Regulatory Reform (DBERR), the carbon emission savings from CHP in 2006 as compared to fossil fuels was 4.2 million tonnes of carbon (MtC), which equates to 0.76 MtC per 1,000 MWe of installed capacity. The methodology for calculating these numbers is provided in the June 2003 Energy Trends publication. This indicates that the potential for carbon savings through the application of CCGT CHP scheme could be very large[5].

[5] Existing industrial CHP predominantly uses OCGTs (Open Cycle Gas turbines); the carbon saving from CCGT CHP would be greater than from OCGTs.

3. METHODOLOGY

3.1 Introduction

In this section we set out our methodology for the calculation of the technical potential heat load available based on relevant emissions from the EU ETS NAP II data[6]. Our assumptions were sent to Greenpeace for review prior to the commencement of the analysis (and in turn circulated to a 'Peer Review' group) and were adjusted based on the comments received.

3.2 Assumptions

Our assumptions are set out in a number of steps, providing a simple process for this analysis.

3.2.1 Step 1

Initially we determined which industrial sectors are suitable for CHP, by identifying existing CHP plant within the NAP data and those identified within the DBERR DUKES[7] publication. We were then able to remove from the analysis those heat loads which are unsuitable for CHP development.

On the basis of the above, we removed from the study the following sectors:

- Aluminium;
- Cement;
- Ceramics;
- Downstream Gas;
- Iron and Steel,
- Lime; and
- Offshore (only emissions related to facilities actually offshore).

Although there is some potential in the Iron and Steel sector, we understand this to be limited and so including this entire sector would bias the final results.

In addition we have also removed the emissions allocated to the power generation and other electricity producers sectors.

3.2.2 Step 2

In this second stage we have separated from the analysis those sites that already have CHP according to the NAP data, and those sites which are likely to be supplied by these existing CHP stations. The second part of this step involved identifying the postcodes of the existing CHP stations from the NAP II data and matching these with sites which claim no CHP but are located in the same postcode.

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6 The treatment of CHP in EU ETS NAP II data is described in Annex A.

7 http://www.berr.gov.uk/energy/statistics/publications/dukes/page39771.html

From this filtering process we have developed two lists, the first contains all existing industrial sites with access to CHP (whether or not there is scope for future expansion of that CHP), and the second includes all sites that have no CHP.

3.2.3 Step 3

Following step 2, we concentrated on the analysis of those industrial sites that currently do not have any access to CHP.

Utilising this list we performed a postcode matching analysis in which we mapped the industrial sites by postcode location across the United Kingdom. The intention of this step was to identify potential clusters of industrial heat loads that might then be met by CCGT CHP plants. We define a cluster as adjacent postcodes that contain potential industrial heat loads.

As part of this analysis we developed an optimistic and pessimistic approach as follows:

- Optimistic – all clusters of industrial sites have the potential for CCGT CHP development; and
- Pessimistic – half of these clusters have potential. This is because some of the clusters are likely to be constrained by physical and geographical obstacles.

These two scenarios were then taken forward and, based on the level of emissions from each site, we calculated the potential heat loads as described below.

3.2.4 Step 4

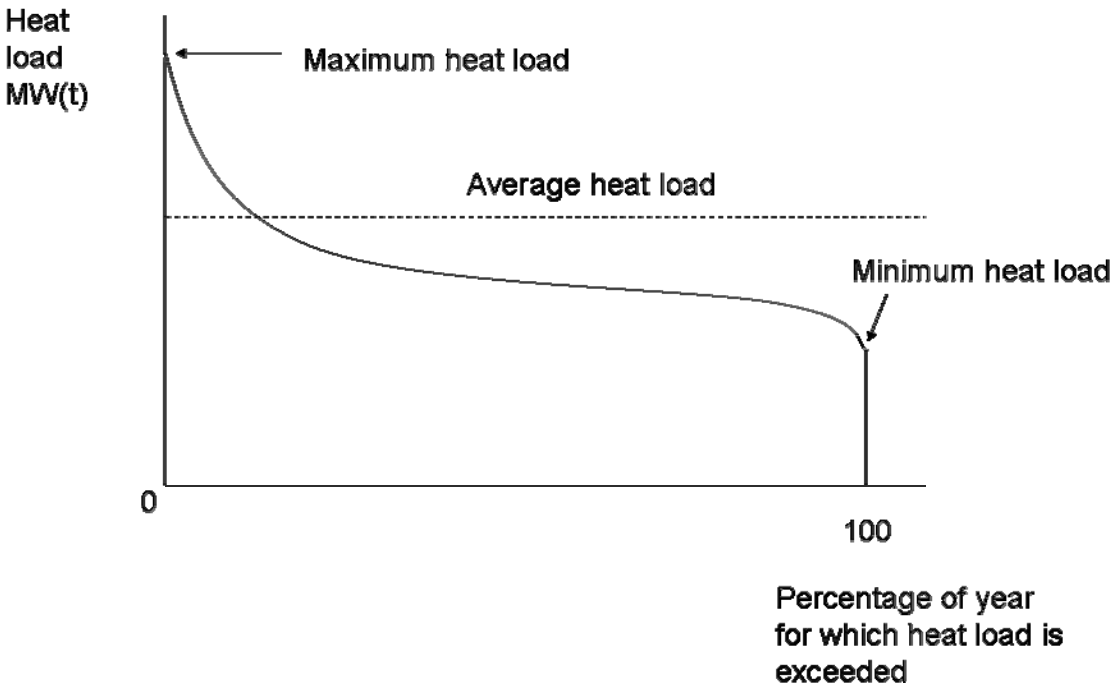
Step 4 involved converting the relevant emission data from the NAP II allocations into potential heat loads. For this it was important to ensure that we used the appropriate breakdown of fossil fuels currently used in each industry, as this impacts on the calculation of heat loads from the relevant emissions. Therefore to determine the heat loads we:

- used the breakdown of fossil fuels used by industry, as presented in the Digest of UK Energy Statistics (DUKES); and
- applied standard emission factors and heat production efficiencies based on DUKES data and Pöyry Energy Consulting modelling.

3.2.5 Step 5

Once we had calculated the heat loads for these industrial sites without CHP we had a MWh(t) figure of potential CCGT CHP development. We converted this MWh(t) value into MW(t) of heat production capacity, by assuming that each CHP scheme would be sized to meet the average heat load over the year. In practice, this would not be precisely the case in every situation, but certainly a CHP scheme is likely to be sized somewhere between the minimum and maximum heat loads. This is illustrated in the schematic heat load duration curve presented in Figure 1.

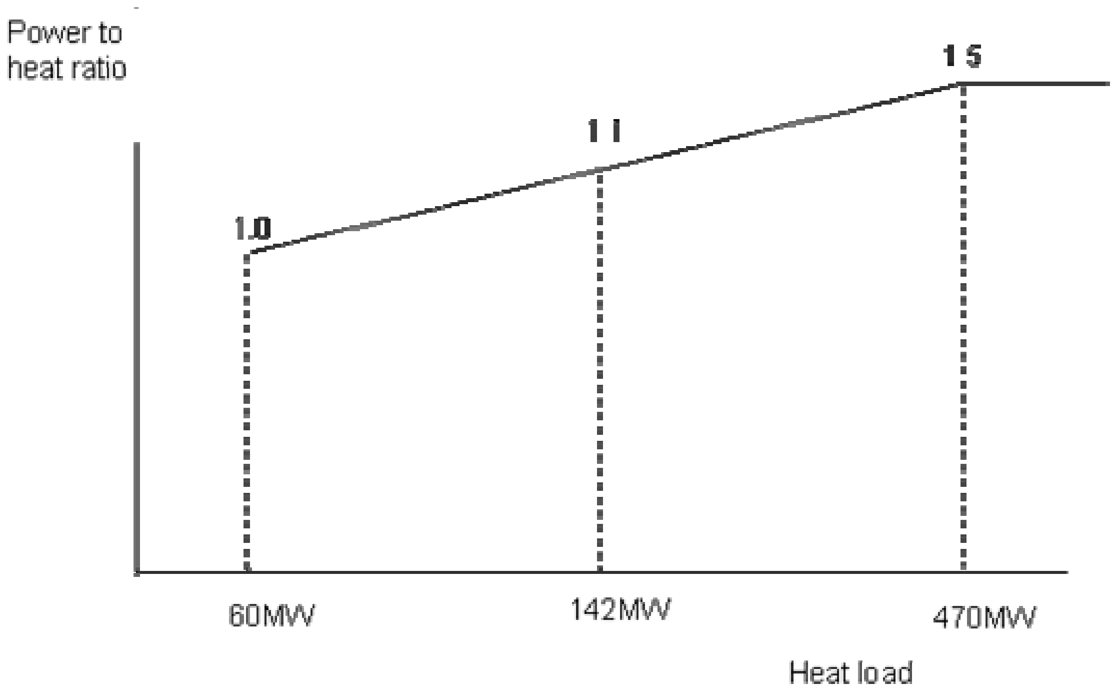
Figure 1 – Heat load duration curve



Source: Pöyry Energy Consulting

Finally we clustered the MW(t) into MW(e) of electricity generating capacity, assuming the power to heat ratios shown in Figure 2.

Figure 2 – Power to heat ratios for conversion from heat load to electrical generation



Source: Pöyry Energy Consulting

Figure 2 assumes a linear relationship between the data provided by Defra for various sizes of CCGT CHP[8].

3.2.6 Step 5a

In task 5 we developed the MW electrical potential of the previously identified clusters. In order to assess CCGT CHP potential we filtered out those sites below 50MW. We do not believe it would be rational to build a CCGT CHP at less that 50MW, although we accept that of course open cycle gas turbines (OCGTs) could be developed for such loads[9].

3.2.7 Step 5b

Finally, we performed a specific filter for those sites in the chemical industry. This is because certain chemical processes are known to be unsuitable for CHP development. For the pessimistic scenario we have assumed that only half of the chemical sites will be available for CHP, while on the optimistic side we have assumed that all these industrial chemical sites are available.

This then provided final estimates (pessimistic and optimistic) for the potential for CHP in those industrial sites that currently have no access to CHP.

8 'Analysis of the UK Potential for Combined Heat and Power', Defra, October 2007.

9 In fact, the inclusion of sub 50MW loads has very little impact on our final results for CHP potential (see Section 4).

3.2.8 Step 6

In this step we reverted back to the list of industrial sites that already have CHP as developed within Step 2. In this list there were two entries for each relevant NAP II Installation, one which contains emissions from CHP at the site and an entry which included all emissions (CHP and non-CHP). Then, in order to gauge the level of additional CHP potential, we subtracted the emissions allocated to CHP from the total emissions at the site. This gave a list of emissions which could be allocated to installation itself.

This revised list of installations and emission values was then analysed using the methodology set out in sStep 3 through to Step 5b.

3.2.9 Step 7

In this final step we calculated the total values of CCGT CHP potential in UK industry based on the assumptions described above.

This provided potential heat loads and electrical capacity for all sites with no CHP and for sites that have existing CHP. Additionally, these results are broken down based on our optimistic and pessimistic assumptions set out in Step 3, on clustering, and on Step 5b, (the chemicals sector). Finally, the results are split by those industrial clusters that have a greater potential than 50MW. These results are presented in section 4.

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4. RESULTS

4.1 Overview

This chapter presents the results for the technical potential for heat and electrical capacity from the analysis undertaken on the EU ETS NAP II data in line with the methodology set out in section 2. This section also outlines at a high level how CHP is treated in the NAP II allocations.

4.2 Total capacity

Table 3 and Table 4 present the results for the potential capacity for CHP from those individual and clustered sites currently with CHP and those currently with no CHP (for all clusters, and separately for those clusters greater than 50MW). The table presents the optimistic and pessimistic case; the optimistic case includes all sites, while the pessimistic case removes 50% of the additional heat load made available by clustering the sites (this does not impact upon large single sites). The tables also presents figures filtered to take account of the uncertainty around the chemical industry, with Table 3 including all of the heat from sites within the chemical industry, while Table 4 removes 50% of this capacity.

Table 3 – Potential heat and electrical capacity (includes all chemical industry)

	Sites with CHP		Site with no CHP	
	Thermal (GWth)	Electrical (GWe)	Thermal (GWth)	Electrical (GWe)
Optimistic	6.4	9.3	5.5	7.0
Optimistic > 50MW	6.2	9.1	4.8	6.3
Pessimistic	4.8	6.9	3.6	4.5
Pessimistic >50MW	4.7	6.8	3.3	4.2

Source: Pöyry Energy Consulting

As this analysis only considers the additional potential for CHP, these results do not include any potential capacity from the replacement of existing CHP, meaning that the overall capacity for CHP could be greater than these results. In addition, because a proportion the of current CHP facilities uses aging technology, it is less efficient. Therefore, when these facilities are replaced, the new technology will be more efficient which will increase both the power output and the level of carbon emissions savings (see section 4.6) than the current levels.

Table 4 – Potential heat and electrical capacity (includes only 50% of chemicals)

	Sites with CHP		Site with no CHP	
	Thermal (GWth)	Electrical (GWe)	Thermal (GWth)	Electrical (GWe)
Optimistic	6.0	8.7	4.8	6.2
Optimistic > 50MW	5.8	8.5	4.2	5.5
Pessimistic	4.4	6.3	2.9	3.7
Pessimistic >50MW	4.3	6.3	2.6	3.4

Source: Pöyry Energy Consulting

4.3 Consideration of the results

As we have previously stated, the results shown in this report present a technical assessment of the potential for industrial CCGT CHP based on emissions from the EU ETS NAP II allocations.

Therefore, from our own experiences and information provided by industry experts we have identified a number of factors which could still influence these results... For example, in certain industries, heat created from within the industrial process is utilised elsewhere. This means that it would be inefficient to replace this heat with CHP, as the waste heat will continue to be produced on site.

There is also concern over the reliability of heat supply which means that customers, such as refineries, have to maintain their own steam boilers at 40% load as insurance against losing steam from the CHP (which would lead to financial losses). If the heat recovery boiler of the CCGT could also be directly fired by natural gas, therefore increasing reliability, it could allay these concerns and give access to the demand being met by on site steam boilers.

A final consideration which has been identified is the view that being able to source heat from a number of fuel sources gives greater security of supply. This allows for hedging of price fluctuations and shortages of certain fuels which might be more difficult to achieve with gas fired CCGT CHP.

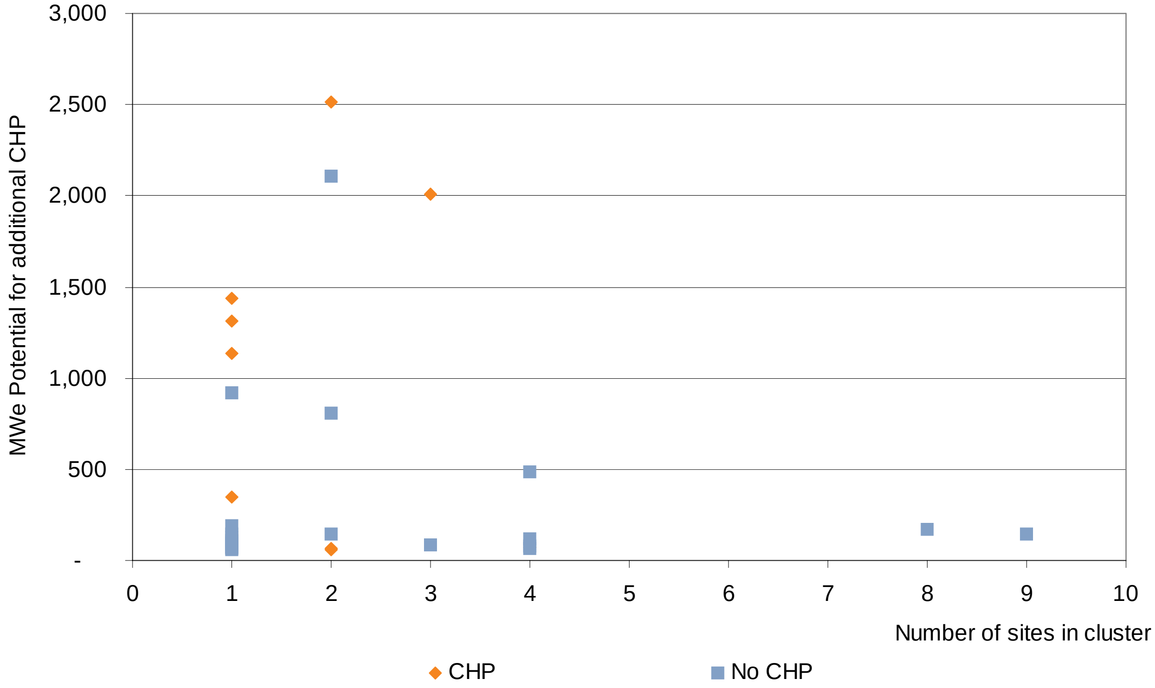
4.4 Distribution of clusters

Figure 3 and Figure 4 present the distribution of the derived clusters based on the electrical technical potential of each cluster and the number of sites which make up each individual cluster. Each site is assumed to correspond to one company, and as explained in the methodology (section 3.2.3), the clustered sites are within adjacent postcodes and thus close enough to be able to share the heat output generated from a single CHP located in each cluster.

The analysis presented in Figure 3 (sites greater than 50MW) indicates that the clusters with the greatest potential for additional CHP tend to be made up from two or three medium to large sites, however there are a number of large single site clusters. This distribution also highlights that the largest clusters tend to have existing CHP capacity.

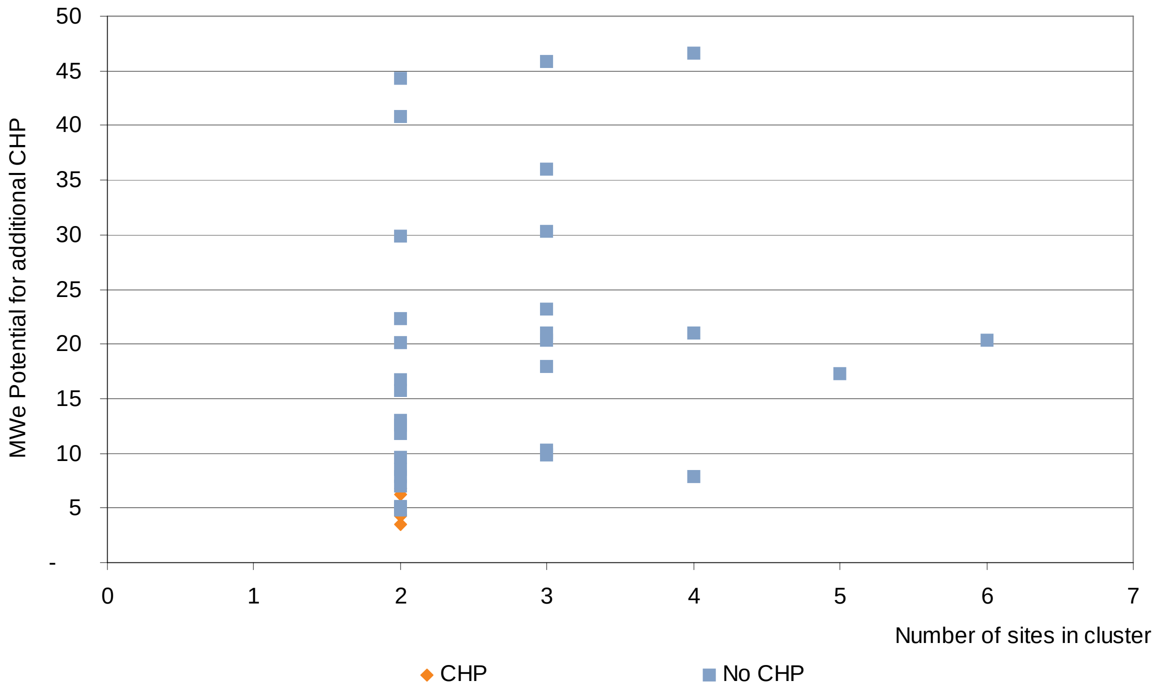
Those clusters under 50MW (Figure 4) are composed of two or three sites (single sites under 50MW are excluded from this analysis as stated within the methodology). The majority of these clusters have no existing CHP.

Figure 3 – Distribution of the clusters considering the number of sites within each cluster and the combined MWe potential capacity for CHP (>50MW)



Source: Pöyry Energy Consulting

Figure 4– Distribution of the clusters considering the number of sites within each cluster and the combined MWe potential capacity for CHP (<50MW)



Source: Pöyry Energy Consulting

4.5 Capacity at the largest clusters

Prior to this point we have separated those sites with existing CHP from those which have no CHP. This was due to the separation within the EU ETS NAP II data, and for ease of calculating the potential heat and electrical capacities. However, from this point on the analysis will focus on the heat and electrical capacity based on the geographical location of the industrial sites, so that the relative size of the clusters can be examined. We have based the cluster analysis on the figures derived from our optimistic scenario as we were able to remove the majority of the data uncertainty which surrounds these sites through our detailed examination of each of our chosen clusters (see section 5).

By combining the results from those sites with existing CHP, and those currently without, we were able to identify the clustered sites with the greatest potential for large scale CCGT CHP. The list of sites presented here is by no means complete, as there are a number of additional sites that could benefit from smaller scale CCGT CHP.

Table 5 shows the industrial locations identified for the case studies in section 5 together with the combined heat potential at each of these sites and the associated electrical capacity based on our calculations. This table identifies that of the total optimistic capacity of 16.3GWe across the UK (see Table 1), 13.2GWe is located at the 9 sites below. More detail with regard to these sites is provided in section 5.

Table 5 – Clusters with greatest potential for new or additional CCGT CHP technology

	Thermal (MWth)	Electrical (MWe)
Coryton	960	1,440
Ellesmere Port	905	1,358
Fawley	876	1,315
Grangemouth	1,375	2,064
Immingham	1,701	2,552
Pembroke	1,406	2,110
St Fergus	537	805
Teesside (Seal Sands)	432	627
Teesside (Wilton)	611	916
Total Capacity		**13,187**

Source: Pöyry Energy Consulting

4.6 Estimated carbon savings[10]

4.6.1 Savings from the portfolio of CHP schemes

Emissions savings from CHP must take into account not only developments in electricity-only and heat-only plants, but also improvements in CHP. Actual changes in emissions savings will thus depend on the relative improvements in each of the technologies. Therefore we have used the following assumptions:

- the electricity displaced will be from gas generation with 48% delivered efficiency, giving a carbon intensity of 104 gC/kWh;
- the heat displaced will be from new 90% efficient gas boilers (56 gC/kWh);
- for OCGTs CHP efficiency is assumed to be 35% with an overall efficiency assumed at 78%, whereas for CCGT technology we have assumed 42% CHP efficiency and 80% total efficiency; and
- for the calculation, the fuel for CHP is assumed to be gas and the average load factor is 60%.

10 Based on data and methodology from DBERR DUKES 2007.

4.6.1.1 OCGT

Table 6 represents the savings from future OCGT CHP compared with the alternative of electricity only CCGT. For this calculation we have assumed the average electrical efficiency of CHP will be 35% with an overall efficiency of 78%.

Table 6 – Savings from future OCGT CHP

	Output (GWh)	Emissions factor (gC/kWh)	Carbon emissions (MtC)
Equivalent emissions from electricity	5,256 (elec)	104 (elec)	0.55
Equivalent emissions from heat	6,457 (ther)	56 (ther)	0.36
Emissions from CHP	15,017 (fuel)	50 (fuel)	0.75
Savings per GWe			**0.16**

Source: DBERR data and Pöyry Energy Consulting Analysis

From this calculation it is shown that savings from OCGT CHP compared to electricity only CCGT is in the order of 0.16 MtC/GWe.

4.6.1.2 CCGT

Table 7 represents the savings from future CCGT CHP compared with the alternative of electricity only CCGT. For this calculation we have assumed the average electrical efficiency of CHP will be 42% with an overall efficiency of 80%.

Table 7 – Savings from future CCGT CHP

	Output (GWh)	Emissions factor (gC/kWh)	Carbon emissions (MtC)
Equivalent emissions from electricity	5,256 (elec)	104 (elec)	0.55
Equivalent emissions from heat	4,755 (ther)	56 (ther)	0.27
Emissions from CHP	12,514 (fuel)	50 (fuel)	0.63
Savings per GWe			**0.19**

Source: DBERR data and Pöyry Energy Consulting Analysis

From this calculation it is shown that savings from CCGT CHP compared to electricity only CCGT is in the order of 0.19 MtC/GWe.

To assess the sensitivity of these results we have applied an increased load factor of 72% for CHP to the CCGT calculation. By applying this increased load factor the savings from CCGT CHP compared to electricity only CCGT could be in the order of 0.23 MtC/GWe, compared to 0.19 MtC/GWe with a 60% load factor.

This gives a range of savings from CCGT CHP compared to alternative electricity only CCGT from 0.19 MtC/GWe up to 0.23 MtC/GWe.

As a final sensitivity we have assumed that CHP replaces a mix of both gas and coal fired power stations rather than gas fired power stations alone. For this analysis we have assumed the same efficiency as previously in the gas fired power station (48%), while assuming 36% efficiency at the coal fired stations. Table 8 presents these results.

Table 8 – CCGT CHP savings replacing gas and coal fired power stations

	Output (GWh)	Emissions factor (gC/kWh)	Carbon emissions (MtC)
Equivalent emissions from electricity (gas)	2,628 (elec)	104 (elec)	0.27
Equivalent emissions from electricity (Coal)	2,628 (elec)	220 (elec)	0.59
Equivalent emissions from heat	4,755 (ther)	56 (ther)	0.27
Emissions from CHP	12,514 (fuel)	50 (fuel)	0.63
Savings per GWe			**0.51**

Source: DBERR data and Pöyry Energy Consulting Analysis

From this calculation it is shown that if we assume the new CCGT CHP will replace an even mix of coal and gas fired power stations, savings will be the order of between 0.51 MtC/GWe at 60% CHP load factor and 0.61 MtC/GWe at 72% CHP load factor.

However, we must qualify these results on the basis that it is unlikely that coal power? stations are a viable alternative to gas fired CCGT CHP. This view is influenced by the likelihoods of 100% auctioning of CO_2 allowances in EU ETS Phase III and of the need to fit selective catalytic reduction (SCR) for NOx control, by 2016. The recent controversy over Kingsnorth and CCS also points to difficulties in developing new coal plants.

There is, moreover, a more fundamental point. The concept of large scale CHP based on CCGTs envisages the development of CHP-CCGTs as a direct alternative to electricity only CCGTs. Therefore, measuring the CO_2 saving from CHP-CCGTs against a mix of electricity-only CCGTs and coal then implies rewarding CHP with some of the CO_2 saving which would in any case arise from building electricity only CCGTs rather than coal.

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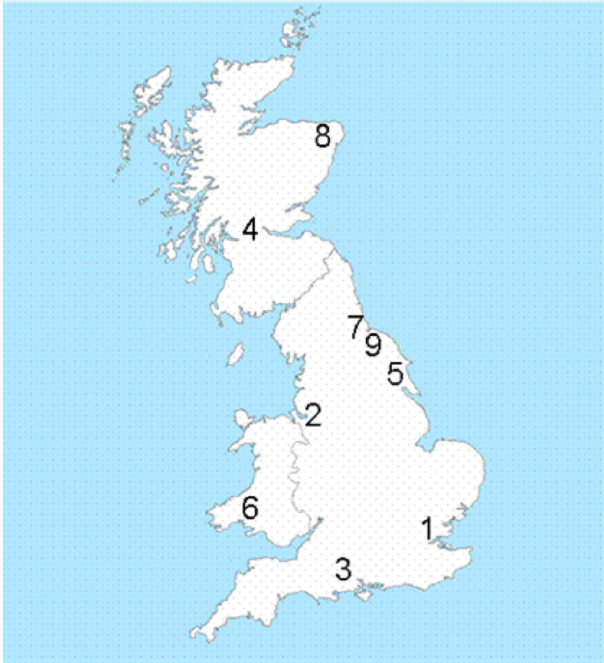
5. CASE STUDIES

5.1 Introduction

The following section presents our case studies illustrating the technical potential for large scale CHP at industrial locations across the United Kingdom. The industrial sites examined are those which we have identified as having the greatest technical potential for the construction of efficient CCGT CHP close to heat demand. Figure 5 below marks the location of the nine industrial sites identified for the case studies.

Figure 5 – Map of industrial sites examined in our case studies



1	Coryton
2	Ellesmere Port
3	Fawley
4	Grangemouth
5	Immingham
6	Pembroke
7	Seal Sands
8	St Fergus
9	Wilton

Source: Pöyry Energy Consulting

The case studies are presented in four sections. The first provides an overview of the site, including location and relevant features of the area as well as the identified heat load and associated electrical generation potentially available from additional CCGT CHP. The second section details any existing on-site generation and information on the key participants operating out of the site. In this section we have identified both existing CHP and conventional generation that is operating at these industrial locations.

In the third section we describe the future plans for generation at these sites. We have identified that a number of the industrial locations already have plans for new or replacement generation; but this is not necessarily CHP generation. For this section we have utilised company information together with DBERR Section 36 consents and the 'Platts' Power Station Tracker.

Finally, the case studies provide industry comment from the Peer Review group set up by Greenpeace to ensure that the study reflects the most up-to-date information available from the industry. These views also provide a unique insight into the pros and cons of installing large scale CCGT CHP generation at the identified locations.

5.2 CORYTON

Coryton, Stanford-le-hope, Essex, SS17 9ll.

	MW Thermal	MW Electrical
Potential for additional CCGT CHP	960	1,440

5.2.1 Background

The Petroplus Coryton refinery is located on a 589-hectare site in the south-east United Kingdom, approximately 40km east of London. The refinery is an integrated atmospheric-vacuum distillation, fluid catalytic cracking refinery with a crude oil throughput capacity of 172,000 barrels per day and additional throughput capacity of up to 70,000 barrels per day of other feedstocks.

This potential electrical load is based solely on emissions data from the Petroplus Holdings refinery. This refinery terminal and bitumen business, previously owned by BP, was sold to Petroplus on 1 June 2007.

The refinery's main units include: an atmospheric distillation unit; a vacuum distillation unit; a fluid catalytic cracking unit, an isomerization unit; a catalytic reforming unit; an alkylation unit; and several desulphurization units.

5.2.2 Existing generation

DBERR DUKES data indicate that there is currently a CHP with a capacity of 35.3MWe on site.

In addition, directly west of Coryton Refinery is a gas fired CCGT power station owned by Intergen. The CCGT is a 732 MW CCGT, including low emissions gas turbines and air-cooled condensers, but is not classified as CHP.

5.2.3 Future developments

Beyond the Intergen power station is the derelict site of what was Shell Haven refinery which shut down in December 1999. In 2000 Shell granted P&O exclusive rights to develop part of the site of the former refinery into a major container and multi-use port, with associated industry. P&O will also help develop plans for the remainder of the site. Following an initial rejection of planning application, P&O successfully appealed the decision in 2007. This decision increases the possibility of additional industry at the site and should increase the potential heat load at this location.

5.2.4 Industry comment

We have been unable to contact any experts regarding this site.

5.3 ELLESMERE PORT

Ellesmere Port, Cheshire, CH65

	MW Thermal	MW Electrical
Potential for additional CCGT CHP	905	1,358

5.3.1 Background

Ellesmere Port is a large industrial town and cargo port in the district of Ellesmere Port and Neston, Cheshire, England, situated in the Wirral Peninsula on the estuary of the River Mersey, to the north of Chester.

This potential heat load is made up from a number of industrial sites within the Ellesmere Port area. However, a large proportion of the potential relates to the Stanlow refinery and manufacturing complex owned by Shell.

5.3.1.1 Shell Stanlow Manufacturing Complex

The Stanlow Manufacturing Complex is at the heart of Britain's oil and chemical production industry. Stanlow lies on the south bank of the Manchester Ship Canal. It processes 12 million tonnes of crude oil a year, mainly from the North Sea.

The complex integrates the refinery with the adjoining Shell Chemicals plants. Crude oil is received at the Tranmere oil terminal on the Mersey and is transferred by pipeline to storage at Stanlow. Finished products are delivered by pipeline (40%) via the northern end of the UK oil pipeline (UKOP), road (30%) from the loading terminal at Stanlow and water (30%), via the Manchester Ship Canal.

5.3.2 Existing generation

Information from the DBERR Dukes publication indicates the current CHP capacity to be 109MWe at the Stanlow site, with an additional CHP facility operating at the nearby Bridgewater paper company with a capacity of 40MWe.

5.3.3 Future developments

There is no information regarding any future development at this site.

5.3.4 Industry comment

We have been unable to contact any experts regarding this site.

5.4 FAWLEY

Fawley, Southampton, SO45 1TX

	MW Thermal	MW Electrical
Potential for additional CCGT CHP	876	1,315

5.4.1 Background

The ExxonMobil refinery at Fawley on Southampton Water is the largest in the UK. The refinery processes some 300,000 barrels of crude oil a day, and supplies around 14% of all petroleum products in the UK.

This potential electrical load is based solely on emissions data from the ExxonMobil refinery.

At Fawley, ExxonMobil Chemical produces over a million tonnes of chemical products every year, manufacturing halobutyl rubber that is used in products such as tyre linings.

5.4.2 Current generation

There is currently an onsite CHP station with a capacity of 135MWe at the Fawley refinery; ExxonMobil introduced this facility as part of a policy to help reduce on-site emissions.

In addition, there is an oil-fired power station close by operated by RWE. It is powered by heavy fuel oil. The station was built in the 1960s and is also located on Southampton Water. It began operation as a 2,000MW power station with four 500MW generating units. Two units closed during the 1990s, and the remainder of the plant will close by 2015 due to the restriction placed on its generation as part of the Large Combustion Plant Directive.

5.4.3 Future developments

Although there are no public plans to replace the Fawley power station, the site provides an ideal location for a new CCGT CHP plant. The existing infrastructure in the area should help reduce the initial capital costs.

5.4.4 Industry comment

We have been unable to contact any experts regarding this site.

5.5 GRANGEMOUTH

Grangemouth, Falkirk, Stirling, Scotland

	MW Thermal	MW Electrical
Potential for additional CCGT CHP	1,375	2,064

5.5.1 Background

Situated close to the Firth of Forth, Grangemouth was expanded during the 1970's bringing the refining capacity to around 10 million tonnes per year. It is directly connected to the North Sea oil fields via the Forties Pipeline System, from which it sources the majority of its crude oil at a significant freight advantage versus its competitors. It is also connected to its own deep water terminal at Finnart on the west coast of Scotland via which it imports alternative crudes.

This potential heat load is made up from a number of industrial sites within the Grangemouth area. However, a large proportion of the potential relates to the Ineos refinery and chemical plant which were previously owned by BP.

5.5.1.1 Ineos Refining and Chemicals

In 2005, Ineos completed the purchase of BP's Innovene olefins, derivatives and refining subsidiary for $9bn. The petrochemicals facility manufactures over 2 million tonnes of chemical products per annum and the refinery has an annual capacity of 10 million tonnes. The site is strategically placed to make use of crude oil and natural gas liquids from the North Sea and transforms them into petrol, fuel products and a range of olefins and polymer products.

5.5.2 Existing generation

Current CHP capacity at Grangemouth is 295MWe and is operated for the Ineos – Innovene group.

The gas fired CHP plant started its commercial operation in July 2001. It is equipped with a 130 MW Siemens V94.2 gas turbine and also produces 2x250 t/h of steam for the needs of the Ineos - Innovene manufacturing group.

5.5.3 Future developments

In addition to the existing potential heat loads at the Grangemouth site, Ineos Enterprises has submitted a planning application for a major investment in a new biodiesel production plant. The plant (if it receives planning permission) will have at least 500 ktes of capacity; the strategy is to achieve at least 2 million tonnes of biodiesel output by 2012.

5.5.4 Industry comment

Not all current CHP at Grangemouth is 'Good Quality', and much of the steam is delivered from ageing boilers. Therefore, although it is difficult to estimate the level of additional CHP, there may be an opportunity to replace existing CHP.

5.6 IMMINGHAM

Immingham, Humber Estuary, North East Lincolnshire

	MW Thermal	MW Electrical
Potential for additional CCGT CHP	1,701	2,552

5.6.1 Background

The potential thermal and electrical capacities outlined above are made up from three industrial sites. The majority of the potential is from the two refineries owned by ConocoPhillips and Total (the Lindsay Refinery).

5.6.1.1 ConocoPhillips refinery

The Humber refinery is one of the most complex refineries in ConocoPhillips' portfolio and one of the most sophisticated in Europe. It is a fully integrated refinery that produces a high proportion of transportation fuels, such as gasoline and diesel fuel. Humber's fluid catalytic cracking unit/thermal cracking/coking configuration means that substantial volumes of other feedstocks, such as low-sulphur fuel oil and vacuum gas oil, are processed alongside crude oil to fully utilise Humber's cracking capability.

5.6.1.2 Total Lindsay refinery

Lindsay Oil Refinery (LOR) is currently Britain's third largest, with a processing capacity in excess of 10 million tonnes per annum (over 200,000 barrels per day). Coming on-stream in 1968, and now incorporating some of the most advanced refining and conversion processes available, LOR has the flexibility to process over 40 different types of crude oil, with the refinery ideally situated geographically to take advantage of North Sea oil, which accounts for between 85% and 95% of the refinery feedstock.

5.6.2 Existing generation

The CCGT CHP plant operated by Immingham CHP is the largest cogeneration plant in Europe with a capacity of 730MWe. The plant has four boilers and each boiler is capable of supplying more than half of the maximum demand of each refinery, the basic design concept being to always have available 3x50% of the total steam requirements of both refineries combined. This means that, if one of the boilers is forced to shut down, refinery steam demands can continue to be met – a crucial factor in refinery operation.

The Immingham CHP plant is a fully qualifying scheme as defined under both the UK Good Quality CHP programme and under the EU Cogeneration Directive. It has benefited from UK government measures designed to encourage quality CHP, in particular enhanced capital allowance treatment and exemption from the Climate Change Levy.

In addition there is a 38MWe gas turbine CHP at the Lindsay refinery, this is combined with a 140 tonne/hr waste heat boiler.

5.6.3 Future developments

On 1 August 2006, DBERR accepted the Section 36 application by ConocoPhillips to expand the capacity at the Immingham CHP plant by 450 MW, from 730 MW to 1,180 MWe. This expansion will make Immingham CHP one of the world's largest and most efficient power stations, and an additional source of low carbon heat and power for UK. Commercial operation of the expansion is currently expected to start in summer 2009.

5.6.4 Industry Comment

From our discussions with relevant industry contacts, it was suggested that following the upgrade of Immingham CHP to 730MWe and an increase in the number of smaller industrial users in the area developing their on-site CHP, the potential may be reduced.

Furthermore it was stated that a proportion of the emissions allocated to the sites are created from processes that cannot be replaced by heat from CHP (i.e. the use of Petroleum as a catalyst or raising heat from refinery gases). Also, due to concerns about the reliability of heat supply, consuming sites tend to operate their boilers at part-load in case CHP supply fails.

However, following further discussions it was confirmed that there is significant potential, particularly if the reliability of CHP heat supplies can be assured.

5.7 PEMBROKE

Pembroke, Pembrokeshire, Southwest Wales

	MW Thermal	MW Electrical
Potential for additional CCGT CHP	1,406	2,110

5.7.1 Background

The total above relates to the combined potential CHP MW capacity for Milton Haven and Pembroke, although the Pembroke and Milton Haven sites are on opposite sides of the mouth of the River Cleddau. This obviously increases the complexity of building any CCGT CHP and transporting the heat across the river. We believe there are a number of options for development in this area; one would be to build two separate CCGT CHP stations, either side of the Cleddau.

5.7.1.1 Chevron Pembroke refinery

Pembroke Refinery is situated on the Pembroke coast and came on stream in 1964. Capacity at that time was 6 million tonnes per year and over the years has been increased to 10.5 million tonnes with the addition of extra processing and upgrading units. The deep and sheltered waters provide one of the few ports in Europe that can accommodate the largest tankers. The refinery specialises in processing heavy, lower-quality crudes, allowing it to take advantage of the significant price differential that exists between light crude oils and lower-valued heavy sour crudes.

5.7.1.2 Milton Haven refinery

Milford Haven facility was operated by Total as a 70/30 joint venture with Murco until late 2007 when Murco acquired the majority interest. The refinery originally came on stream in 1973 under Amoco's ownership, and Murco joined as a partner in 1981 when a catalytic cracker was added.

A major upgrade was carried out in 1981 and since then further units have been added, notably a naptha isomerisation unit and a hydrodesulphurisation unit.

5.7.2 Existing generation

There is currently an 18MWe CHP at the site.

5.7.3 Future developments

5.7.3.1 RWE npower

RWE npower has submitted an updated Environmental Statement (ES) for its planned electricity-only 2GW CCGT at Pembroke. Although an ES examining the likely impact of the gas fired CCGT plant was submitted in 2005, the company has since carried out further detailed consultation and environmental surveys, making it necessary to update the data in the ES. The project has a grid connection agreement that starts in 2008/9.

5.7.3.2 Milford Energy

Milford Energy, a joint venture between BG Group and Petroplus, is looking at upgrading the old 18MWe CHP plant on the Petroplus site to a 40MWe CHP plant. The plant has Section 14 consent and will provide energy for the LNG terminal.

5.7.3.3 Milford Power

Milford Power has withdrawn its application for Section 36 consent to build a 1,600-MW CCGT and is looking again at the technical aspects of the project, particularly the size, configuration and cooling. The project could be as large as 2GW and could be phased in over a number of years. Petroplus expects to resubmit a Section 36 application in the near future.

5.7.4 Industry Comment

There have been plans in place to develop CHP in this area over the last decade; however the exact reasons why a scheme has never been built remain unclear.

It has also been estimated that high grade steam can be transported up to two miles. This raises the possibility of a single site transferring heat across the Cleddau river.

5.8 SEAL SANDS

Seal Sands, Teesside, Middlesbrough TS2

	MW Thermal	MW Electrical
Potential for additional CCGT CHP	432	627

5.8.1 Background

The Seal Sands complex stands on the North side of the River Tees which produces a natural barrier between this site and the Wilton development owned by SembCorp (see 5.10). Although the Seal Sands complex is smaller than the Wilton site, it has grown in recent years and continues to attract the largest industrial users. (In March 2008 Ineos completed the purchase of the BASF chemical site with a view to expand the facility subject to approval by the competition authorities).

This potential heat load is made up from a number of industrial sites within the Seal Sands region, the largest share of the heat load relates to the Petroplus refinery and at the ConocoPhillips facility.

5.8.1.1 Petroplus Refinery

The Teesside refinery is located on a 40 hectare site. Built in 1966 it was acquired by Petroplus in the year 2000. The refinery is focused on straight run distillation with a capacity of 117,000 barrels per day.

The Teesside refinery is able to produce low sulphur diesel that already meets the EU 2009 mandatory maximum 10ppm sulphur limit for gasoline and diesel. The refinery supplies approximately 17% of all commercial diesel demand in the UK.

5.8.2 Existing generation

There are a number of small CHP plants in the area, the largest of which is the 75MWe RWE npower CHP at the now Ineos Chemical facility (formally BASF – see above).

5.8.2.1 RWE npower – Ineos

The 75MWe plant comprises a 40MWe gas turbine, alongside a steam turbine generator producing a further 35MW of electricity.

5.8.2.2 RWE npower - ConocoPhillips

The plant is based on a 40MWe Frame 6 gas turbine generator and a 60 tonne unfired waste heat recovery boiler combined with an 18MWe steam turbine. The project started as conventional generation but conversion to CHP was completed in October 2005.

5.8.3 Future developments

5.8.3.1 Thor-cogeneration (px-group)

The company is seeking permission to build a 1,020 MW CHP station at the Seal Sands plant in North Tees. All key consents have been applied for, and construction was expected to begin later in 2007. However the development is still awaiting Section 36 permission.

5.8.3.2 ConocoPhillips

ConocoPhillips has applied for Section 36 consent to build an 800MW CHP station at its Teesside oil terminal at Seal Sands near Middlesbrough. The CHP plant will provide power and steam to a proposed LNG import facility and nearby businesses. Waste heat will also be used for vaporisation of LNG.

5.8.4 Industry Comments

There are currently plans in place to develop a further large scale CHP at the site. It is expected that this facility will provide heat to multiple sites in the area. This type of facility would look to mirror the infrastructure currently in place at the nearby Wilton International site.

5.9 ST FERGUS

St Fergus, Aberdeenshire, Scotland, AB42 3EP

	MW Thermal	MW Electrical
Potential for additional CCGT CHP	537	805

5.9.1 Background

The St Fergus Gas Terminal has facilities operated by Total (with an adjacent distribution terminal built by British Gas-Transco), Shell and ExxonMobil. Opened in 1977, these facilities receive and process gas from the North Sea and provide a natural gas supply throughout the UK.

5.9.1.1 Total

The St Fergus Gas Terminal was originally constructed in two phases to process gas from the Frigg Field – Phase 1 in 1977; Phase 2 in 1978. A further phase was constructed when the Alwyn Field with its richer gas was discovered in the 1980s, with Phase 1 being decommissioned. This third phase was subsequently expanded by the addition of a third gas train upon the entry of the Bruce Field. Phase 2 and the pipeline connected to it from Vesterled, which is part of the Norwegian Gassled system.

5.9.1.2 ExxonMobil (Sage terminal)

The Scottish Area Gas Evacuation (SAGE) gas plant at St Fergus, accepts gas from the Beryl field and from the Brae, Scott and Britannia fields. It also processes gas from the Atlantic and Cromarty fields owned and operated by Amerada Hess and BG Group.

5.9.1.3 Shell

Shell operates the Far North Liquids and Gas System (FLAGS), linking associated gas deposits in the Brent oil system with St Fergus. The resultant liquids are sent to the Mossmorran Plant in Fife, where the constituent parts are separated out.

5.9.2 Existing generation

There is currently no CHP generation at St Fergus, although the existing SSE power station at Peterhead is within 10km.

5.9.3 Future developments

There is no information regarding any future development at this site.

5.9.4 Industry Comment

We have been unable to contact any experts regarding this site.

5.10 WILTON INTERNATIONAL

Wilton International, Teesside, Middlesbrough, TS10

	MW Thermal	MW Electrical
Potential for additional CCGT CHP	611	916

5.10.1 Background

The Wilton International site, owned by SembCorp Utilities (UK) Limited, is one of few sites in Western Europe with special development status, designed for heavy industrial use such as chemicals and process plant.

Many of the world's leading chemical and manufacturing companies are already well established at Wilton, including blue chip multinationals such as INVISTA, DuPontSA, Huntsman, Dow and Uniqema.

The site already has CHP but the potential for further CHP generation (highlighted in the table above) at the Wilton International site is based on emissions from the Huntsman Petrochemical olefins 6 cracker. The olefins 6 cracker is one of the largest single train ethylene units in Europe.

In addition 'Ensus' is expected to complete the development of its bioethanol plant in early 2009 and will have an annual production capacity of over 400 million litres. This plant will use established technology to ferment and distil wheat grain and the ethanol produced will be water soluble, biodegradable and non-toxic.

5.10.2 Existing generation

The Wilton site has purpose built CHP and the steam production is a key draw for industry attracted to the site. The site has its own distribution network comprising of the Wilton Power Station, four primary substations, 80 secondary switch houses, and approximately 400 miles of power cables and 268 transformers.

5.10.2.1 Wilton Power Station

This station is a 175MWe CHP Plant capable of producing up to 600 tonnes of steam an hour.

5.10.2.2 SembCorp biomass plant

The station became the UK's first large scale 'wood to energy' plant when it began full commercial operations in October 2007. It uses 300,000 tonnes of wood a year as its biomass fuel. Taking wood from a variety of sustainable sources in the UK, the plant is capable of generating 30 MW of electricity. This facility is currently not CHP but it would be possible to upgrade it to provide steam if the right incentives were put in place.

5.10.2.3 Teesside Power Station

Recently acquired by the GDF / Suez group, the station has traditionally provided heat to the Wilton International site. Although not set up as a pure CCGT CHP, the 1875 MWe

Teesside Power Station was built with the potential of delivering 600tonnes/hr of steam, however delivery has only been around 100/200 tonnes/hr.

5.10.3 Future development

Ground works have begun on a 40 MWe, 162 tonne per hour steam CHP project at the site. SembCorp has signed an agreement with AkerKvaerner Engineering Services to provide the engineering design, construction and commissioning work for the CHP plant, which is to comprise an open cycle gas turbine and heat recovery steam generator.

5.10.4 Industry Comment

The Wilton site provides heat to its customers through a number of sources including on site CHP and steam from the nearby Teesside Power Station. In addition some of the on site industry generates its own steam, and in some cases sell this back to the site.

At the current time the owners believe that the current heat load is being met but this may change if new industry sets up at the site. It appears that the speed at which new industry joins the site will impact on whether they undertake a process of replacement through large scale CCGT CHP or continue to increase steam capacity through incremental increases of current CHP.

Any large scale CCGT CHP scheme would have to be carefully considered along side the aims of the Wilton site's aim of maintaining security of supply through multiple sources, but it would not be ruled out.

There was concern about current incentives in place to encourage CHP and its financing through the uncertainty of what will happen after the end of incentive schemes, such as the Climate Change Levy and the EU ETS.

ANNEX A - TREATMENT OF CHP IN EU ETS NAP II

The government has adopted a standard methodology in order to take account of the creation of a Good Quality Combined Heat and Power (GQ CHP) sector for Phase II. All schemes certified under the UK's CHP Quality Assurance (CHPQA) programme are included in the GQ CHP sector.

The CHPQA's assessment of whether a CHP scheme qualifies as Good Quality depends on two key parameters:

- the Quality Index (QI), which is an indicator of the energy efficiency and environmental performance of a scheme; and
- power efficiency, which is the total annual power output (TPO) divided by the total annual fuel energy input (TFI).

For schemes that meet the Threshold QI Criterion, the qualifying power capacity (QPC) is the same as the total power capacity, i.e. QPC = TPC.

For schemes that do not qualify as Good Quality CHP for the whole of their output, the QPC is calculated as the portion of the power generating capacity that would provide a QI value of 100 for existing schemes, and 105 for new schemes based on design data, under conditions of Maximum Heat Output under Normal Operating Conditions. Such schemes are referred to as partially qualified CHP schemes.

The relevant emissions for GQ CHP schemes are then calculated as the average of a GQ CHP scheme's historic emissions from 2001 to 2003, after dropping its lowest year of emissions from the baseline. Adjustments are also made to account for CHP schemes that are partially qualified.

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