CHP Ready Guidance for Combustion and Energy from Waste Power Plants

V1.0 February 2013

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List of Abbreviations

Abbreviation	Description
AQMA	Air Quality Management Area
BAT	Best Available Techniques
BREF	BAT Reference Document
CBA	Cost Benefit Analysis
CCR	Carbon Capture Ready / Carbon Capture Readiness
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
CHP-R	Combined Heat and Power Ready
DECC	Department of Energy and Climate Change
DCO	Development Consent Order
DUKES	Digest of United Kingdom Energy Statistics
EED	Energy Efficiency Directive
EfW	Energy from Waste
ELV	Emission Limit Value
EU	European Union
GWh	Gigawatt hours
HHV	Higher Heating Value
IED	Industrial Emissions Directive
IPPC	Integrated Pollution Prevention and Control
km	Kilometres
kW	Kilowatts
LCPD	Large Combustion Plant Directive
MW	Megawatts
NPPF	National Planning Policy Framework
NPS	National Policy Statement
PPC	Pollution Prevention and Control
SEPA	Scottish Environment Protection Agency
UK	United Kingdom

Contents

Foreword

The Environment Agency requires that all applications for Environmental Permits for new installations regulated under the Environmental Permitting (England and Wales) Regulations 2010 demonstrate the use of Best Available Techniques (BAT) for a number of criteria, including energy efficiency. One of the principal ways in which energy efficiency can be improved is through the use of Combined Heat and Power (CHP). With respect to the use of CHP, there are three BAT tests which should be applied. These are as follows:

First BAT Test:

The Environment Agency considers that BAT for energy efficiency for new combustion power plant or Energy from Waste (EfW) plant is the use of CHP in circumstances where there are technically and economically viable opportunities for the supply of heat from the outset.

The term CHP in this context represents a plant which also provides a supply of heat from the electrical power generation process to either a district heating network or to an industrial / commercial building or process.

However, it is recognised that opportunities for the supply of heat do not always exist from the outset (i.e. when a plant is first consented, constructed and commissioned).

Second BAT Test:

In cases where there are no immediate opportunities for the supply of heat from the outset, the Environment Agency considers that BAT is to build the plant to be CHP-Ready (CHP-R) to a degree which is dictated by the likely future opportunities which are technically viable and which may, in time, also become economically viable.

The term 'CHP-R' in this context represents a plant which is initially configured to generate electrical power only but which is designed to be ready, with minimum modification, to supply heat in the future. The term 'minimum modification' represents an ability to supply heat in the future without significant modification of the original plant / equipment[1]. Given the uncertainty of future heat loads, the initial electrical efficiency of a CHP-R plant (before any opportunities for the supply of heat are realised) should be no less than that of the equivalent non-CHP-R plant.

For these cases, the Environment Agency has developed this CHP-R Guidance to be used for applications for Environmental Permits for new plants under the Environmental Permitting (England and Wales) Regulations 2010.

Third BAT Test:

Once an Environmental Permit has been issued for a new CHP-R plant, the applicant / operator should carry out periodic reviews of opportunities for the supply of heat to realise CHP. Such opportunities may be created both by new heat loads being built in the vicinity of the plant, and / or be due to changes in policy and financial incentives which improve the economic viability of a heat distribution network for the plant being CHP.

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[1] Further information in this regard is provided in Section 4 (CHP-R Assessment).

Use of the CHP-R Guidance

Insert 1 illustrates the three BAT tests (i.e. the BAT Assessment process for CHP and CHP-R) and shows how this CHP-R Guidance should be used.

INSERT 1: BAT ASSESSMENT PROCESS FOR CHP AND CHP-R

Is the New Power / EfW Plant required to be CHP or CHP-R?

- No - The applicant / operator should demonstrate that the provision of CHP is not compatable with original operating regime / intention.
- Yes - ***Proceed to Next Step***

Are there opportunities for the supply of heat?

- No - The applicant / operator should demonstrate that there are no opportunties for supply of heat.
- Yes - ***Proceed to Next Step***

FIRST BAT TEST: Will the Power / EfW Plant be CHP at the Outset?

- Yes - The applicant / operator should justify this is BAT
- No (i.e. no CHP or degree of CHP does not represent BAT) ***Proceed to CHP-R Assessment (Requirement 1)***

CHP-R Assessment: Requirement 1

- Of the identified opportunities for the supply of heat, appropriate selection of heat loads should be undertaken.
- ***Proceed to Requirement 2***

CHP-R Assessment: Requirement 2

- Identify the CHP Envelope. Can the Plant supply the selected heat load(s)?
- **Yes** - ***Proceed to Requirement 3***
- **No** - ***Proceed to Requirement 4***

CHP-R Assessment: Requirement 3

- Identify the effect of the selected heat load(s) on the Plant.
- ***Proceed to Requirement 4***

CHP-R Assessment: Requirement 4

- Identify technical provisions and space requirements for CHP-R.
- ***Proceed to Requirement 5***

CHP-R Assessment: Requirement 5

- Is the Plant >300MW and therefore required to be Carbon Capture Ready?
- ***Yes*** - Identify the 'CHP and Carbon Capture Envelope'. ***Then proceed to Requirement 6***
- ***No*** - ***Proceed to Requirement 6***

CHP-R Assessment: Requirement 6

- Identify costs associated with the provision of CHP-R.
- ***Proceed to CHP-R BAT Assessment***

SECOND BAT TEST: CHP-R Assessment

- The applicant / operator should justify the degree to which the new Power / EfW Plant will be CHP-R.

THIRD BAT TEST: Periodic Review

- Once CHP-R Plant is operating, the applicant / operator should carry out periodic reviews of opportunities for the supply of heat (both existing and new).

As described above, this CHP-R Guidance should primarily be used to help satisfy the requirements of the second BAT test. However, elements of this CHP-R Guidance may also be relevant to the first and third BAT tests. For example, whilst a new plant may incorporate CHP at the outset, there may still be opportunities for the supply of additional heat in the future. In this case, it may also be appropriate for the new plant to incorporate a number of elements of CHP-R.

Furthermore, it should also be noted that whilst the primary focus of this CHP-R Guidance is on the demonstrations required in an application for an Environmental Permit, the principles contained within may also have implications on Development Consent Order (DCO) applications for new plant. Therefore, it is recommended that this CHP-R Guidance (and the requirements for CHP-R) is also considered prior to making a DCO application, in particular because the first and second BAT tests may affect the layout, space requirements and building design for the implementation of CHP. Additionally, the Planning Authority may take into account the ability of the new plant to supply heat as part of its assessment on whether the development constitutes an appropriate use of land. In this regard, the Environment Agency may also provide comments to the Planning Authority on the suitability of the location for the new plant with respect to potential heat loads, with an emphasis on co-locating heat sources and loads wherever possible. In this respect, the Environment Agency anticipates that new EfW plants are likely to have greater flexibility in terms of their location than new combustion power plants. However, new combustion power plants will generally be able to apply a wider search radius for economic opportunities for the supply of heat by virtue of their far greater potential heat output[2].

[2] Further information in this regard is provided in Section 3 (Consideration of CHP in Planning).

Applicability of the CHP-R Guidance

This CHP-R Guidance applies to applications for Environmental Permits under the Environmental Permitting (England and Wales) Regulations 2010 for:

- New combustion power plants (referred to as power plants) with a gross rated thermal input of 50 or more MegaWatts (MW); and
- New EfW plants with a throughput of more than 3 tonnes per hour of non-hazardous waste or 10 tonnes per day of hazardous waste.

Accordingly, this CHP-R Guidance is applicable to:

- Applicants / operators for new plants such that they can:
  - Provide sufficient information to the Environment Agency in an application for an Environmental Permit to demonstrate BAT for a new plant which uses CHP at the outset or is designed to be CHP-R;
  - In the case of a CHP-R plant, show that the new plant is designed to be ready, with minimum modification, to supply heat in the future;
  - In the case of a CHP-R plant, make adequate technical provisions such that the new plant is ready, with minimum modification, to supply heat in the future; and,
  - Carry out periodic reviews of opportunities for the supply of heat.
- The Environment Agency when assessing an application for an Environmental Permit for a new plant which uses CHP at the outset or is designed to be CHP-R.

For any application under the Environmental Permitting (England and Wales) Regulations 2010 which includes combustion power plant for supplying heat, the Environment Agency would expect the use of CHP to be considered and implemented (wherever practicable) in line with principles described in the Draft H2 Energy Efficiency Guidance.

In addition, whilst it is considered that CHP is technically feasible for all types of new plants, it is recognised that in some cases (such as peaking plant and anaerobic digestion plants) the provision of CHP would not be compatible with original operating regimes / intentions. Therefore, in such cases, applicants for Environmental Permits should provide evidence as to why their plant should be excluded from being CHP-R.

1 Introduction

CHP is the generation of electrical power and usable heat in a single process. This is also known as cogeneration. CHP is a well proven technology for reducing primary energy usage (hence providing primary energy savings) and reducing carbon emissions.

1.1 Benefits of Combined Heat and Power

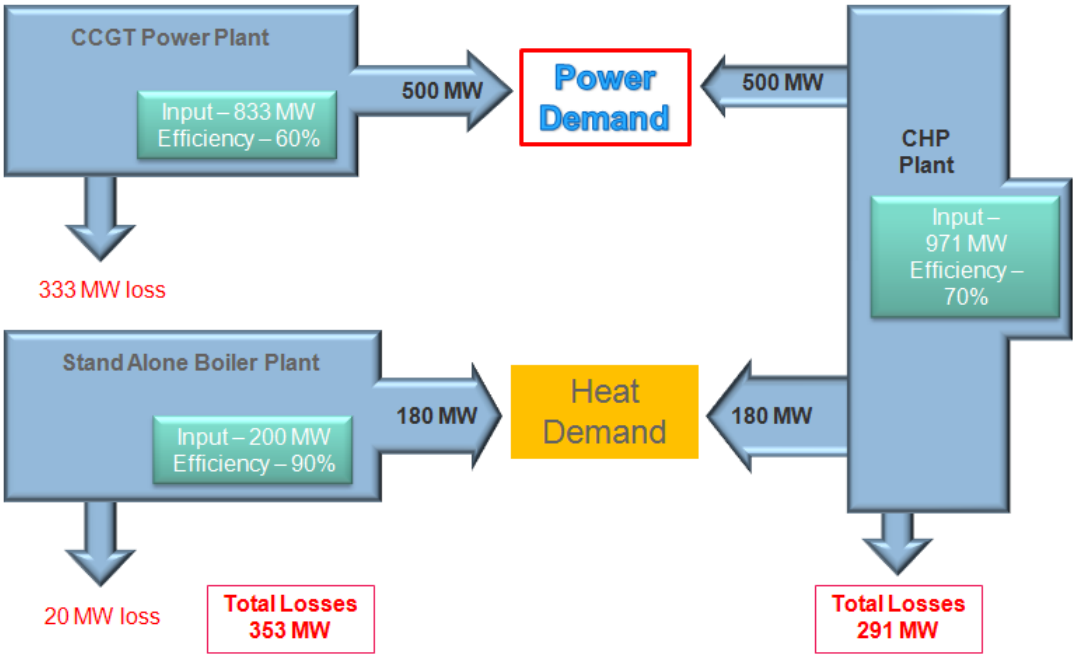
Generating electrical and heat together in a CHP plant is more efficient than generating them separately, thus delivering a reduction in both primary energy usage and carbon emissions. This is demonstrated by the following cases which considers a site that has a requirement for 120 MW of electrical power and 180 MW of heat. This could be:

- Separately supplied by a stand-alone plant (for the electrical power) and a stand-alone boiler plant (for the heat); or
- Supplied by a CHP plant.

This is demonstrated for a typical Combined Cycle Gas Turbine (CCGT) power plant in Case 2a and for a typical EfW plant in Case 2b. These cases are illustrated in Insert 2.

INSERT 2: ILLUSTRATION OF THE PRIMARY ENERGY SAVINGS RESULTING FROM THE USE OF CHP

Case 2a: Consideration of a Typical CCGT Power Plant



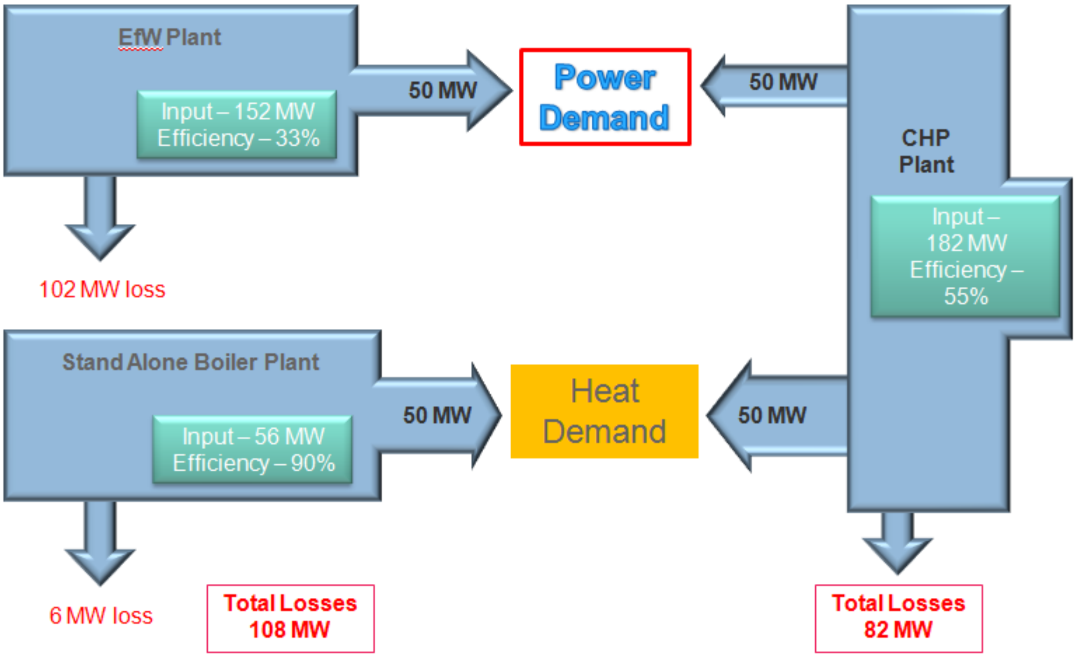
Case 2a assumes that:

- CCGT power plant supplying 500 MW of electrical power has an efficiency of 60%, therefore an energy input of 833 MW;
- Stand-alone boiler plant supplying 180 MW of heat has an efficiency of 90%, therefore an energy input of 200 MW; and,
- CHP plant supplying 680 MW has an efficiency of 70%, therefore an input of 971 MW.

In this example, using a CHP plant (to replace the separate CCGT power plant and stand-alone boiler plant) would represent a primary energy saving of approximately 6%. This corresponds to an energy saving of approximately 62 MW.

INSERT 2: ILLUSTRATION OF THE PRIMARY ENERGY SAVINGS RESULTING FROM THE USE OF CHP

Case 2b: Consideration of a Typical EfW Plant



Case 2b assumes that:

- Stand-alone EfW plant supplying 50 MW of electrical power has an efficiency of 33%, therefore an energy input of 152 MW;
- Stand-alone boiler plant supplying 50 MW of heat has an efficiency of 90%, therefore an energy input of 56 MW; and,
- CHP plant supplying 100 MW has an efficiency of 55%, therefore an input of 182 MW.

In this example, using a CHP plant (to replace the separate EfW plant and stand-alone boiler plant) would represent a primary energy saving of approximately 12%. This corresponds to an energy saving of approximately 25 MW.

In addition, whilst the corresponding savings in carbon dioxide emissions would depend on the fuels used in the CHP plant, and the fuels displaced from the separate stand-alone plant, they are considered to be both substantial and significant.

1.2 CHP in the UK

Unlike many other European countries, the UK does not have widely developed infrastructure for heat. This is due to a number of constraints, both regulatory and financial in nature. These constraints have meant that, in the UK, there has been limited consideration given in the selection of locations for new plants to areas with high heat demand densities (i.e. where CHP schemes could be more readily established).

Improved incentives and support measures could see an increased amount of realised CHP schemes and a new market opening up for infrastructure / networks for heat in the future. With such a new market, similar to many other European countries, CHP schemes would likely be based on bespoke CHP plants which are designed to supply electricity and heat right from the outset. However, as an infrastructure / network for heat is not available on a wide scale in the UK, basing new plants on such a model is unlikely to be suitable.

Until such a time when wide scale infrastructures / networks for heat are available in the UK, it is prudent to ensure that new plants which are initially required to generate electrical power only have included sufficient flexibility in their design to be ready (without significant modification) to supply heat in the future as and when opportunities become available. In allowing sufficient flexibility in their design to be ready to supply heat in the future, new plants could be considered CHP-R and 'CHP Lockout' (where a plant cannot supply heat without significant modification) can be avoided.

1.3 Potential for Good Quality CHP

In recognition of the role that CHP can play in meeting the UK's Energy Policy priorities, the Government has committed to promoting 'Good Quality CHP'. Good Quality CHP is that which has been certified as highly efficient under the CHP Quality Assurance Programme and, in accordance with the European Union (EU) Energy Efficiency Directive (Directive 2012/27/EU), achieves at least 10% primary energy savings.

Based on information given in DUKES[3], in 2011 there were 1,880 Good Quality CHP schemes in the UK with an electrical capacity of 6.111 GigaWatts (GW). The corresponding electrical power and heat generation was 27 191 GigaWatt hours (GWh) and 48 627 GWh respectively, providing an estimated 13.97 Mt of carbon dioxide savings. This is equivalent to the annual carbon dioxide output of 2.3 GW of CCGT power plant electrical power generation, or 5.3 GW of super-critical coal power plant electrical power generation, both operating with a 90% capacity factor.

However, it is recognised that more can be done and that there is a cost-effective potential for a doubling of Good Quality CHP by 2020[4].

[3] Available at: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx#

[4] Further information in this regard is provided in Section 4 (CHP-R Assessment).

1.4 Incentives and Support Mechanisms for CHP in the UK

Depending on the type of plant proposed, there are a variety of incentives and support measures for plants which incorporate CHP in the UK. For example[5]:

- Up to 1 April 2013, exemption (via Levy Exemption Certificates) from the Climate Change Levy of all fuel inputs to (and electricity outputs from) Good Quality CHP;
- Enhanced Capital Allowances for Good Quality CHP equipment / machinery in Non-Utility Sectors;
- Business Rates exemption for embedded CHP equipment / machinery; and,
- Support under the Renewables Obligation and / or Renewables Heat Incentive[6] for some types of plant that incorporate CHP. .

However, it should be noted that the above measures may be subject to change as a result of changes in Government Policy. Therefore, it may be that additional incentives and support measures for plants which incorporate CHP may be available in the future.

1.5 Information on CHP in the UK

Information on CHP in the UK can be found on the CHP Focus Website at:

http://chp.decc.gov.uk/cms/

This website contains comprehensive information on all aspects of CHP. The website also contains a link to the UK CHP Development Map, which can be found at:

http://chp.decc.gov.uk/developmentmap/

This website provides a useful search tool at the initial planning and pre-application stage when searching for the likely extent and nature of CHP opportunities (i.e. potential heat loads) in the area surrounding the new plant.

[5] Adapted from Digest of UK Energy Statistics (DUKES) 2011 – Chapter 6 (Combined Heat and Power).

[6] At the time of writing, DECC are intending to consult on amendments to the Renewable Heat Incentive (RHI) tariff arrangements for renewable CHP plants which are not eligible for the "half Renewable Obligation Certificates uplift" which applies to plant accredited before 1 April 2013.

2 Policy, Regulation and Guidance concerning CHP

The following Section considers the main aspects of existing Policy, Regulations and Guidance concerning CHP, including:

- The Industrial Emissions Directive and use of BAT;
- The Energy Efficiency Directive; and
- The Waste Framework Directive.

2.1 The Industrial Emissions Directive and use of BAT

In November 2011, the EU adopted Directive 2010/75/EU on industrial emissions (the Industrial Emissions Directive (IED)). The IED entered into force in January 2012. The IED recasts seven existing EU Directives related to industrial emissions into a single instrument to improve the permitting, compliance and enforcement regimes adopted by Member States.

In particular, the IED incorporated the requirements of two existing EU Directives.

- **Directive 2008/1/EC concerning integrated pollution prevention and control (the Integrated Pollution Prevention and Control Directive (IPPC Directive))**

The purpose of the IPPC Directive was to achieve integrated prevention and control of pollution arising from certain potentially polluting processes and to ensure a high level of protection for the environment taken as a whole. Measures were laid down to prevent or, where that was not practicable, reduce emissions in the air, water and land introducing Emissions Limit Values (ELV) and Best Available Techniques (BAT). With regard to plants, combustion installations with a rated thermal input exceeding 50 MW were subject to the IPPC Directive.

- **Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants (the Large Combustion Plant Directive (LCPD))**

The purpose of the LCPD was to limit the emissions of certain pollutants (including oxides of nitrogen, sulphur dioxide and particulates) into the atmosphere from large combustion processes by imposing ELVs. With regard to plants, combustion installations with a rated thermal input exceeding 50 MW were subject to the LCPD.

The IED is intended to achieve a high level of protection for the environment and human health while simplifying the existing legislation and cutting unnecessary administrative costs. The IED makes provisions for the continuation of the requirements and principles of the IPPC Directive and the LCPD and introduces new, more stringent, ELVs with full compliance by existing plants required by 1 January 2016[7]. Member States are required to enact the IED by 7 January 2013.

[7] However, the operator may take one of the "bounded flexibilities" available through Chapter III of the IED.

The Environmental Permitting (England and Wales) Regulations 2010 currently transpose the IPPC Directive and the LCPD into UK Legislation. Amendments to these Regulations are proposed to transpose the IED into UK Legislation.

With regards to BAT, the IPPC Directive required that there was an information exchange between Member States and the industries concerned, and that the results of this information exchange be published every three years. The EU IPPC Bureau published the latest BAT Reference Document (BREF) for Large Combustion Plants (Large Combustion Plant BREF) in July 2006. The IED retains the requirement for information exchange and also goes further in specifying that the Reference Documents should be updated as least every 8 years.

As part of a comprehensive contribution to the on-going update for the Large Combustion Plant BREF, the UK Technical Working Group (of which the Environment Agency is a member) submitted a summary of the UK position for BAT for new and existing plants in May 2011. As previously stated, CHP is a well proven technology for reducing primary energy usage (hence providing primary energy savings) and reducing carbon dioxide emissions. For this reason, the UK submission states that BAT for energy efficiency for a plant is the use of CHP where there are economically viable opportunities for the supply of heat from the outset. Where there are no opportunities for the supply of heat from the outset, BAT for energy efficiency is CHP-R.

Further to this, the LCPD required applicants for Environmental Permits to examine the technical and economic feasibility of CHP. Based on this requirement, the Environment Agency's H2 Energy Efficiency Guidance recommends the use of CHP where opportunities exist. Where opportunities exist, the H2 Energy Efficiency Guidance includes a methodology for assessing the feasibility of CHP, including a Cost-Benefit Analysis of the available opportunities.

2.2 The Energy Efficiency Directive

In October 2012, the EU adopted Directive 2012/27/EU on energy efficiency (the Energy Efficiency Directive (EED)). The EED aims to establish a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20% headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date. In addition, the EED lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy, and provide for the establishment of indicative national energy efficiency targets for 2020. Of relevance to this CHP-R Guidance, the EED repeals Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market (the Cogeneration Directive).

In terms of CHP (or co-generation), the EED states (at Paragraph 35) that "high efficiency cogeneration and district heating and cooling has significant potential for saving primary energy, which is largely untapped in the Union. Member States should carry out a comprehensive assessment of the potential for high-efficiency cogeneration and district heating and cooling. These assessments should be updated, at the request of the Commission, to provide investors with information concerning national development plans and contribute to a stable and supportive investment environment".

The EED also states (at Paragraph 35) that "new electricity generation installations and existing installations which are substantially refurbished or whose permit or licence is updated should, subject to a cost-benefit analysis showing a cost-benefit surplus, be equipped with high-efficiency cogeneration units to recover waste heat stemming from the production of electricity". Further information is included at Article 14(5) / 14(7) (concerning installations considered to be included) and Article 14(6) / 14(8) (concerning installations considered to be excluded) of the EED.

This sets the scene for the consideration of CHP opportunities (and the associated benefits) within applications. Of relevance to this CHP-R Guidance, the cost-benefit analysis is considered to represent elements of the first and second BAT tests.

Furthermore, at Annex II, the EED prescribes how primary energy savings can be calculated and thus how highly-efficient cogeneration (i.e. Good Quality CHP) can be defined.

2.3 The Waste Framework Directive

Of relevance to EfW plants is Directive 2008/98/EC on waste and repealing certain Directives (The Waste Framework Directive).

Article 23 (Issue of Permits), Item 4 states that "it shall be a condition of any permit covering incineration or co-incineration with energy recovery that the recovery of energy take place with a high level of energy efficiency".

Accordingly, this sets the scene for the consideration of CHP opportunities (and the associated benefits) within applications.

3 Consideration of CHP in Planning

3.1 Planning Policies concerning CHP

In England, the National Planning Policy Framework (NPPF) sets out the UK Governments Planning Policies and how they are expected to be applied by applicants at the planning stage of any development. The NPPF replaces many of the documents in the existing suite of Planning Policy Statements, Planning Policy Guidelines, Circulars and accompanying Guidance which would previously have required assessment as part of an application for a new plant. In particular of relevance to this CHP-R Guidance is the replacement of Planning and Climate Change - Supplement to Planning Policy Statement 1 (December 2007).

In terms of new plants, the NPPF does not contain specific policies or considerations. However, specific policies and considerations for new plants greater than 50 MW are detailed in the framework set up through the Planning Act 2008, published in National Policy Statements (NPS). For new plants greater than 50 MW, the following NPS are likely to be relevant:

- EN-1 Overarching Energy NPS;
- EN-2 Fossil Fuel Electricity Generating Infrastructure NPS; and
- EN-3 Renewable Energy Infrastructure NPS.

These NPS are available to download at:

http://www.decc.gov.uk/en/content/cms/meeting_energy/consents_planning/nps_en_infra/nps_en_infra.aspx

Within EN-1 Overarching Energy NPS, Section 4.6 details the requirements for consideration of CHP. This states (at Paragraph 4.6.12) that in the event that future CHP opportunities have been identified "the IPC [Infrastructure Planning Commission, now integrated with the Planning Inspectorate] may wish to impose requirements to ensure that the generating station is CHP-Ready unless ... [they are] satisfied that the applicant has demonstrated that the need to comply with the requirement to be Carbon Capture Ready will preclude any provision for CHP"[8].

For new plants less than 50 MW, the NPS are likely to be a material consideration.

3.2 Development Consent Orders

In England, as part of any application for a Development Consent Order (DCO) under the Planning Act 2008 (previously Section 36 Consent under the Electricity Act 1989), applications for new plants (greater than 50 MW) must show that they have fully considered the opportunities for CHP. Typically, this is undertaken by submitting a

[8] It should be noted here that this CHP-R Guidance assumes that the requirement to be Carbon Capture Ready (CCR) has not precluded any provision to be CHP-R.

CHP Assessment with the application (in line with Section 4.6 of EN-1 Overarching Energy NPS) which contains details on:

- "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.
- And, if the proposal is for generation without CHP:
- 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"[9].

For DCO granted for new plants for "generation without CHP", the subsequent application for an Environmental Permit should build on the conclusions of the CHP Assessment and contain sufficient information to demonstrate the new plant will be built CHP-R (for the chosen location and design). This CHP-R Guidance is to be used in these instances.

Additionally, whilst CHP Assessments may only require waste heat[10] to be made available, being CHP-R may require both process heat and waste heat to be made available according to the likely future CHP opportunities identified.

3.3 The Environment Agency's Role as a Consultee to the Planning Process

The primary focus of this CHP-R Guidance is on the demonstrations required in an application for an Environmental Permit for new plants under the Environmental Permitting (England and Wales) Regulations 2010. However, the principles contained within this CHP-R Guidance may also have implications on consent applications (i.e. Planning Permission (under the Town and Country Planning Act 1990) or a DCO (under the Planning Act 2008)) for the new plant. Indeed, the Environment Agency will be consulted on these applications, as well as applications for extensions of / variations to existing plants.

The Environment Agency Document "Guidelines for Developments requiring Planning Permission and Environmental Permits" sets out the Environment Agency's role in the planning process and its approach to responding to applications for developments which will also require an Environmental Permit. In particular, these Guidelines recognise that there may be some interdependencies between planning and permitting requirements. In the case of such interdependencies, the Guidelines recommend early

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[9] Department of Trade and Industry's (DTI) (now DECC) Document "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, December 2006"

[10] One example of 'waste heat' is hot water from the cooling system which could be used as a heat source for Liquefied Natural Gas Plant Vaporisers or Greenhouses.

engagement with the Environment Agency via their planning pre-application service and, in some cases, a "parallel-tracking" approach is recommended whereby the preparation and submission of the planning and permitting applications is carried out at the same time.

Therefore, it is recommended that this CHP-R Guidance (and the requirements for CHP-R) is considered prior to making a consent application for a new plant, in particular because the first and second BAT tests may affect the layout, space requirements and building design for the implementation of CHP. Accordingly, the Environment Agency recommends that the requirement for new plants to be CHP or CHP-R is discussed at the earliest possible stage, ideally during planning pre-application. In any case, where a DCO is required the applicant will have to make similar demonstrations under both the planning and permitting applications in terms of suitability of the location for CHP, potential opportunities for heat supply and CHP-R.

When consulted by the Planning Authorities on relevant consent applications for new plants, the Environment Agency will highlight the need for the plant to be CHP or CHP-R and will make reference to this CHP-R Guidance. Where a DCO is required, the Environment Agency will additionally comment on the results of the CHP Assessment. Where a DCO is not required, the Environment Agency will recommend to the Planning Authorities that the location of the plant with respect to potential opportunities for heat supply is considered as part of the planning process. Where the Environment Agency is aware of potential heat loads in the area, they will provide details of these to the Planning Authorities.

The Environment Agency will not object to applications for new plants where they are located in areas where there are no opportunities for heat supply. However, where relevant, the Environment Agency will highlight the lack of opportunities to the Planning Authorities and this may influence the Planning Authority in its consideration of the suitability of the proposed location. When consulted on applications for modifications to existing plants (which will also require a variation to the Environmental Permit), the Environment Agency will highlight the need for the plant to be CHP or CHP-R (where relevant), but is unlikely to provide comments in the suitability of the location of the plant for CHP.

Additionally, the Planning Authority may take into account the ability of the new plant to supply heat as part of its assessment on whether the development constitutes an appropriate use of land. In this regard, the Environment Agency may also provide comments to the Planning Authority on the suitability of the location for the plant with respect to potential heat loads, with an emphasis on co-locating heat sources and loads wherever possible. In this respect, the Environment Agency anticipates that new EfW plants are likely to have greater flexibility in terms of their location than new combustion power plants, while new combustion power plants will generally be able to apply a wider search radius for economic opportunities for the supply of heat by virtue of their far greater potential heat output.

4 CHP-R Assessment

This Section should be read in conjunction with the CHP-R Assessment Form which is provided in Appendix A. Additional Guidance Notes on the use of the CHP-R Assessment Form are also provided in Appendix A.

The CHP-R Assessment should demonstrate that the new plant is designed to be ready, with minimum modification, to supply heat in the future. The term 'minimum modification' represents an ability to supply heat in the future without significant modification of the original plant / equipment. For example, a CHP-R plant will not be required to replace major items of original plant / equipment, but should retain the capability for additional plant / equipment to be installed at a later date.

In this regard, the CHP-R Assessment allows for the provision of supporting information regarding any appropriate technical provisions which demonstrate that the new plant is ready to supply heat in the future. As these technical provisions are provided alongside a justification of the chosen location and selected heat loads, it is noted that the degree to which any new plant will be CHP-R will be location-specific. Therefore, BAT (under the Environmental Permitting (England and Wales) Regulations 2010) is assessed on a site-specific basis.

The requirements for the CHP-R Assessment are listed in this Section. Supporting information is provided in the Appendices:

- Appendix B provides five Case Studies / Worked Examples using the CHP-R Assessment Form.
- Appendix C provides Additional Economic Supporting Information.
- Appendix D provides Additional Technical Supporting Information.

4.1 Requirement 1: Plant, Plant Location and Potential Heat Loads

EN-1 - Overarching Energy NPS states that "a 2009 Report for DECC on district heating networks suggested that ... a district heating network using waste heat from a generating station would be cost-effective where there was a demand for 200 MWth of heat within 15 km".

As such, it is noted that to be commercially viable for CHP, new plants should ideally be sited close to potential heat loads / heat customers with the actual distance varying with the size of the plant and the nature of the demand for heat. With this in mind, it is likely that the search radius for CHP opportunities for large combustion power plants is likely to be greater than that for a typical EfW plant. However, there is likely to be greater location flexibility for EfW plants than for large combustion power plants, potentially making it easier to co-locate EfW plants with suitable heat loads. Accordingly, wherever possible, the location criteria for selection of new plant must include the potential for immediate CHP opportunities in balance with other factors.

However, it is recognised that there are often other important factors which dictate a plant’s location which may take precedence over immediate CHP opportunities. In these cases, where there are no immediate CHP opportunities, BAT is to build the power or EfW plant to be CHP-R to a degree which is dictated by the likely future opportunities which are technically viable and which may, in time, become economically viable. As such, in these cases, determining CHP-R requires consideration to be given to the likely extent and nature of future opportunities in the chosen location.

This is addressed under this Requirement.

Demonstrations under Requirement 1:

- A description of the plant;
- A description of plant location;
- A description of the factors influencing the selection of the plant location;
- A description of the likely extent and nature of CHP opportunities (i.e. potential heat loads) in the area (an indicative search radius of 10 km should be used for plants less than 300 MW, and 15 km for plants greater than 300 MW);
- The appropriate selection of heat loads (which must be agreed with the Environment Agency at the Environmental Permit Pre-Application Stage, or (preferably) at the pre-planning application stage) to take forwards in the CHP-R Assessment;
- A justification for the appropriate selection of heat loads; and,
- Identification of the expected supply and return requirements for the selected heat load / heat loads.

In terms of the 'appropriate selection of heat loads', regard should be given to the role that CHP can play in meeting the UK's Energy Policy priorities, particularly in terms of Good Quality CHP. As noted in Section 1.3 (Potential for Good Quality CHP), Good Quality CHP is that which achieves at least 10% primary energy savings. Therefore, the selection of heat loads should be such that, wherever possible, 10% primary energy savings could be achieved in the future. However, where this is not possible, the selection of heat loads should be such that maximum primary energy savings could eventually be achieved in the future whilst not necessarily meeting the criteria for Good Quality CHP. Accordingly, the appropriate selection of heat loads will likely include a discussion with the Environment Agency and potential heat load recipient(s), and / or a degree of qualitative economic screening. It should be noted that the heat loads for assessment must be agreed with the Environment Agency.

For further information, please see Additional Economic Supporting Information in Appendix C.

It should be noted that the subsequent Requirements, listed below, discuss a methodology for one selected heat load. However, if the appropriate selection of heat loads requires that more than one heat load is taken forward, then the CHP-R Assessment should be undertaken for all selected heat loads.

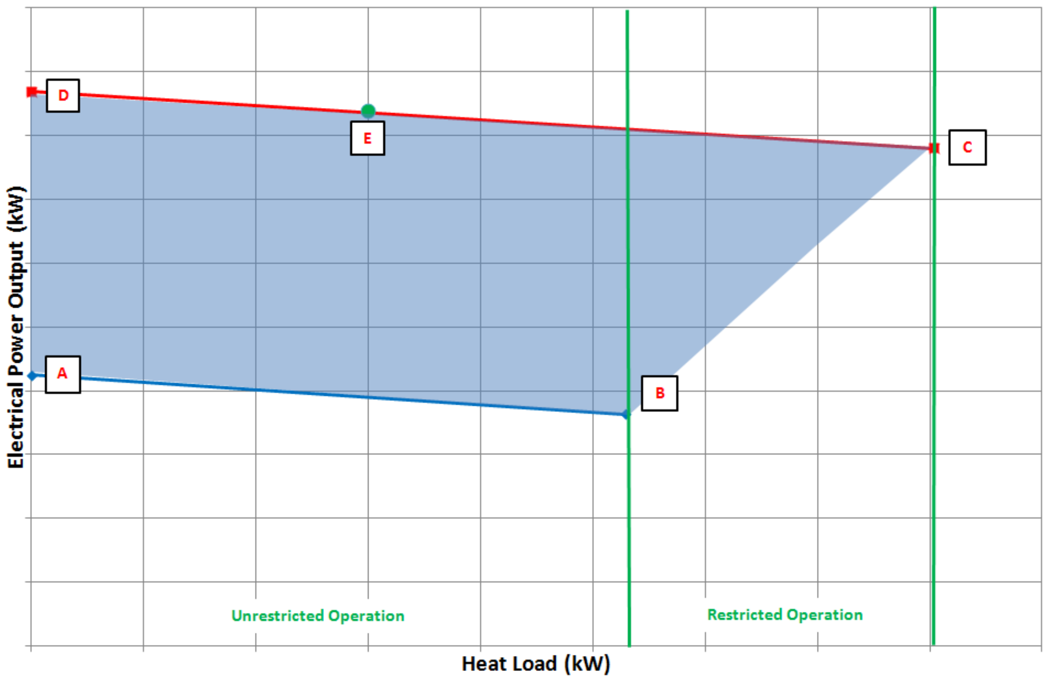
4.2 Requirement 2: Identification of 'CHP Envelope'

Obtaining a supply of heat from a plant is most likely to be achieved by extracting steam from the steam cycle. Alternatively (or additionally), for some types of applications where only low grade heat is required (such as Liquefied Natural Gas Plants and Greenhouses), a supply of heat from a plant can be achieved by extracting hot water from the cooling system.

A plant which is CHP will have a known heat load size and profile at the outset, and therefore an optimal design for electrical power generation with heat generation can be achieved, including optimised extraction points. A plant which is CHP-R will not have a known heat load size or profile at the outset, and therefore an optimal design for electrical power generation only should be achieved. Indeed, given the uncertainty of future heat loads, the initial electrical efficiency of a CHP-R plant (before any opportunities for the supply of heat are realised) should be no less than that of a non-CHP-R plant.

Therefore, in demonstrating CHP-R, consideration needs to be given to the ability of the new plant to meet future heat loads within its likely operational profile. This consideration allows for the identification of a 'CHP Envelope'. The CHP Envelope represents the potential operational ranges of the new plant where it could be technically feasible to operate electrical power generation with heat generation. A graphical representation of the CHP Envelope is provided in Insert 3.

INSERT 3: GRAPHICAL REPRESENTATION OF THE CHP ENVELOPE



The following explanations are given for the points on Insert 3:

- A: The minimum electrical power output with no heat load (corresponds to the minimum stable plant load, also known as Minimum Stable Generation).
- B The minimum electrical power output at the maximum heat load (corresponds to the minimum stable plant load).
- Line A to B: The minimum electrical power output for any given heat load (corresponds to the minimum stable plant load).
- C: The maximum electrical power output at the maximum heat load (corresponds to 100% plant load).
- D: The maximum electrical power output with no heat load (corresponds to 100% plant load).

- Line D to C: The maximum electrical power output for any given heat load (corresponds to 100% plant load).
- E: Proposed operational point of the plant.
- Unrestricted Operation: If a selected heat load is located in this region, the plant will have the ability to operate at any load between minimum stable plant load and 100% plant load (i.e. is not load restricted).
- Restricted Operation: If a selected heat load is located in this region, the plant will not have the ability to operate over its full operational range (i.e. is load restricted).

This is addressed under this Requirement.

Demonstrations under Requirement 2:

Identification of:

- The potential heat extraction at 100% Plant Load, and the effects on the plant;
- The potential heat extraction at Minimum Stable Plant Load, and effects on the plant; and,
- Whether the plant can supply the selected heat load.

4.3 Requirement 3: Operation of Plant with the Identified Heat Load

Within the identified CHP Envelope, the effect of the selected heat load on the proposed operation of the plant should be determined.

This is addressed under this Requirement.

Demonstrations under Requirement 3:

Identification of:

- The likely effects of the selected heat load on the plant.

4.4 Requirement 4: Technical Provisions and Space Requirements

Determination of the effect of the selected heat load on the operation of the plant (under Requirement 3) will have required suitable extraction points to be identified.

These extraction points should be described under this Requirement.

Furthermore, determination of the CHP Envelope (under Requirement 2) will allow for consideration to be given to potential options which could be incorporated into the plant (either within the initial design or at a later stage) should a CHP opportunity be realised outside the identified CHP Envelope (i.e. outside the potential operating ranges of the plant).

The potential options should be described under this Requirement.

In addition, within the demonstration of CHP-R for all opportunities, it is important that consideration is given to the provision of additional space which may be needed.

This is addressed under this Requirement.

Demonstrations under Requirement 4:

- Identification of likely suitable extraction points in the plant for the identified heat load. Additional Technical Supporting Information is provided in Appendix D;
- Identification of the potential options which could be incorporated in the plant, should the CHP opportunity be realised outside the identified CHP Envelope;
- Description of how the future costs and burdens associated with supplying the identified heat load / potential CHP opportunity have been minimised through the implementation of an appropriate CHP-R design; and,
- Provision of site layout plan of the plant, indicating available space which could be made available for CHP.

4.5 Requirement 5: Integration of CHP and Carbon Capture

Through the EU Directive on the geological storage of carbon dioxide (Directive 2009/31/EC) (the Carbon Capture and Storage (CCS) Directive), it is now required that developers of new plants with an electrical power output of 300 MW or more carry out an assessment to determine whether the plant is Carbon Capture Ready (CCR). Based on this requirement, current UK Policy now stipulates that "no power station at or over 300 MW ... would be consented unless it could demonstrate it would be CCR"[11]. Therefore, for plants with an electrical power output at or over 300 MW, consideration should be given to the ability of the plant to satisfy the requirements of CCR in conjunction with CHP-R[12].

This consideration allows for the identification of a 'CHP and Carbon Capture Envelope'. The CHP and Carbon Capture Envelope represents the likely range for the operation of the new plant with carbon capture where it could be technically feasible to operate electrical power generation with carbon capture and heat generation at a later date. Determination of the CHP and Carbon Capture Envelope will allow for consideration to be given (either within the initial design or at a later stage) to: options for useful integration of the two systems; or, potential options which could be incorporated into the plant with carbon capture should a CHP opportunity be realised outside the identified CHP and Carbon Capture Envelope (i.e. outside the operating capability of the plant with carbon capture).

This is addressed under this Requirement.

Demonstrations under Requirement 5:

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[11] Carbon Capture Readiness (CCR): A Guidance Note for Section 36 Electricity Act, 1989 Consent Applications. Crown Copyright URN 09D/819.

[12] For power plants with an electrical power output of less than 300 MW, no demonstrations under this Requirement are necessary.

Identification of:

- The expected supply and return requirements identified for carbon capture[13];
- The effects of carbon capture on the operation of the plant;
- The CHP and Carbon Capture Envelope including:
  - The potential heat extraction at 100% Plant Load, and the effects on the plant.
  - The potential heat extraction at Minimum Stable Plant Load, and effects on the plant.
  - Identification of whether the plant with carbon capture can supply the selected identified heat load.
  - Identification of the potential options which could be incorporated into the plant for useful integration of any realised CHP system and carbon capture system.

4.6 Requirement 6: Economics of CHP-R

An integral part of any BAT test is a consideration of the economic viability of the chosen option. With regard to the second BAT test, the economic viability is dictated by the potential future opportunities for heat supply and the:

- Associated potential future revenues / benefits; and,
- Likely additional initial costs of making the new plant CHP-R for the selected potential future opportunities for heat supply.

Therefore, in addition to the technical assessments of CHP-R (Requirement 2 to Requirement 5), applications for an Environmental Permit for a CHP-R plant should also conduct a high level economic assessment. The high level economic assessment may build on the results of the qualitative economic screening (if completed under Requirement 1) and demonstrate, for the selected potential future opportunity for heat supply, the associated potential future revenues / benefits and likely additional initial costs for the plant to be CHP-R. For further information, please see Additional Economic Supporting Information in Appendix C.

[13] For the majority of new power plants which are required to demonstrate CCR, post-combustion carbon capture technology is referenced. For this carbon capture technology is it likely that a supply of low pressure steam will be required.

5 BAT Assessment

In cases where there are no immediate opportunities for the supply of heat from the outset, the Environment Agency considers that BAT is to build a new plant to be CHP-R to a degree which is dictated by the foreseeable future opportunities which are technically viable and which may, in time, become economically viable.

Therefore, based on the CHP-R Assessment, there should be an identification of the extent to which the new plant will be CHP-R and thus whether the proposals represent BAT.

Within this CHP-R Guidance, the term BAT is considered to have the same definition at that under the IED (given at Article 3 (Definitions), Item 10).

This definition is:

"'Best available techniques' means the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impacts on the environment as a whole:

> (a) 'techniques' includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
>
> (b) available techniques' means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced in the Member State in question, as long as they are reasonably accessible to the operator;
>
> (c) 'best' means most effective in achieving a high general level of protection of the environment as a whole".

The BAT Assessment (including consideration of the economic viability[14]) should include:

- A basic description of the proposed plant;
- A description of the potential heat loads (including their appropriate selection) which have been used in the CHP-R Assessment; and,
- A justification of the degree to which the new plant will be CHP-R based on the results of the CHP-R Assessment including:
  - The CHP Envelope (i.e. the likely range for the operation of the new plant where it could be technical feasible to operate electrical power generation with heat generation at a later date);
  - Whether the selected heat loads are within the CHP Envelope (i.e. whether they are within the operating capability of the plant);

[14] This is considered to represent the Cost-Benefit Analysis.

- What the effect of the selected heat load(s) will be on the proposed operation of the new plant;
- What technical provisions and space requirements are envisaged;
- (If the plant is required to be CCR), the CHP and Carbon Capture Envelope (i.e. the likely range for the operation of the plant with carbon capture where it could be technical feasible to operate electrical power generation with carbon capture and heat generation at a later date);
- (If the plant is required to be CCR), whether the heat loads are within the 'CHP and Carbon Capture Envelope' (i.e. whether they are within the operating capability of the plant with carbon capture); and,
- The results of the high level economic assessment (or the Cost-Benefit Analysis) establishing the economic viability of CHP-R.

Appendix A: CHP-R Assessment Form

#	Description	Units	Notes / Instructions
Requirement 1: Plant, Plant Location and Potential Heat Loads			
1.1	Plant Name		The plant name.
1.2	Plant Description		To include a basic description of the plant, considering (as a minimum): • The type of plant; • The rated gross thermal input (based on the Higher Heating Value (HHV)) of the plant • The maximum continuous electrical power rating; • The proposed fuel(s); • The proposed combustion technology; and • High-level discussion of the anticipated plant design (e.g. number of combustion units / number of steam turbines / cooling technology)
1.3	Plant Location (Postcode / Grid Ref)		The location of the plant. This should include a plan showing the proposed plant site boundary, and the land in its vicinity.

1.4	Factors Influencing Selection of Plant Location		This should include a description of the factors that have been used to select the location of the plant. The description should make reference to the following factors as appropriate: • Likely potential for CHP opportunities*; • Availability of sufficient land capacity; • Current land use*; • Compatibility with the policies of the relevant Local Plan(s) and the NPPF together with other relevant planning considerations; • CHP provisions contained within the relevant Planning documents*; • Environmental considerations (such as proximity to sensitive receptors including: Air Quality Management Areas (AQMAs); and Statutory Designated Sites (and the likely presence of Protected Species)); • Proximity of suitable connection point to the National Grid Electricity Transmission System, and available capacity for export to the Electricity Transmission System; • Proximity to / availability of fuel source; • Proximity to / availability of cooling water; • Likely suitability for CCS (if applicable)*; and • Any other relevant considerations. * For the purposes of demonstrating CHP-R the items marked (*) must be included.

1.5	Operation of Plant		
a)	Proposed Operational Plant Load	%	This should clearly describe the proposed operating load point of the plant. For example: • For gas turbine plant, this should comprise the number of gas turbines in operation and the load as % of gas turbine base load. • For steam plant, this should comprise the main steam flow as a percentage of maximum turbine continuous rating (%TMCR).
b)	Thermal Input at Proposed Operational Plant Load	MW	The plant thermal input (based on the Lower Heating Value (LHV)) at proposed operational plant load. Identified from modelling.
c)	Net Electrical Output at Proposed Operational Plant Load	MW	The plant net electrical output at proposed operational plant load. Identified from modelling.
d)	Net Electrical Efficiency at Proposed Operational Plant Load	%	The plant net electrical efficiency at proposed operational plant load based on the LHV. Identified from modelling.
e)	Maximum Plant Load	%	This is the maximum possible plant load. The value to be used is 100%.
f)	Thermal Input at Maximum Plant Load	MW	The plant thermal input (based on the LHV) at 100% plant load. Identified from modelling.
g)	Net Electrical Output at Maximum Plant Load	MW	The plant net electrical output at 100% plant load. Identified from modelling. This is represented by Point D on Insert 3.
h)	Net Electrical Efficiency at Maximum Plant Load	%	The plant net electrical efficiency at 100% plant load based on the LHV. Identified from modelling. This is represented by Point D on Insert 3.

i)	Minimum Stable Plant Load	%	This is the minimum stable plant load. This will vary with type of plant, and may be governed by the combustion stability or capability to meet emissions limits at low plant loads.
j)	Thermal Input at Minimum Stable Plant Load	MW	The plant thermal input (based on the LHV) at minimum stable plant load.
k)	Net Electrical Output at Minimum Stable Plant Load	MW	The plant net electrical output at minimum stable plant load. Identified from modelling. This is represented by Point A on Insert 3.
l)	Net Electrical Efficiency at Minimum Stable Plant Load	%	The plant net electrical efficiency at minimum stable plant load based on the LHV. Identified from modelling. This is represented by Point A on Insert 3.
1.6	Identified Potential Heat Loads		
			This should include a description of the identified potential heat loads in the vicinity of the plant. A plan showing all identified potential heat loads in the vicinity should be provided. For each potential heat load the following information should be provided: • Name of identified heat load / recipient; • Size of heat load (MW) • Location of identified heat load / recipient including distance from the plant(where the identified heat load / recipient is a District Heating Network, the primary service location(s) should be provided); • Nature of use of potential heat load; and • Typical export and return requirements of the potential heat load.

1.7	Selected Heat Load(s)		
a)	Category (e.g. Industrial / District Heating)		Of the identified potential heat loads under Requirement 1.6, appropriate selection of heat loads should be undertaken in discussion with the Potential Heat Load Recipient / Environment Agency. It should be noted that the heat loads for assessment must be agreed with the Environment Agency **If more than one heat load is taken forward, then an assessment should be undertaken for all selected heat loads.**
b)	Maximum Heat Load Extraction Required	MW	Of the identified potential heat loads under Requirement 1.6, appropriate selection of heat loads should be undertaken in discussion with the Potential Heat Load Recipient / Environment Agency. It should be noted that the heat loads for assessment must be agreed with the Environment Agency **If more than one heat load is taken forward, then an assessment should be undertaken for all selected heat loads. .**
1.8	Export and Return Requirements of Heat Load		
a)	Description of Heat Load Extraction		To complete, based on potential heat load extraction for CHP (e.g. steam / hot water)
b)	Description of Heat Load Profile		To complete, based on potential heat load profile (e.g. constant or intermittent / fixed or variable load)
c)	Export Pressure	bar a	To complete, based on the requirements at the terminal point with the heat load customer.
d)	Export Temperature	°C	To complete, based on the requirements at the terminal point with the heat load customer.
e)	Export Flow	t/h	To complete, based on the requirements at the terminal point with the heat load customer.
f)	Return Pressure	bar a	To complete, if applicable, based on the requirements at the terminal point with the heat load customer.

g)	Return Temperature	°C	To complete, if applicable, based on the requirements at the terminal point with the heat load customer.
h)	Return Flow	t/h	To complete, if applicable, based on the requirements at the terminal point with the heat load customer.
Requirement 2: Identification of CHP Envelope			
2.0	Comparative Efficiency of a Standalone Boiler for supplying the Heat Load	90 % LHV	This is used only to calculate the primary energy savings (or reduction in primary energy usage) as a comparative guide.
2.1	Heat Extraction at 100% Plant Load		
a)	Maximum Heat Load Extraction at 100% Plant Load	MW	This is the maximum possible heat load extraction within the technical limitations of the plant at 100% plant load (i.e. heat load extraction beyond which major plant modification would be required). This will vary with type of plant. This is represented by Point C on Insert 3.
b)	Maximum Heat Extraction Export Flow at 100% Plant Load	t/h	This should be consistent with the: • Steam conditions given in 1.8; and • The figure given in 2.1(a).
c)	CHP Mode Net Electrical Output at 100% Plant Load	MW	The plant with CHP net electrical output at 100% plant load. Identified from modelling. This is represented by Point C on Insert 3.
d)	CHP Mode Net Electrical Efficiency at 100% Plant Load	%	The plant with CHP net electrical efficiency at 100% plant load based on the LHV. Identified from modelling. This is represented by Point C on Insert 3.
e)	CHP Mode Net CHP Efficiency at 100% Plant Load	%	The plant with CHP net CHP efficiency at 100% plant load based on the LHV. Identified from modelling. This is represented by Point C on Insert 3.

f)	Reduction in Primary Energy Usage for CHP Mode at 100% Plant Load	%	The reduction in primary energy usage (i.e. measure of primary energy savings) is based on the EED and is given by: $\left[1-\frac{1}{\frac{CHP\ H_\eta}{Ref\ H_\eta}+\frac{CHP\ E_\eta}{Ref\ E_\eta}}\right]\cdot 100$ Or (with reference to the values calculated in this CHP-R Assessment) this can also be given by: $\left[1-\frac{1}{\frac{CHP_\eta}{H+E}\left[\frac{H}{Ref\ H_n}+\frac{E}{Ref\ E_n}\right]}\right]\cdot 100$ Where: CHP Hη : CHP Heat Efficiency CHP Eη : CHP Electrical Efficiency CHPη : CHP Efficiency Ref Hη : Reference Heat Efficiency[15] Ref Eη : Reference Electrical Efficiency[16] H : Heat Load Extraction E : CHP Mode Net Electrical Output
2.2	Heat Extraction at Minimum Stable Plant Load		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load	MW	This is the maximum possible heat load extraction within the technical limitations of the plant at minimum stable plant load (i.e. heat load extraction beyond which major plant modification would be required). This will vary with type of plant. This is represented by Point B on Insert 3.
b)	Maximum Heat Extraction Export Flow at Minimum Stable Plant Load	t/h	This should be consistent with the: • Steam conditions given in 1.8; and • The figure given in 2.2(a).

[15] This is the Comparative Efficiency of a Standalone Boiler for supplying the Heat Load [2.0].

[16] This is the power plant net electrical efficiency without heat extraction.

c)	CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	The plant with CHP net electrical output at minimum stable plant load. Identified from modelling. This is represented by Point B on Insert 3.
d)	CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	The plant with CHP net electrical efficiency at minimum stable plant load based on the LHV. Identified from modelling. This is represented by Point B on Insert 3.
e)	CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	The plant with CHP net CHP efficiency at minimum stable plant load based on the LHV. Identified from modelling. This is represented by Point B on Insert 3.
f)	Reduction in Primary Energy Usage for CHP Mode at Minimum Stable Plant Load	%	The reduction in primary energy usage (i.e. measure of primary energy savings) is based on the EED. This is given by 2.1(f).
2.3	Can the Plant supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP Envelope')?		Should be identified: Yes or No
Requirement 3: Operation of the Plant with the Selected Identified Heat Load			
3.1	Proposed Operation of Plant with CHP		
a)	CHP Mode Net Electrical Output at Proposed Operational Plant Load	MW	The plant with CHP net electrical output at proposed operational plant load. Identified from modelling. This is represented by Point E on Insert 3.
b)	CHP Mode Net Electrical Efficiency at Proposed Operational Plant Load	%	The plant with CHP net electrical efficiency at proposed operational plant load based on the LHV. Identified from modelling. This is represented by Point E on Insert 3.

c)	CHP Mode Net CHP Efficiency at Proposed Operational Plant Load	%	The plant with CHP net CHP efficiency at proposed operational plant load based on the LHV. Identified from modelling. This is represented by Point E on Insert 3.
d)	Reduction in Net Electrical Output for CHP Mode at Proposed Operational Plant Load	MW	The extraction of heat from the plant will cause a corresponding loss in electrical power. Typically, the higher the quality of the extracted heat, the greater the corresponding loss in electrical power. The reduction in electrical power output due to the heat load extraction at proposed operational plant load is given by: (Net Electrical Output at Proposed Operational Plant Load) – (CHP Mode Net Electrical Output at Proposed Operational Plant Load).
e)	Reduction in Net Electrical Efficiency for CHP Mode at Proposed Operational Plant Load	%	The reduction in net electrical efficiency (based on the LHV due to the heat load extraction at proposed operational plant load is given by: (Net Electrical Efficiency at Proposed Operational Plant Load) – (CHP Mode Net Electrical Efficiency at Proposed Operational Plant Load).
f)	Reduction in Primary Energy Usage for CHP Mode at Proposed Operational Plant Load	%	The reduction in primary energy usage (i.e. measure of primary energy savings) is based on the EED. This is given by 2.1(f).
g)	Z Ratio		The Z-Ratio compares the heat exported to the reduction in electrical power. A higher Z-Ratio indicates a more efficient method of heat supply. This is given by: (Maximum Heat Load Extraction Required) / (Reduction in Net Electrical Output for CHP Mode at Proposed Operational Plant Load)

Requirement 4: Technical Provisions and Space Requirements			
4.1	Description of Likely Suitable Extraction Points		Demonstration of CHP-R does not require that suitable extraction points are fitted from the outset, but rather it is technically feasible to retrofit at a later date. Therefore, based on the likely heat load, a suitable method (or suitable methods) of extraction should be identified, along with the associated technical requirements of such extraction. For example, for heat load extraction from a CCGT power plant for a District Heating Scheme, a quantity of low pressure steam would be required. A suitable method of extraction would involve extracting a quantity of low pressure steam from the Intermediate Pressure / Low Pressure Turbine Crossover (if present). If this is not possible, but steam can be extracted from the Cold Reheat Pipe, a suitable method of extraction would involve extracting the steam and passing it through a let-down station or back pressure steam turbine. Additional information is presented in Appendix D.
4.2	Description of Potential Options which could be incorporated in the Plant, should a CHP Opportunity be realised outside the 'CHP Envelope'		If heat load extraction in sufficient quantities is not possible, consideration should be given to potential options which could be incorporated into the plant should the realised CHP opportunity be outside the identified 'CHP Envelope'. For example: • Back-up boilers operated by the plant operator / head load recipient; and • The use of heat storage equipment.
4.3	Description of how the future Costs and Burdens associated with supplying the Identified Heat Load / Potential CHP Opportunity have been minimised through the implementation of an appropriate CHP-R design		A description of how the future costs and burdens of CHP have been minimised. This may include discussions with major plant or component manufactures to investigate modifications to design which could allow for the maximum heat supply without compromising the initial performance, flexibility and reliability of the plant.

4.4	Provision of Site Layout of the Plant, indicating Available Space which could be made available for CHP-R		Following identification of suitable extraction points and potential options which could be incorporated into the design of the plant should a CHP opportunity be realised outside the 'CHP Envelope', demonstration of CHP-R comprises indication of the available space for the extraction points / potential options. For example: • When operating within the 'CHP Envelope', in addition to the extraction points, there may be a need for space to be provided for: - Supply and return pipes within the plant site, for steam and / or hot water; - The Water Treatment Plant / Demineralisation Plant, which may need to be increased in size if steam is to be piped off-site without condensate return; - A let-down station or back pressure steam turbine; and, - Back-up boilers, which could supply heat in the event that the plant is off-line. • When operating outside the 'CHP Envelope', there may be a need for space to be provided for: - Back-up boilers; and - Heat storage equipment. It is noted that the available space for the provision of additional balance of plant systems / control and instrumentation systems should be in the most suitable location, and therefore may not always be on the plant site itself.

Requirement 5: Integration of CHP and Carbon Capture			
5.1	Is the Plant required to be CCR?		Should be identified: Yes or No
5.2	Export and Return Requirements Identified for Carbon Capture		
	100% Plant Load		
a)	Heat Load Extraction for Carbon Capture at 100% Plant Load	MW	This is the heat load extraction required for carbon capture at 100% Plant Load. This does not include the heat available for export.
b)	Description of Heat Export (e.g. Steam / Hot Water)		To complete, based on the likely heat load extraction for carbon capture at 100% Plant Load.
c)	Export Pressure	bar a	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at 100% Plant Load.
d)	Export Temperature	°C	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at 100% Plant Load.
e)	Export Flow	t/h	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at 100% Plant Load.
f)	Return Pressure	bar a	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at 100% Plant Load.
g)	Return Temperature	°C	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at 100% Plant Load.
h)	Return Flow	t/h	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at 100% Plant Load.
i)	Likely Suitable Extraction Points		Based on the likely heat load extraction for carbon capture a suitable method (or suitable methods) of extraction should be identified.
	Minimum Stable Plant Load		
j)	Heat Load Extraction for Carbon Capture at Minimum Stable Plant Load	MW	This is the heat load extraction required for carbon capture at Minimum Stable Plant Load. This does not include the heat available for export.

k)	Description of Heat Export (e.g. Steam / Hot Water)		To complete, based on the likely heat load extraction for carbon capture at Minimum Stable Plant Load.
l)	Export Pressure	bar a	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at Minimum Stable Plant Load.
m)	Export Temperature	°C	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at Minimum Stable Plant Load.
n)	Export Flow	t/h	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at Minimum Stable Plant Load.
o)	Return Pressure	bar a	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at Minimum Stable Plant Load.
p)	Return Temperature	°C	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at Minimum Stable Plant Load.
q)	Return Flow	t/h	To complete, based on the likely requirements at the terminal point with the Carbon Capture Plant at Minimum Stable Plant Load.
r)	Likely Suitable Extraction Points		Based on the likely heat load extraction for carbon capture, a suitable method (or suitable methods) of extraction should be identified.
5.3	Operation of Plant with Carbon Capture (without CHP)		
a)	Maximum Plant Load with Carbon Capture	%	This is the maximum possible plant load with carbon capture. The value to be used is 100%.
b)	Carbon Capture Mode Thermal Input at Maximum Plant Load	MW	The plant with carbon capture thermal input (based on the LHV) at 100% plant load. Identified from modelling.
c)	Carbon Capture Mode Net Electrical Output at Maximum Plant Load	MW	The plant with carbon capture net electrical output at 100% plant load. Identified from modelling.
d)	Carbon Capture Mode Net Electrical Efficiency at Maximum Plant Load	%	The plant with carbon capture net electrical efficiency at 100% plant load based on the LHV. Identified from modelling.

e)	Minimum Stable Plant Load with CCS	%	This is the minimum stable plant load with carbon capture. This will vary with type of plant.
f)	Carbon Capture Mode CCS Thermal Input at Minimum Stable Plant Load	MW	The plant with carbon capture thermal input (based on the LHV) at minimum stable plant load.
g)	Carbon Capture Mode Net Electrical Output at Minimum Stable Plant Load	MW	The plant with carbon capture net electrical output at minimum stable plant load. Identified from modelling.
h)	Carbon Capture Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	The plant with carbon capture net electrical efficiency at minimum stable plant load based on the LHV. Identified from modelling.
5.4	Heat Extraction for CHP at 100% Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at 100% Plant Load with Carbon Capture [H]	MW	This is the maximum possible heat load extraction within the technical limitations of the plant with carbon capture at 100% plant load (i.e. heat load extraction beyond which major plant modification would be required). This will vary with type of plant, and Carbon Capture Plant requirement.
b)	Maximum Heat Extraction Export Flow at 100% Plant Load with Carbon Capture	t/h	This should be consistent with the: • Steam conditions given in 1.8; and • The figure given in 5.4(a).
c)	Carbon Capture and CHP Mode Net Electrical Output at 100% Plant Load	MW	The plant with carbon capture and CHP net electrical output at 100% plant load. Identified from modelling.
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at 100% Plant Load	%	The plant with carbon capture and CHP net electrical efficiency at 100% plant load based on the LHV. Identified from modelling.
e)	Carbon Capture and CHP Mode Net CHP Efficiency at 100% Plant Load	%	The plant with carbon capture and CHP net CHP efficiency at 100% plant load based on the LHV. Identified from modelling.
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at 100% Plant Load	%	The reduction in primary energy usage (i.e. measure of primary energy savings) is based on the EED. This is given by 2.1(f).

5.5	Heat Extraction at Minimum Stable Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load with Carbon Capture	MW	This is the maximum possible heat load extraction within the technical limitations of the plant with carbon capture at minimum stable plant load (i.e. heat load extraction beyond which major plant modification would be required). This will vary with type of plant, and Carbon Capture Plant requirement.
b)	Maximum Heat Extraction Export Flow at Minimum Stable Plant Load with Carbon Capture	t/h	This should be consistent with the: • Steam conditions given in 1.8; and • The limit given in 5.5(a).
c)	Carbon Capture and CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	The plant with carbon capture and CHP net electrical output at minimum stable plant load. Identified from modelling.
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	The plant with carbon capture and CHP net electrical efficiency at minimum stable plant load based on the LHV. Identified from modelling.
e)	Carbon Capture and CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	The plant with carbon capture and CHP net CHP efficiency at minimum stable plant load based on the LHV. Identified from modelling.
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at Minimum Stable Plant Load	%	The reduction in primary energy usage (i.e. measure of primary energy savings) is based on the EED. This is given by 2.1(f).
5.6	Can the Plant with Carbon Capture supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP and Carbon Capture Envelope')?		Should be identified: Yes or No

5.7	Description of Potential Options which could be incorporated in the Plant for useful integration of any realised CHP System and Carbon Capture System		The Carbon Capture Plant will reject large quantities of heat. A description of potential uses of this heat should be provided with regard to how it could be used in any CHP System. If this is not possible, consideration should be given to potential options which could be incorporated into the plant with carbon capture should the realised CHP opportunity be outside the identified 'CHP and Carbon Capture Envelope'.
Requirement 6: Economics of CHP-R			
6.1	Economic Assessment of CHP-R		A clear summary of the high level economic assessment (or Cost-Benefit Analysis) should be provided, stating for the selected potential future opportunity for heat supply, the associated potential future revenues / benefits and likely additional initial costs for the plant to be CHP-R. Unless it can be demonstrated that the additional initial costs for the plant to be CHP-R would be excessive (and outweigh the associated potential future revenues / benefits), it is considered that the economic viability of CHP-R is demonstrated.
BAT Assessment			
	Is the new plant a CHP plant at the outset (i.e. are there economically viable CHP opportunities at the outset)?		Should be identified: Yes or No. If yes, then the new plant is considered BAT.
	If not, is the new plant a CHP-R plant at the outset?		Should be identified: Yes or No If no, applicants should provide evidence as to why their plant should be excluded from being CHP-R.
	Once the new plant is CHP-R, is it BAT?		Should be identified: Yes or No (as a result of periodic reviews of opportunities for heat supply once the CHP-R plant becomes operational).

Appendix B: Case Studies / Worked Examples

This Appendix provides a number of Case Studies / Worked Examples using the CHP-R Assessment Form.

The Case Studies / Worked Examples are summarised below:

	Description
Case Study 1	Case Study 1 is based on a large multi-shaft CCGT power plant, which incorporates an IP / LP crossover pipe. Two selected heat loads are considered simultaneously. These are a heat load associated with an industrial use, and a heat load associated with district heating.
Case Study 2	Case Study 2 is based on a large multi-shaft CCGT power plant, which incorporates an IP / LP crossover pipe. One selected heat load is considered, which is associated with an industrial use.
Case Study 3	Case Study 3 is based on a biomass plant. One selected heat load is considered, which is associated with district heating.
Case Study 4	Case Study 4 is based on an EfW plant. One selected heat load is considered, which is associated with district heating.
Case Study 5a	Case Study 5a is based on a small single-shaft CCGT power plant, which does not incorporate an IP / LP crossover pipe. One selected heat load is considered, which is associated with district heating. Within Case Study 5a, although the selected heat load lies inside the CHP Envelope, the steam cannot be extracted from the IP turbine exhaust. Therefore, the steam is extracted from the cold reheat pipe, passed through a let-down station and supplied to the District Heating System.
Case Study 5b	Case Study 5b provides further assessment of Case Study 5a. Accordingly, Case Study 5b is also based on a small single shaft CCGT power plant, which does not incorporate an IP / LP crossover pipe. One selected heat load is considered, which is associated with district heating. Similar to Case Study 5a, although the selected heat load lies inside the CHP Envelope, the steam cannot be extracted from the IP turbine exhaust. Therefore, the steam is extracted from the cold reheat pipe, passed through a back pressure steam turbine and supplied to the District Heating System.

Case Study / Worked Example 1

#	Description	Units	Notes / Instructions
Requirement 1: Plant, Plant Location and Potential Heat Loads			
1.1	Plant Name		Case Study 1
1.2	Plant Description		Plant comprises: • Multi-shaft (1 + 1) Configuration; • IP / LP crossover pipe available as an extraction point; • Hybrid Cooling; and • UK ambient conditions.
1.3	Plant Location (Postcode / GridRef)		Not required for the Case Study
1.4	Factors Influencing Selection of Plant Location		Not required for the Case Study
1.5	Operation of Plant		
a)	Proposed Operational Plant Load	%	100
b)	Thermal Input at Proposed Operational Plant Load	MW	764.5
c)	Net Electrical Output at Proposed Operational Plant Load	MW	434.1
d)	Net Electrical Efficiency at Proposed Operational Plant Load	%	56.8
e)	Maximum Plant Load	%	100
f)	Thermal Input at Maximum Plant Load	MW	764.5
g)	Net Electrical Output at Maximum Plant Load	MW	434.1
h)	Net Electrical Efficiency at Maximum Plant Load	%	56.8
i)	Minimum Stable Plant Load	%	40
j)	Thermal Input at Minimum Stable Plant Load	MW	432.1
k)	Net Electrical Output at Minimum Stable Plant Load	MW	212.4
l)	Net Electrical Efficiency at Minimum Stable Plant Load	%	49.2
1.6	Identified Potential Heat Loads		
			30 MW of District Heating and 30 MW of Industrial Steam
1.7	Selected Heat Load(s)		

a)	Category (e.g. Industrial / District Heating)		District Heating (DH) / Industrial (I)
b)	Maximum Heat Load Extraction Required	MW	60
1.8	Export and Return Requirements of Heat Load		
a)	Description of Heat Load Extraction		Hot water (DH) / Superheated steam (I)
b)	Description of Heat Load Profile		Constant
c)	Export Pressure	bar a	5 (DH) / 20 (I)
d)	Export Temperature	°C	95 (DH) / 300 (I)
e)	Export Flow	t/h	645 (DH) / 40 (I)
f)	Return Pressure	bar a	3 (DH) / 5 (I)
g)	Return Temperature	°C	55 (DH) / 82.2 (I)
h)	Return Flow	t/h	645 (DH) / 36 (I) (Note: Only 90% of the industrial steam is returned)
Requirement 2: Identification of CHP Envelope			
2.0	Comparative Efficiency of a Standalone Boiler for supplying the Heat Load	90 % LHV	90
2.1	Heat Extraction at 100% Plant Load		
a)	Maximum Heat Load Extraction at 100% Plant Load	MW	161 (42.5 (DH) / 118.5 (I))
b)	Maximum Heat Extraction Export Flow at 100% Plant Load	t/h	910 (DH) / 157 (I)
c)	CHP Mode Net Electrical Output at 100% Plant Load	MW	389
d)	CHP Mode Net Electrical Efficiency at 100% Plant Load	%	51.0
e)	CHP Mode Net CHP Efficiency at 100% Plant Load	%	72.0
f)	Reduction in Primary Energy Usage for CHP Mode at 100% Plant Load	%	11.6
2.2	Heat Extraction at Minimum Stable Plant Load		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load	MW	106
b)	Heat Extraction Export Flow at Minimum Stable Plant Load	t/h	620 (DH) / 102 (I)

c)	CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	182
d)	CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	42.0
e)	CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	66.5
f)	Reduction in Primary Energy Usage for CHP Mode at Minimum Stable Plant Load	%	11.2
2.3	Can the Plant supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP Envelope')?		Yes
Requirement 3: Operation of the Plant with the Selected Identified Heat Load			
3.1	Proposed Operation of Plant with CHP		
a)	CHP Mode Net Electrical Output at Proposed Operational Plant Load	MW	419
b)	CHP Mode Net Electrical Efficiency at Proposed Operational Plant Load	%	54.8
c)	CHP Mode Net CHP Efficiency at Proposed Operational Plant Load	%	62.7
d)	Reduction in Net Electrical Output for CHP Mode at Proposed Operational Plant Load	MW	15.1
e)	Reduction in Net Electrical Efficiency for CHP Mode at Proposed Operational Plant Load	%	3.5
f)	Reduction in Primary Energy Usage for CHP Mode at Proposed Operational Plant Load	%	5.0
g)	Z Ratio		4.0
Requirement 4: Technical Provisions and Space Requirements			

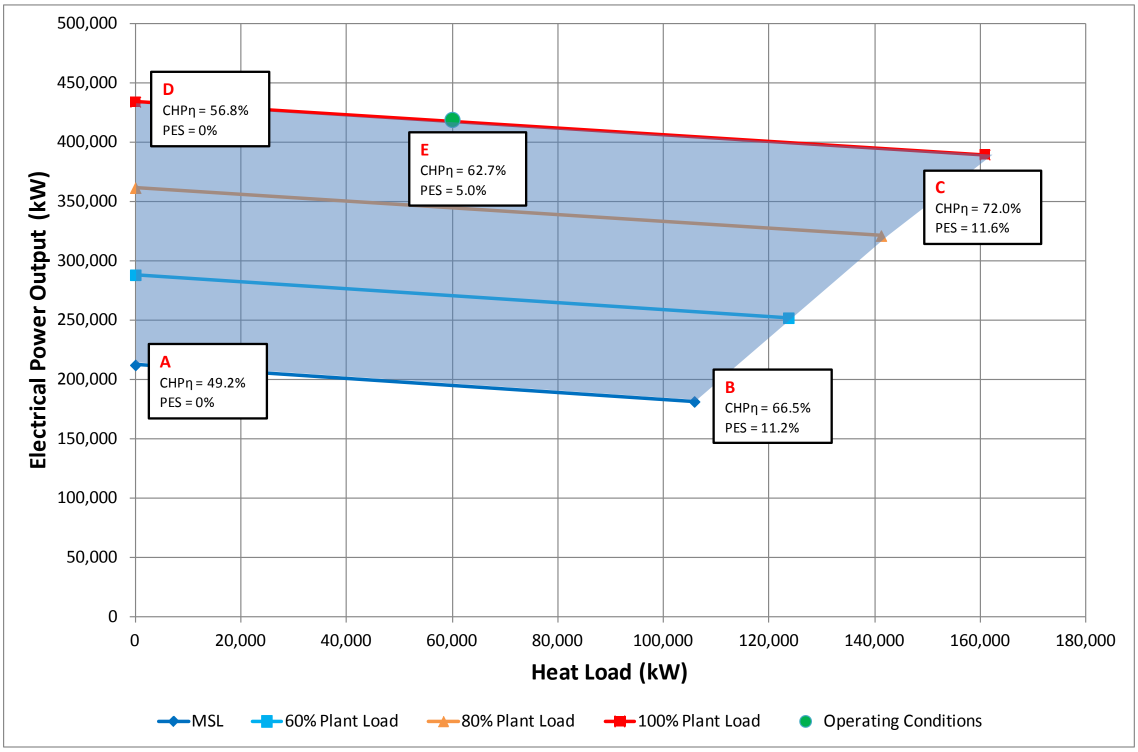
4.1	Description of Likely Suitable Extraction Points		Steam for the District Heating System is extracted from the Low Pressure (LP) cross over pipe, (which supplies steam to the LP turbine from the exhaust of the Intermediate Pressure (IP) turbine). Steam for the Industrial Process is extracted from the cold reheat line. To facilitate this, a cold reheat header would be required.
4.2	Description of Potential Options which could be incorporated in the Plant, should a CHP Opportunity be realised outside the 'CHP Envelope'		N / A (CHP opportunity lies within the CHP Envelope)
4.3	Description of how the future Costs and Burdens associated with supplying the Identified Heat Load / Potential CHP Opportunity have been minimised through the implementation of an appropriate CHP-R design		Not required for the Case Study
4.4	Provision of Site Layout of the Plant, indicating Available Space which could be made available for CHP-R		Please see Layout CS 01. The District Heating System will (likely) include: extraction piping; control and shut-off valves, and actuators; a Pressure Reduction and De-superheating Station; District Heaters; District Heating supply and return lines; condensate return piping (to the condensate header); interconnecting piping; drains; pipe bridges / supports; and Control and Instrumentation / electrical connections. The Industrial Process will (likely) include: the installation of a cold reheat header; extraction piping; control and shut-off valves, and actuators; a Pressure Reduction and De-Superheating Station; condensate return piping; interconnecting pipeline; drains pipe bridges / supports; and Control and Instrumentation / electrical connections. A Stand-by Boiler is also included. Provision is also made for possible extension of the Water Treatment Plant.
Requirement 5: Integration of CHP and Carbon Capture			

5.1	Is the Plant required to be CCR?		Yes
5.2	Export and Return Requirements Identified for Carbon Capture		
	100% Plant Load		
a)	Heat Load Extraction for Carbon Capture at 100% Plant Load	MW	128.9
b)	Description of Heat Export (e.g. Steam / Hot Water)		Low pressure steam
c)	Export Pressure	bar a	3.4
d)	Export Temperature	°C	150
e)	Export Flow	t/h	212.8
f)	Return Pressure	bar a	3.4
g)	Return Temperature	°C	137.4
h)	Return Flow	t/h	212.8
i)	Likely Suitable Extraction Points		LP superheated steam / HP water desuperheating
	Minimum Stable Plant Load		
j)	Heat Load Extraction for Carbon Capture at Minimum Stable Plant Load	MW	71.5
k)	Description of Heat Export (e.g. Steam / Hot Water)		Low pressure steam
l)	Export Pressure	bar a	2.7
m)	Export Temperature	°C	150
n)	Export Flow	t/h	116
o)	Return Pressure	bar a	2.7
p)	Return Temperature	°C	130
q)	Return Flow	t/h	116
r)	Likely Suitable Extraction Points		LP superheated steam / HP water desuperheating
5.3	Operation of Plant with Carbon Capture (without CHP)		
a)	Maximum Plant Load with Carbon Capture	%	100
b)	Carbon Capture Mode Thermal Input at Maximum Plant Load	MW	764.7
c)	Carbon Capture Mode Net Electrical Output at Maximum Plant Load	MW	400.4
d)	Carbon Capture Mode Net Electrical Efficiency at Maximum Plant Load	%	52.4
e)	Minimum Stable Plant Load with CCS	%	40
f)	Carbon Capture Mode CCS Thermal Input at Minimum Stable Plant Load	MW	432

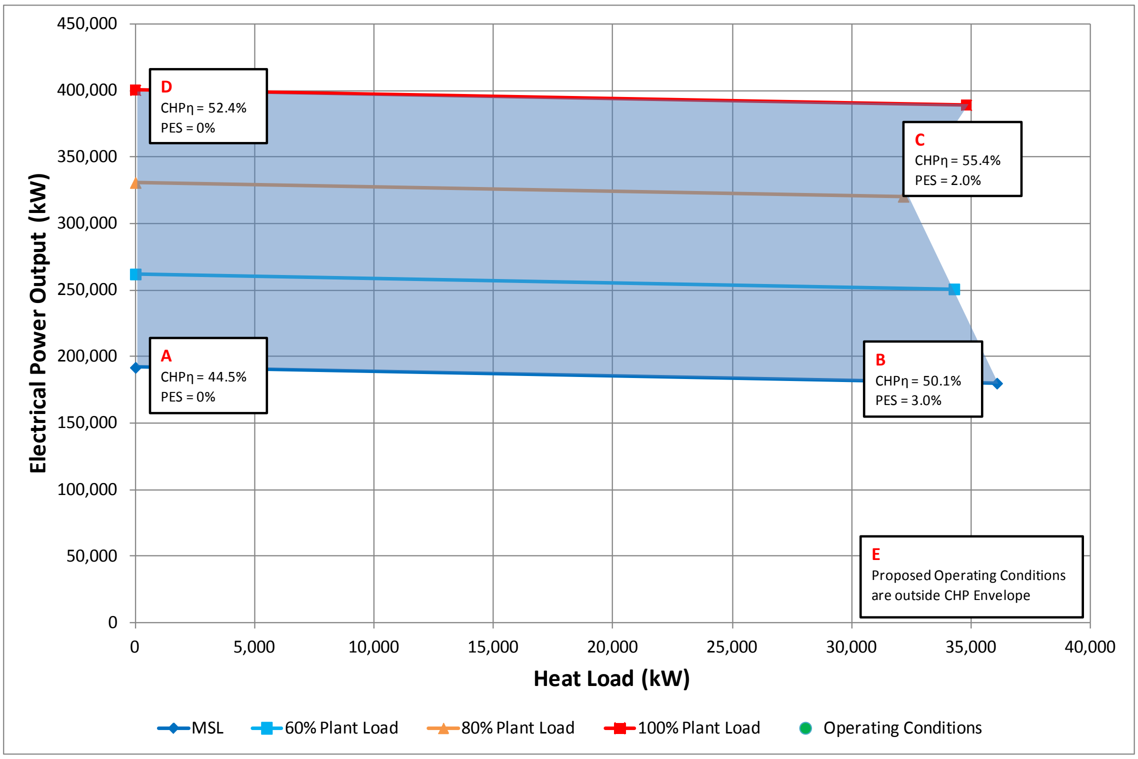
g)	Carbon Capture Mode Net Electrical Output at Minimum Stable Plant Load	MW	192
h)	Carbon Capture Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	44.5
5.4	Heat Extraction for CHP at 100% Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at 100% Plant Load with Carbon Capture [H]	MW	35
b)	Maximum Heat Extraction Export Flow at 100% Plant Load with Carbon Capture	t/h	185 (DH) / 35 (I)
c)	Carbon Capture and CHP Mode Net Electrical Output at 100% Plant Load	MW	389.2
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at 100% Plant Load	%	50.9
e)	Carbon Capture and CHP Mode Net CHP Efficiency at 100% Plant Load	%	55.4
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at 100% Plant Load	%	2.0
5.5	Heat Extraction at Minimum Stable Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load with Carbon Capture	MW	36
b)	Maximum Heat Extraction Export Flow at Minimum Stable Plant Load with Carbon Capture	t/h	191 (DH) / 36 (I)
c)	Carbon Capture and CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	180.1
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	41.7
e)	Carbon Capture and CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	50.1

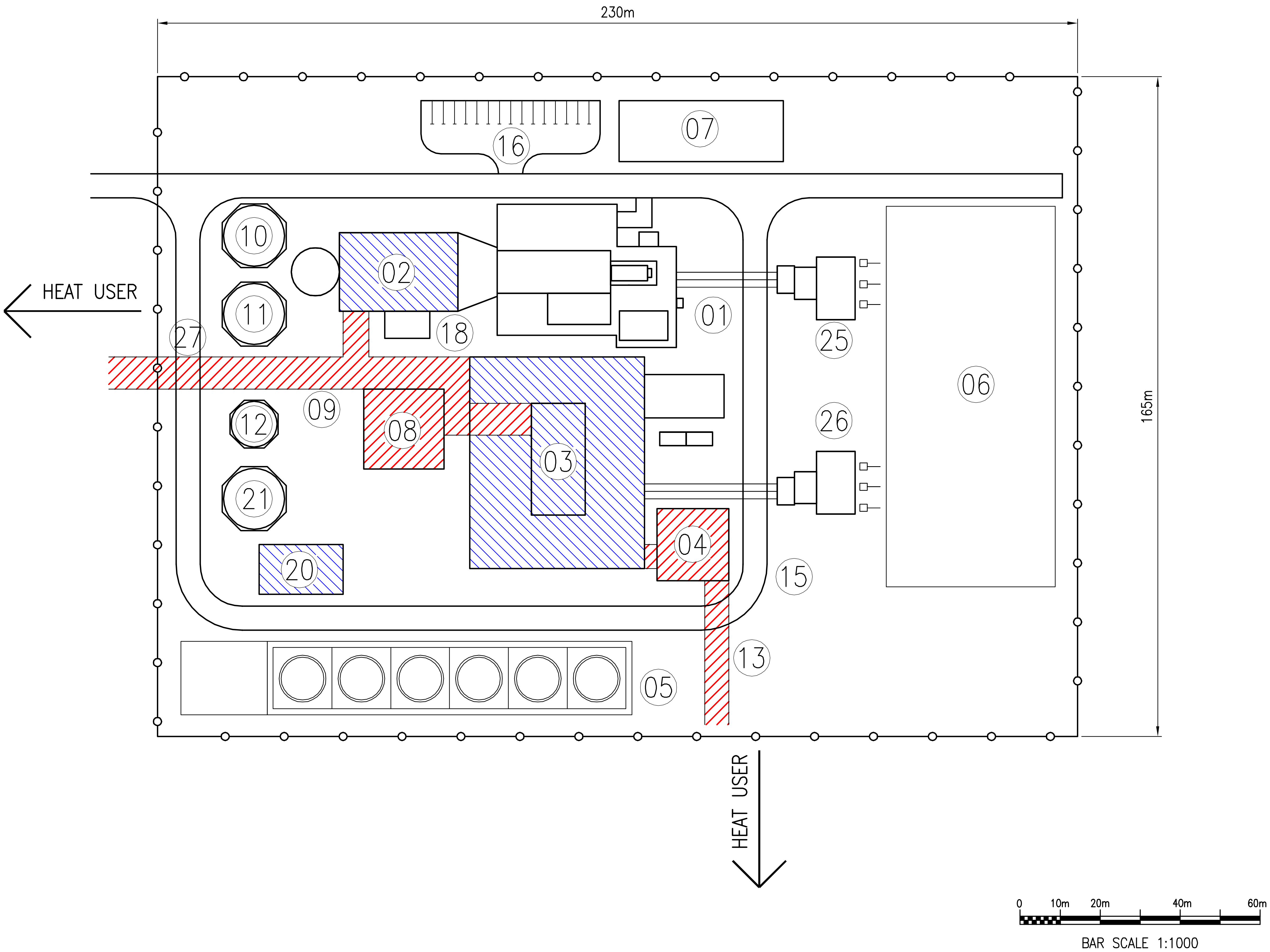
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at Minimum Stable Plant Load	%	3.0
5.6	Can the Plant with Carbon Capture supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP and Carbon Capture Envelope')?		No
5.7	Description of Potential Options which could be incorporated in the Plant for useful integration of any realised CHP System and Carbon Capture System		The plant has sufficient capacity to simultaneously meet the CCS requirements and produce steam from one of the two identified heat loads (either Industrial or District Heating). However, in the case where the plant is required to simultaneously meet the carbon capture requirement and both identified heat loads (Industrial and District Heating), a dedicated auxiliary boiler may form part of the CHP Plant. Therefore, the plant would produce heat for the Carbon Capture Plant requirement and one of the identified heat loads, and the auxiliary boiler would produce heat for the remaining heat load.
Requirement 6: Economics of CHP-R			
6.1	Economic Assessment of CHP-R		Not required for the Case Study
BAT Assessment			
	Is the new plant a CHP plant at the outset (i.e. are there economically viable CHP opportunities at the outset)?		Not required for the Case Study
	If not, is the new plant a CHP-R plant at the outset?		Not required for the Case Study
	Once the new plant is CHP-R, is it BAT?		Not required for the Case Study

CHP Envelope for Case Study 1



CHP and Carbon Capture Envelope for Case Study 1





LEGEND

CCGT PLANT

- 01 GAS TURBINE
- 02 HEAT RECOVERY STEAM GENERATOR
- 03 STEAM TURBINE
- 05 COOLING TOWERS
- 06 A.I SWITCHYARD
- 07 ADMINISTRATION, SHOP & WAREHOUSE
- 10 DEMINERALISED WATER TANK
- 11 RAW WATER TANK
- 12 NEUTRALIZED WATER TANK
- 15 ROAD
- 16 PARKING
- 18 FEED PUMPS
- 20 WATER TREATMENT PLANT
- 21 FIRE PROTECTION TANK
- 25 GAS TURBINE TRANSFORMER
- 26 STEAM TURBINE TRANSFORMER

CHP-R PROVISIONS

- 02 HRSG WITH PROVISIONS FOR IDENTIFIED SUITABLE RETURN POINTS
- 03 STEAM TURBINE WITH PROVISIONS FOR IDENTIFIED SUITABLE EXTRACTION POINTS
- 04 ON SITE SPACE FOR DISTRICT HEATING HEAT EXCHANGERS
- 08 ON SITE SPACE FOR STANDBY BOILER
- 09 ON SITE SPACE FOR INDUSTRIAL STEAM AND CONDENSATE RETURN PIPEWORK (PIPE CORRIDOR)
- 13 ON SITE SPACE FOR DISTRICT HEATING WATER PIPEWORK (PIPE CORRIDOR) INCLUDES SPACE FOR PUMPS AND EXPANSION LOOPS ETC (PIPE CORRIDOR)
- 20 POSSIBLE EXPANSION TO WATER TREATMENT PLANT
- 27 PIPEBRIDGE

Rev	Date	Description	By	Chk	App	Notes:

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Client: ENVIRONMENT AGENCY

Project: CHP-R GUIDANCE

Title: SITE LAYOUT PLAN FOR CASE STUDY 1 CCGT POWER PLANT WITH 30MW DISTRICT HEATING & 30MW INDUSTRIAL CHP USE

Drawn: ALM		Checked:	
Designed: EB		Approved:	
Date: 30/07/2012	Scale: 1:1000	A3	Sheet
Project Number: 3511829A		Drawing Number: CS 01	Revision:

Login: Minikin, Sandra
Plot Date: 09/08/2012 11:40:02
File Name: K:\Projects\3511829A - CHP-R Case Study\Z. Drawings\1. Current\Civil\CS1 mod.dwg

Project Number:	Drawing Number:	Revision:
3511829A	CS 01	

Case Study / Worked Example 2

#	Description	Units	Notes / Instructions
Requirement 1: Plant, Plant Location and Potential Heat Loads			
1.1	Plant Name		Case Study 2
1.2	Plant Description		Plant comprises: • Multi-shaft (2 + 1) Configuration; • IP / LP crossover pipe available as an extraction point; • Hybrid Cooling; and • UK ambient conditions.
1.3	Plant Location (Postcode / GridRef)		Not required for the Case Study
1.4	Factors Influencing Selection of Plant Location		Not required for the Case Study
1.5	Operation of Plant		
a)	Proposed Operational Plant Load	%	100
b)	Thermal Input at Proposed Operational Plant Load	MW	1543
c)	Net Electrical Output at Proposed Operational Plant Load	MW	889
d)	Net Electrical Efficiency at Proposed Operational Plant Load	%	57.6
e)	Maximum Plant Load	%	100
f)	Thermal Input at Maximum Plant Load	MW	1543
g)	Net Electrical Output at Maximum Plant Load	MW	889
h)	Net Electrical Efficiency at Maximum Plant Load	%	57.6
i)	Minimum Stable Plant Load	%	40
j)	Thermal Input at Minimum Stable Plant Load	MW	854.6
k)	Net Electrical Output at Minimum Stable Plant Load	MW	429
l)	Net Electrical Efficiency at Minimum Stable Plant Load	%	50.2
1.6	Identified Potential Heat Loads		
			200 MW Industrial
1.7	Selected Heat Load(s)		

a)	Category (e.g. Industrial / District Heating)		Industrial
b)	Maximum Heat Load Extraction Required	MW	200
1.8	Export and Return Requirements of Heat Load		
a)	Description of Heat Load Extraction		Superheated steam
b)	Description of Heat Load Profile		Constant
c)	Export Pressure	bar a	20
d)	Export Temperature	°C	300
e)	Export Flow	t/h	273
f)	Return Pressure	bar a	5
g)	Return Temperature	°C	82.2
h)	Return Flow	t/h	273
Requirement 2: Identification of CHP Envelope			
2.0	Comparative Efficiency of a Standalone Boiler for supplying the Heat Load	90 % LHV	90
2.1	Heat Extraction at 100% Plant Load		
a)	Maximum Heat Load Extraction at 100% Plant Load	MW	251
b)	Maximum Heat Extraction Export Flow at 100% Plant Load	t/h	337
c)	CHP Mode Net Electrical Output at 100% Plant Load	MW	807
d)	CHP Mode Net Electrical Efficiency at 100% Plant Load	%	52.3
e)	CHP Mode Net CHP Efficiency at 100% Plant Load	%	68.5
f)	Reduction in Primary Energy Usage for CHP Mode at 100% Plant Load	%	8.1
2.2	Heat Extraction at Minimum Stable Plant Load		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load	MW	164
b)	Heat Extraction Export Flow at Minimum Stable Plant Load	t/h	220
c)	CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	376

d)	CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	44.0
e)	CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	63.1
f)	Reduction in Primary Energy Usage for CHP Mode at Minimum Stable Plant Load	%	8.1
2.3	Can the Plant supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP Envelope')?		Yes
Requirement 3: Operation of the Plant with the Selected Identified Heat Load			
3.1	Proposed Operation of Plant with CHP		
a)	CHP Mode Net Electrical Output at Proposed Operational Plant Load	MW	823
b)	CHP Mode Net Electrical Efficiency at Proposed Operational Plant Load	%	53.3
c)	CHP Mode Net CHP Efficiency at Proposed Operational Plant Load	%	66.3
d)	Reduction in Net Electrical Output for CHP Mode at Proposed Operational Plant Load	MW	66
e)	Reduction in Net Electrical Efficiency for CHP Mode at Proposed Operational Plant Load	%	7.5
f)	Reduction in Primary Energy Usage for CHP Mode at Proposed Operational Plant Load	%	6.5
g)	Z Ratio		3.0
Requirement 4: Technical Provisions and Space Requirements			
4.1	Description of Likely Suitable Extraction Points		Steam for the Industrial Process is extracted from the cold reheat line. To facilitate this, a cold reheat header would be required.

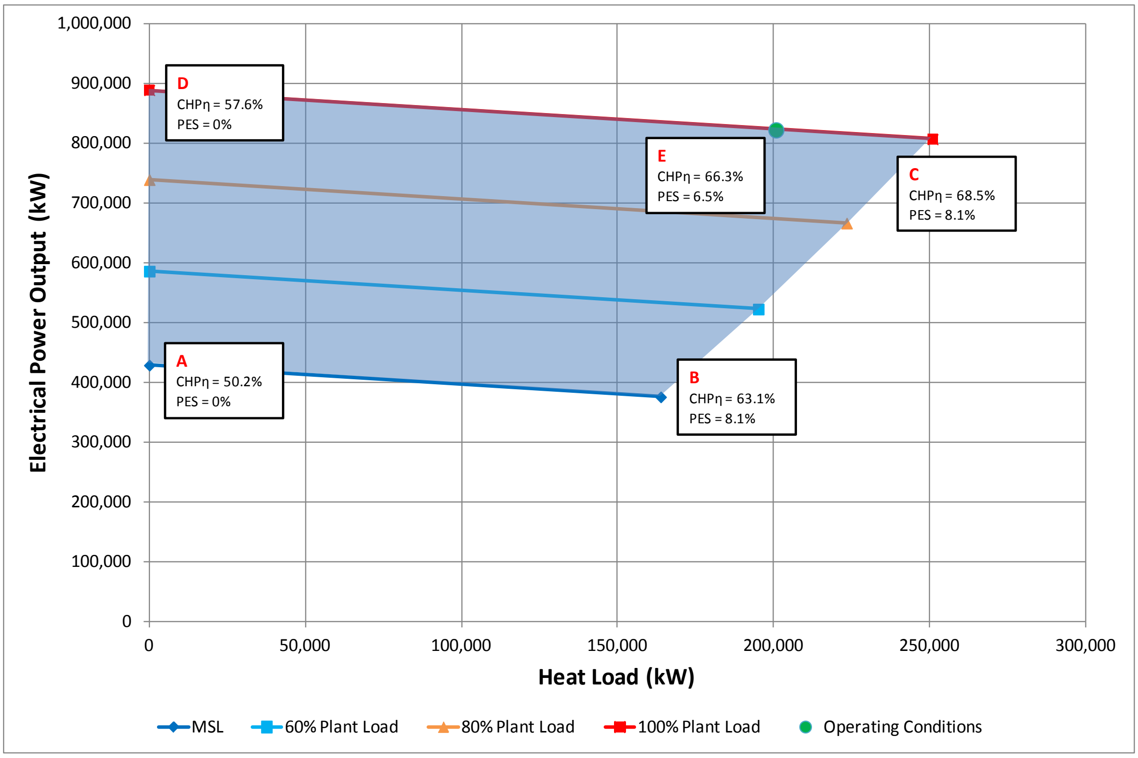
4.2	Description of Potential Options which could be incorporated in the Plant, should a CHP Opportunity be realised outside the 'CHP Envelope'		N / A (CHP opportunity lies within the CHP Envelope)
4.3	Description of how the future Costs and Burdens associated with supplying the Identified Heat Load / Potential CHP Opportunity have been minimised through the implementation of an appropriate CHP-R design		Not required for the Case Study
4.4	Provision of Site Layout of the Plant, indicating Available Space which could be made available for CHP-R		Please see Layout CS 02. The Industrial Process will (likely) include: the installation of a cold reheat header; extraction piping; control and shut-off valves, and actuators; a Pressure Reduction and De-Superheating Station; condensate return piping; interconnecting pipeline; drains pipe bridges / supports; and Control and Instrumentation / electrical connections. A Stand-by Boiler is also included. Provision is also made for possible extension of the Water Treatment Plant.
Requirement 5: Integration of CHP and Carbon Capture			
5.1	Is the Plant required to be CCR?		Yes
5.2	Export and Return Requirements Identified for Carbon Capture		
	100% Plant Load		
a)	Heat Load Extraction for Carbon Capture at 100% Plant Load	MW	258
b)	Description of Heat Export (e.g. Steam / Hot Water)		Low pressure steam
c)	Export Pressure	bar a	3.4
d)	Export Temperature	°C	150
e)	Export Flow	t/h	425.7
f)	Return Pressure	bar a	3.4
g)	Return Temperature	°C	137
h)	Return Flow	t/h	425.7
i)	Likely Suitable Extraction Points		LP superheated steam / HP water desuperheating
	Minimum Stable Plant Load		

j)	Heat Load Extraction for Carbon Capture at Minimum Stable Plant Load	MW	142.5
k)	Description of Heat Export (e.g. Steam / Hot Water)		Low pressure steam
l)	Export Pressure	bar a	2.7
m)	Export Temperature	°C	150
n)	Export Flow	t/h	232
o)	Return Pressure	bar a	2.7
p)	Return Temperature	°C	130
q)	Return Flow	t/h	232
r)	Likely Suitable Extraction Points		LP superheated steam / HP water desuperheating
5.3	Operation of Plant with Carbon Capture (without CHP)		
a)	Maximum Plant Load with Carbon Capture	%	100
b)	Carbon Capture Mode Thermal Input at Maximum Plant Load	MW	1542
c)	Carbon Capture Mode Net Electrical Output at Maximum Plant Load	MW	822
d)	Carbon Capture Mode Net Electrical Efficiency at Maximum Plant Load	%	53.3
e)	Minimum Stable Plant Load with CCS	%	40
f)	Carbon Capture Mode CCS Thermal Input at Minimum Stable Plant Load	MW	856
g)	Carbon Capture Mode Net Electrical Output at Minimum Stable Plant Load	MW	389
h)	Carbon Capture Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	45.5
5.4	Heat Extraction for CHP at 100% Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at 100% Plant Load with Carbon Capture [H]	MW	86.5
b)	Maximum Heat Extraction Export Flow at 100% Plant Load with Carbon Capture	t/h	117
c)	Carbon Capture and CHP Mode Net Electrical Output at 100% Plant Load	MW	791

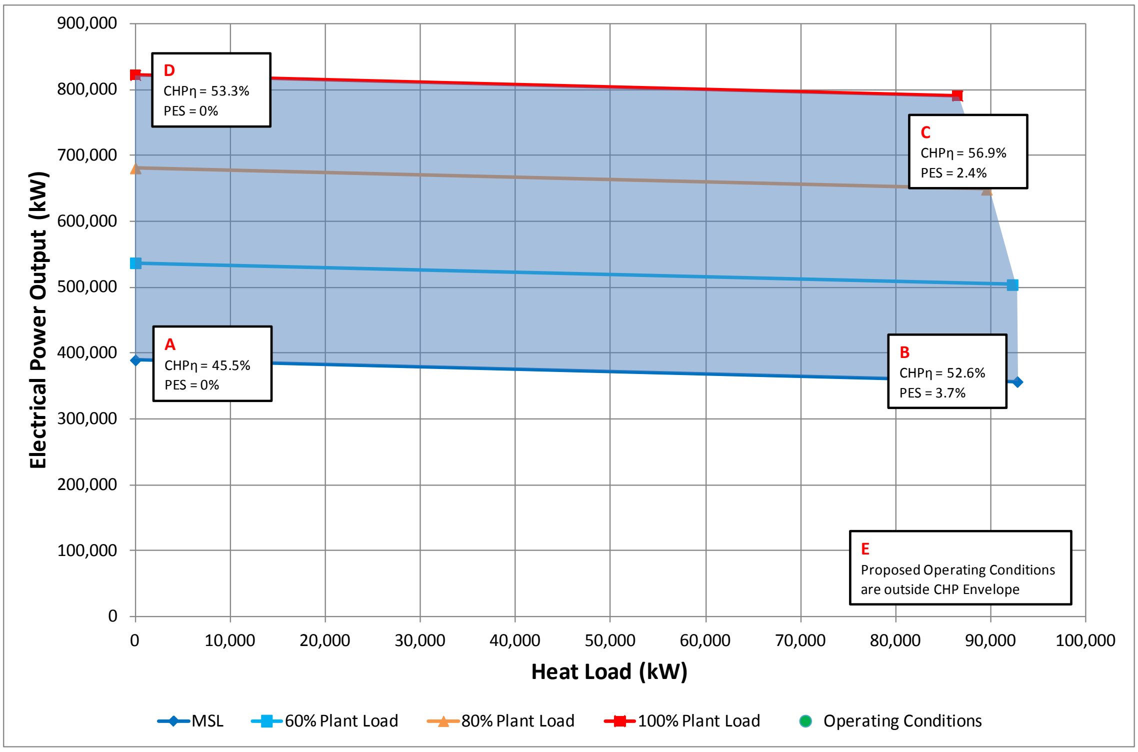
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at 100% Plant Load	%	51.3
e)	Carbon Capture and CHP Mode Net CHP Efficiency at 100% Plant Load	%	56.9
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at 100% Plant Load	%	2.4
5.5	Heat Extraction at Minimum Stable Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load with Carbon Capture	MW	93
b)	Maximum Heat Extraction Export Flow at Minimum Stable Plant Load with Carbon Capture	t/h	125
c)	Carbon Capture and CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	357
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	41.7
e)	Carbon Capture and CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	52.6
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at Minimum Stable Plant Load	%	3.7
5.6	Can the Plant with Carbon Capture supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the ‘CHP and Carbon Capture Envelope’)?		No
5.7	Description of Potential Options which could be incorporated in the Plant for useful integration of any realised CHP System and Carbon Capture System		In the case where the plant is required to simultaneously meet the carbon capture requirement and the identified heat load, a dedicated auxiliary boiler may form part of the CHP Plant.

Requirement 6: Economics of CHP-R			
6.1	Economic Assessment of CHP-R		Not required for the Case Study
BAT Assessment			
	Is the new plant a CHP plant at the outset (i.e. are there economically viable CHP opportunities at the outset)?		Not required for the Case Study
	If not, is the new plant a CHP-R plant at the outset?		Not required for the Case Study
	Once the new plant is CHP-R, is it BAT?		Not required for the Case Study

CHP Envelope for Case Study 2



CHP and Carbon Capture Envelope for Case Study 2



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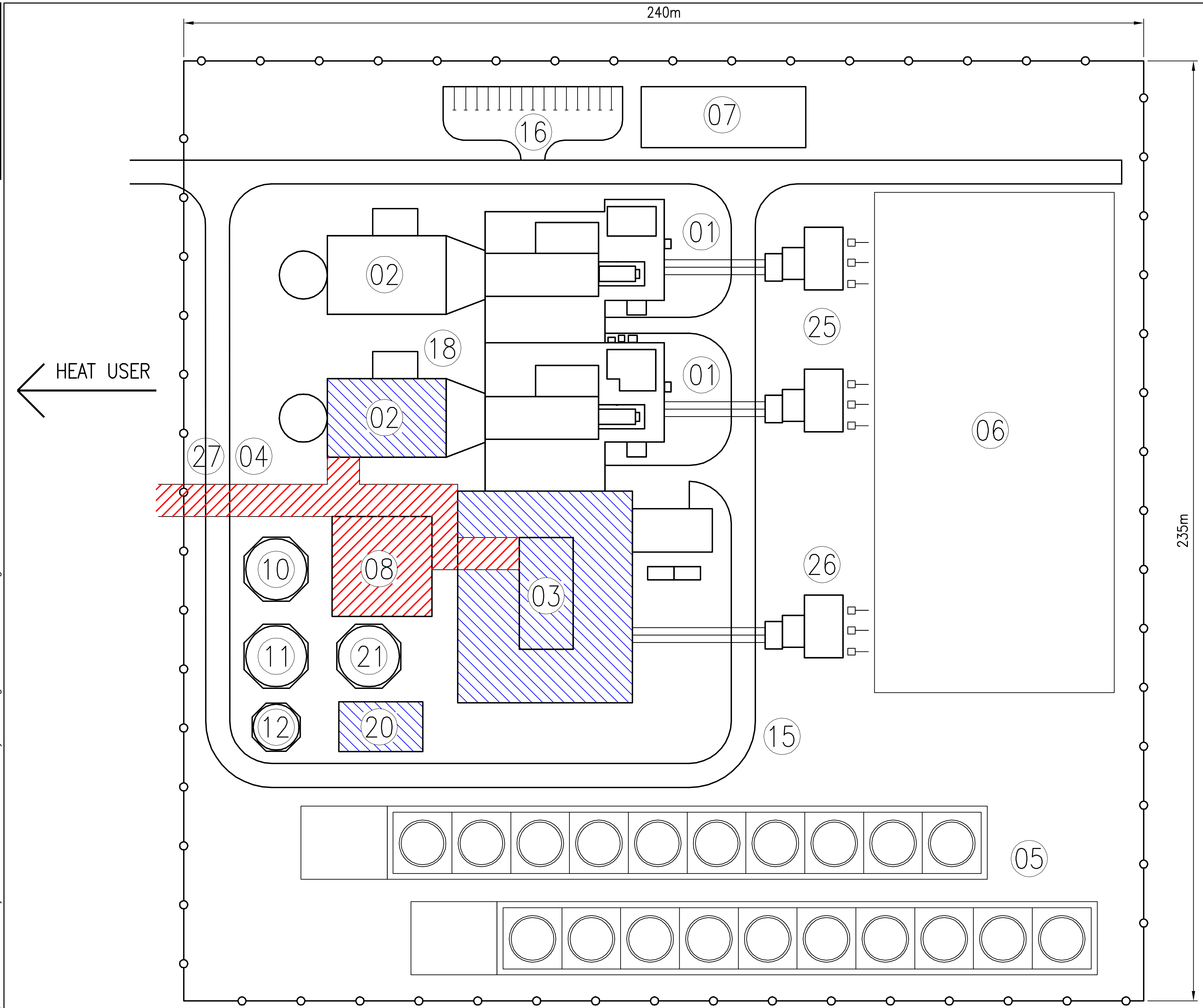
Plot Date: 09/08/2012 11:41:26
File Name: K:\Projects\3511829A - CHP-R Case Study\Z. Drawings\1. Current\Civil\CS2.dwg

Project Number: 3511829A | Drawing Number: CS 02 | Revision:



LEGEND

CCGT PLANT

- (01) GAS TURBINE
- (02) HEAT RECOVERY STEAM GENERATOR
- (03) STEAM TURBINE
- (05) COOLING TOWERS
- (06) A.I. SWITCHYARD
- (07) ADMINISTRATION, SHOP & WAREHOUSE
- (10) DEMINERALISED WATER TANK
- (11) RAW WATER TANK
- (12) NEUTRALIZED WATER TANK
- (15) ROAD
- (16) PARKING
- (18) FEED PUMPS
- (20) WATER TREATMENT PLANT
- (21) FIRE PROTECTION TANK
- (25) GAS TURBINE TRANSFORMER
- (26) STEAM TURBINE TRANSFORMER

CHP-R PROVISIONS

- (02) HRSG WITH PROVISIONS FOR IDENTIFIED SUITABLE RETURN POINTS
- (03) STEAM TURBINE WITH PROVISIONS FOR IDENTIFIED SUITABLE EXTRACTION POINTS
- (04) ON SITE SPACE FOR INDUSTRIAL STEAM PIPEWORK (PIPE CORRIDOR)
- (08) ON SITE SPACE FOR STANDBY BOILER
- (20) POSSIBLE EXPANSION TO WATER TREATMENT PLANT
- (27) PIPEBRIDGE

0 10m 20m 40m 60m

BAR SCALE 1:1000

Rev	Date	Description	By	Chk	App	Notes:

PARSONS BRINCKERHOFF

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Newcastle upon Tyne NE4 7YQ
Tel: 44-(0)191-226-2000
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Client: ENVIRONMENT AGENCY

Project: CHP-R GUIDANCE

Title: SITE LAYOUT PLAN FOR CASE STUDY 2 CCGT POWER PLANT WITH 200MW INDUSTRIAL CHP USE

Drawn: ALM		Checked:	
Designed: EB		Approved:	
Date: 25/07/2012	Scale: 1:1000	A3	Sheet:
Project Number: 3511829A		Drawing Number: CS 02	Revision:

Case Study / Worked Example 3

#	Description	Units	Notes / Instructions
Requirement 1: Plant, Plant Location and Potential Heat Loads			
1.1	Plant Name		Case Study 3
1.2	Plant Description		Biomass Plant
1.3	Plant Location (Postcode / GridRef)		Not required for the Case Study
1.4	Factors Influencing Selection of Plant Location		Not required for the Case Study
1.5	Operation of Plant		
a)	Proposed Operational Plant Load	%	100
b)	Thermal Input at Proposed Operational Plant Load	MW	210
c)	Net Electrical Output at Proposed Operational Plant Load	MW	75
d)	Net Electrical Efficiency at Proposed Operational Plant Load	%	35.8
e)	Maximum Plant Load	%	100
f)	Thermal Input at Maximum Plant Load	MW	210
g)	Net Electrical Output at Maximum Plant Load	MW	75
h)	Net Electrical Efficiency at Maximum Plant Load	%	35.8
i)	Minimum Stable Plant Load	%	60
j)	Thermal Input at Minimum Stable Plant Load	MW	126
k)	Net Electrical Output at Minimum Stable Plant Load	MW	42
l)	Net Electrical Efficiency at Minimum Stable Plant Load	%	33.4
1.6	Identified Potential Heat Loads		
			45 MW District Heating
1.7	Selected Heat Load(s)		
a)	Category (e.g. Industrial / District Heating)		District Heating
b)	Maximum Heat Load Extraction Required	MW	45
1.8	Export and Return Requirements of Heat Load		
a)	Description of Heat Load Extraction		Hot water
b)	Description of Heat Load Profile		Variable

c)	Export Pressure	bar a	5
d)	Export Temperature	°C	95
e)	Export Flow	t/h	970
f)	Return Pressure	bar a	3
g)	Return Temperature	°C	55
h)	Return Flow	t/h	970
Requirement 2: Identification of CHP Envelope			
2.0	Comparative Efficiency of a Standalone Boiler for supplying the Heat Load	90 % LHV	90
2.1	Heat Extraction at 100% Plant Load		
a)	Maximum Heat Load Extraction at 100% Plant Load	MW	40
b)	Maximum Heat Extraction Export Flow at 100% Plant Load	t/h	859
c)	CHP Mode Net Electrical Output at 100% Plant Load	MW	69.7
d)	CHP Mode Net Electrical Efficiency at 100% Plant Load	%	33.2
e)	CHP Mode Net CHP Efficiency at 100% Plant Load	%	52.3
f)	Reduction in Primary Energy Usage for CHP Mode at 100% Plant Load	%	12.3
2.2	Heat Extraction at Minimum Stable Plant Load		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load	MW	18
b)	Heat Extraction Export Flow at Minimum Stable Plant Load	t/h	387
c)	CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	39.3
d)	CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	31.3
e)	CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	45.6
f)	Reduction in Primary Energy Usage for CHP Mode at Minimum Stable Plant Load	%	8.7

2.3	Can the Plant supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP Envelope')?		No (Go to Requirement 4)
Requirement 3: Operation of the Plant with the Selected Identified Heat Load			
3.1	Proposed Operation of Plant with CHP		
a)	CHP Mode Net Electrical Output at Proposed Operational Plant Load	MW	N / A
b)	CHP Mode Net Electrical Efficiency at Proposed Operational Plant Load	%	N / A
c)	CHP Mode Net CHP Efficiency at Proposed Operational Plant Load	%	N / A
d)	Reduction in Net Electrical Output for CHP Mode at Proposed Operational Plant Load	MW	N / A
e)	Reduction in Net Electrical Efficiency for CHP Mode at Proposed Operational Plant Load	%	N / A
f)	Reduction in Primary Energy Usage for CHP Mode at Proposed Operational Plant Load	%	N / A
g)	Z Ratio		N / A
Requirement 4: Technical Provisions and Space Requirements			
4.1	Description of Likely Suitable Extraction Points		An amount of steam for the District Heating System could be supplied from the bleed steam lines for the LP feedwater heaters, downstream of the non return valves.
4.2	Description of Potential Options which could be incorporated in the Plant, should a CHP Opportunity be realised outside the 'CHP Envelope'		Additional amounts of steam could be generated from a stand-by boiler.

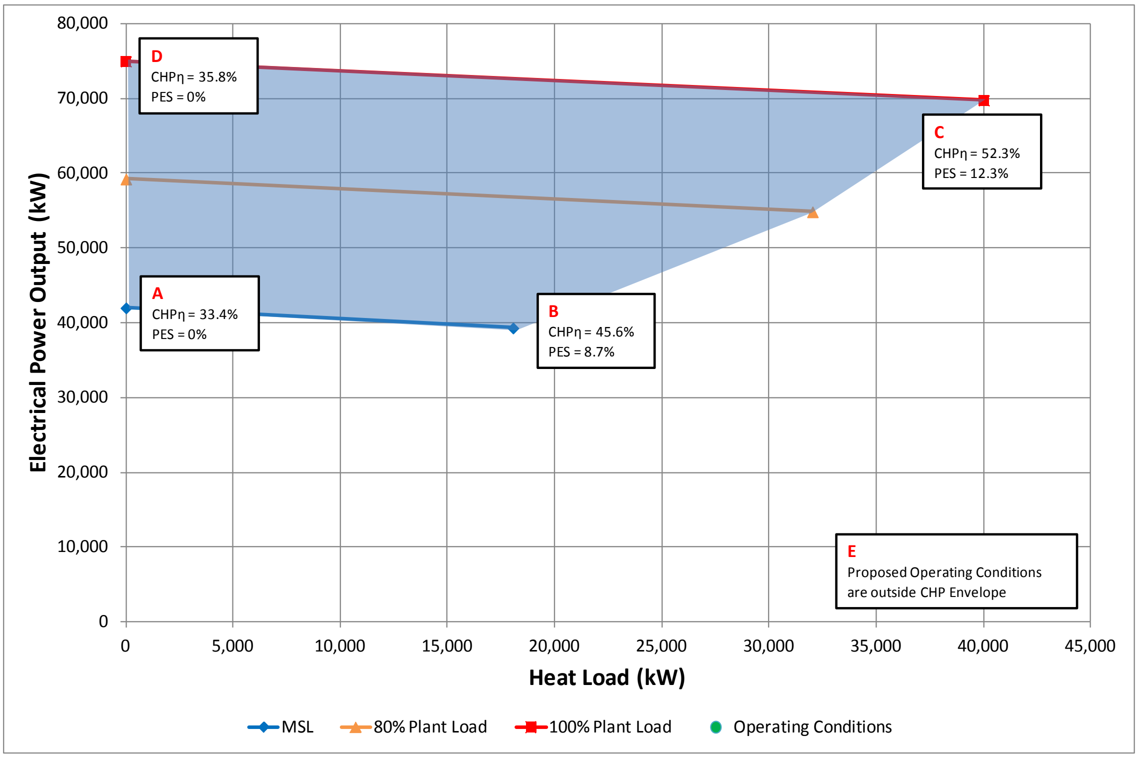
4.3	Description of how the future Costs and Burdens associated with supplying the Identified Heat Load / Potential CHP Opportunity have been minimised through the implementation of an appropriate CHP-R design		Not required for the Case Study
4.4	Provision of Site Layout of the Plant, indicating Available Space which could be made available for CHP-R		Please see Layout CS 03. The District Heating System will (likely) include: extraction piping; control and shut-off valves, and actuators; a Pressure Reduction and De-superheating Station; District Heaters; District Heating supply and return lines; condensate return piping (to the condensate header); interconnecting piping; drains; pipe bridges / supports; and Control and Instrumentation / electrical connections. A Stand-by Boiler is also included. Provision is also made for possible extension of the Water Treatment Plant.
Requirement 5: Integration of CHP and Carbon Capture			
5.1	Is the Plant required to be CCR?		No
5.2	Export and Return Requirements Identified for Carbon Capture		
	100% Plant Load		
a)	Heat Load Extraction for Carbon Capture at 100% Plant Load	MW	N / A
b)	Description of Heat Export (e.g. Steam / Hot Water)		N / A
c)	Export Pressure	bar a	N / A
d)	Export Temperature	°C	N / A
e)	Export Flow	t/h	N / A
f)	Return Pressure	bar a	N / A
g)	Return Temperature	°C	N / A
h)	Return Flow	t/h	N / A
i)	Likely Suitable Extraction Points		N / A
	Minimum Stable Plant Load		
j)	Heat Load Extraction for Carbon Capture at Minimum Stable Plant Load	MW	N / A

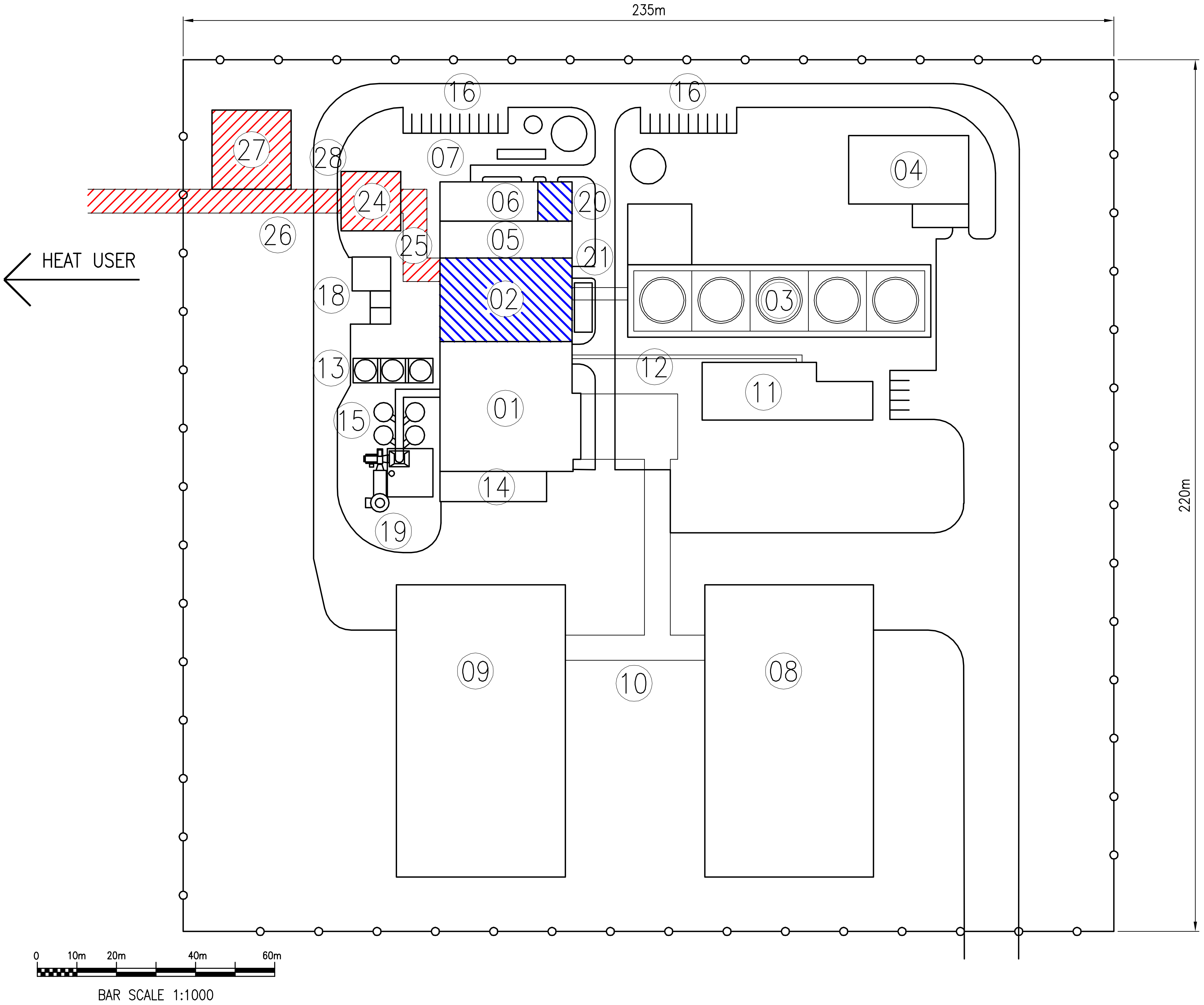
k)	Description of Heat Export (e.g. Steam / Hot Water)		N / A
l)	Export Pressure	bar a	N / A
m)	Export Temperature	°C	N / A
n)	Export Flow	t/h	N / A
o)	Return Pressure	bar a	N / A
p)	Return Temperature	°C	N / A
q)	Return Flow	t/h	N / A
r)	Likely Suitable Extraction Points		N / A
5.3	Operation of Plant with Carbon Capture (without CHP)		
a)	Maximum Plant Load with Carbon Capture	%	N / A
b)	Carbon Capture Mode Thermal Input at Maximum Plant Load	MW	N / A
c)	Carbon Capture Mode Net Electrical Output at Maximum Plant Load	MW	N / A
d)	Carbon Capture Mode Net Electrical Efficiency at Maximum Plant Load	%	N / A
e)	Minimum Stable Plant Load with CCS	%	N / A
f)	Carbon Capture Mode CCS Thermal Input at Minimum Stable Plant Load	MW	N / A
g)	Carbon Capture Mode Net Electrical Output at Minimum Stable Plant Load	MW	N / A
h)	Carbon Capture Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	N / A
5.4	Heat Extraction for CHP at 100% Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at 100% Plant Load with Carbon Capture [H]	MW	N / A
b)	Maximum Heat Extraction Export Flow at 100% Plant Load with Carbon Capture	t/h	N / A
c)	Carbon Capture and CHP Mode Net Electrical Output at 100% Plant Load	MW	N / A
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at 100% Plant Load	%	N / A

e)	Carbon Capture and CHP Mode Net CHP Efficiency at 100% Plant Load	%	N / A
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at 100% Plant Load	%	N / A
5.5	Heat Extraction at Minimum Stable Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load with Carbon Capture	MW	N / A
b)	Maximum Heat Extraction Export Flow at Minimum Stable Plant Load with Carbon Capture	t/h	N / A
c)	Carbon Capture and CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	N / A
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	N / A
e)	Carbon Capture and CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	N / A
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at Minimum Stable Plant Load	%	N / A
5.6	Can the Plant with Carbon Capture supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP and Carbon Capture Envelope')?		N / A
5.7	Description of Potential Options which could be incorporated in the Plant for useful integration of any realised CHP System and Carbon Capture System		N / A
Requirement 6: Economics of CHP-R			
6.1	Economic Assessment of CHP-R		Not required for the Case Study

BAT Assessment			
	Is the new plant a CHP plant at the outset (i.e. are there economically viable CHP opportunities at the outset)?		Not required for the Case Study
	If not, is the new plant a CHP-R plant at the outset?		Not required for the Case Study
	Once the new plant is CHP-R, is it BAT?		Not required for the Case Study

CHP Envelope for Case Study 3





LEGEND

BIOMASS PLANT

- (01) BOILER BUILDING
- (02) STEAM TURBINE
- (03) COOLING TOWERS
- (04) A.I SWITCHYARD
- (05) CONTROL BUILDING
- (06) ADMINISTRATION, SHOP & WAREHOUSE
- (07) FIRE PUMP EQUIPMENT AREA
- (08) STRAW BARN 1
- (09) STRAW BARN 2
- (10) STRAW CONVEYORS
- (11) WOOD STORAGE BUILDING
- (12) WOOD CHIP CONVEYOR
- (13) FLY ASH AND REAGENT STORAGE
- (14) SLAG STORAGE
- (15) FLUE GAS TREATMENT AREA
- (16) PARKING
- (18) TRANSFORMER
- (19) STACK
- (20) WATER TREATMENT PLANT
- (21) SEDIMENTATIONS BASIN

CHP-R PROVISIONS

- (02) STEAM TURBINE WITH PROVISIONS FOR IDENTIFIED SUITABLE EXTRACTION POINTS
- (24) ON SITE SPACE FOR DISTRICT HEATING HEAT EXCHANGERS
- (25) ON SITE SPACE FOR DISTRICT HEATING STEAM AND CONDENSATE RETURN PIPEWORK (PIPE CORRIDOR)
- (26) ON SITE SPACE FOR DISTRICT HEAT WATER PIPEWORK (PIPE CORRIDOR) INCLUDES SPACE FOR PUMPS
- (27) ON SITE SPACE FOR STANDBY BOILER
- (28) PIPEBRIDGE
- (20) POSSIBLE EXPANSION TO WATER TREATMENT PLANT

Rev	Date	Description	By	Chk	App	Notes:

PARSONS BRINCKERHOFF

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William Armstrong Drive
Newcastle upon Tyne NE4 7YQ
Tel: 44-(0)191-226-2000
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Client: ENVIRONMENT AGENCY

Project: CHP-R GUIDANCE

Title: SITE LAYOUT PLAN FOR CASE STUDY 3 BIOMASS POWER PLANT WITH 45MW OF DISTRICT HEATING

Drawn: ALM | Checked:
Designed: EB | Approved:
Date: 01/08/2012 | Scale: 1:1000 | A3 | Sheet:
Project Number: 3511829A | Drawing Number: CS 03 | Revision:

Login: Minikin, Sandra
Plot Date: 09/08/2012 11:42:20
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Case Study / Worked Example 4

#	Description	Units	Notes / Instructions
Requirement 1: Plant, Plant Location and Potential Heat Loads			
1.1	Plant Name		Case Study 4
1.2	Plant Description		Energy from Waste Plant
1.3	Plant Location (Postcode / GridRef)		Not required for the Case Study
1.4	Factors Influencing Selection of Plant Location		Not required for the Case Study
1.5	Operation of Plant		
a)	Proposed Operational Plant Load	%	100
b)	Thermal Input at Proposed Operational Plant Load	MW	84
c)	Net Electrical Output at Proposed Operational Plant Load	MW	25
d)	Net Electrical Efficiency at Proposed Operational Plant Load	%	29.7
e)	Maximum Plant Load	%	100
f)	Thermal Input at Maximum Plant Load	MW	84
g)	Net Electrical Output at Maximum Plant Load	MW	25
h)	Net Electrical Efficiency at Maximum Plant Load	%	29.7
i)	Minimum Stable Plant Load	%	60
j)	Thermal Input at Minimum Stable Plant Load	MW	50.5
k)	Net Electrical Output at Minimum Stable Plant Load	MW	13.6
l)	Net Electrical Efficiency at Minimum Stable Plant Load	%	26.9
1.6	Identified Potential Heat Loads		
			5 MW District Heating
1.7	Selected Heat Load(s)		
a)	Category (e.g. Industrial / District Heating)		District Heating
b)	Maximum Heat Load Extraction Required	MW	5
1.8	Export and Return Requirements of Heat Load		
a)	Description of Heat Load Extraction		Hot water
b)	Description of Heat Load Profile		Constant

c)	Export Pressure	bar a	5
d)	Export Temperature	°C	95
e)	Export Flow	t/h	110
f)	Return Pressure	bar a	3
g)	Return Temperature	°C	55
h)	Return Flow	t/h	110
Requirement 2: Identification of CHP Envelope			
2.0	Comparative Efficiency of a Standalone Boiler for supplying the Heat Load	90 % LHV	90
2.1	Heat Extraction at 100% Plant Load		
a)	Maximum Heat Load Extraction at 100% Plant Load	MW	20
b)	Maximum Heat Extraction Export Flow at 100% Plant Load	t/h	430
c)	CHP Mode Net Electrical Output at 100% Plant Load	MW	22
d)	CHP Mode Net Electrical Efficiency at 100% Plant Load	%	26.1
e)	CHP Mode Net CHP Efficiency at 100% Plant Load	%	49.9
f)	Reduction in Primary Energy Usage for CHP Mode at 100% Plant Load	%	12.6
2.2	Heat Extraction at Minimum Stable Plant Load		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load	MW	10
b)	Heat Extraction Export Flow at Minimum Stable Plant Load	t/h	220
c)	CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	11.9
d)	CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	23.5
e)	CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	43.8
f)	Reduction in Primary Energy Usage for CHP Mode at Minimum Stable Plant Load	%	9.7

2.3	Can the Plant supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP Envelope')?		Yes
Requirement 3: Operation of the Plant with the Selected Identified Heat Load			
3.1	Proposed Operation of Plant with CHP		
a)	CHP Mode Net Electrical Output at Proposed Operational Plant Load	MW	24
b)	CHP Mode Net Electrical Efficiency at Proposed Operational Plant Load	%	28.8
c)	CHP Mode Net CHP Efficiency at Proposed Operational Plant Load	%	34.8
d)	Reduction in Net Electrical Output for CHP Mode at Proposed Operational Plant Load	MW	1
e)	Reduction in Net Electrical Efficiency for CHP Mode at Proposed Operational Plant Load	%	3.0
f)	Reduction in Primary Energy Usage for CHP Mode at Proposed Operational Plant Load	%	3.5
g)	Z Ratio		5.0
Requirement 4: Technical Provisions and Space Requirements			
4.1	Description of Likely Suitable Extraction Points		Steam for the District Heating System could be supplied from the bleed steam lines for the LP feedwater heaters, downstream of the non return valves.
4.2	Description of Potential Options which could be incorporated in the Plant, should a CHP Opportunity be realised outside the 'CHP Envelope'		N / A (CHP opportunity lies within the CHP Envelope)
4.3	Description of how the future Costs and Burdens associated with supplying the Identified Heat Load / Potential CHP Opportunity have been minimised through the implementation of an appropriate CHP-R design		Not required for the Case Study

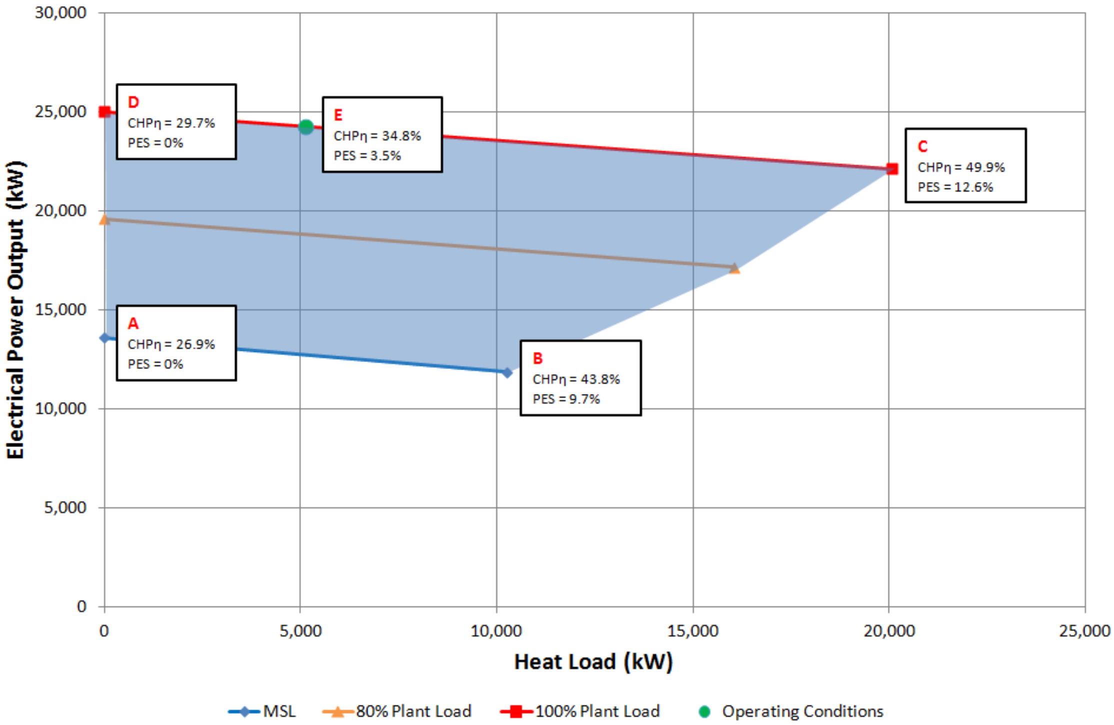
4.4	Provision of Site Layout of the Plant, indicating Available Space which could be made available for CHP-R		Please see Layout CS 04. The District Heating System will (likely) include: extraction piping; control and shut-off valves, and actuators; a Pressure Reduction and De-superheating Station; District Heaters; District Heating supply and return lines; condensate return piping (to the condensate header); interconnecting piping; drains; pipe bridges / supports; and Control and Instrumentation / electrical connections. A Stand-by Boiler is also included. Provision is also made for possible extension of the Water Treatment Plant.
Requirement 5: Integration of CHP and Carbon Capture			
5.1	Is the Plant required to be CCR?		No
5.2	Export and Return Requirements Identified for Carbon Capture		
	100% Plant Load		
a)	Heat Load Extraction for Carbon Capture at 100% Plant Load	MW	N / A
b)	Description of Heat Export (e.g. Steam / Hot Water)		N / A
c)	Export Pressure	bar a	N / A
d)	Export Temperature	°C	N / A
e)	Export Flow	t/h	N / A
f)	Return Pressure	bar a	N / A
g)	Return Temperature	°C	N / A
h)	Return Flow	t/h	N / A
i)	Likely Suitable Extraction Points		N / A
	Minimum Stable Plant Load		
j)	Heat Load Extraction for Carbon Capture at Minimum Stable Plant Load	MW	N / A
k)	Description of Heat Export (e.g. Steam / Hot Water)		N / A
l)	Export Pressure	bar a	N / A
m)	Export Temperature	°C	N / A
n)	Export Flow	t/h	N / A
o)	Return Pressure	bar a	N / A
p)	Return Temperature	°C	N / A
q)	Return Flow	t/h	N / A

r)	Likely Suitable Extraction Points		N / A
5.3	Operation of Plant with Carbon Capture (without CHP)		
a)	Maximum Plant Load with Carbon Capture	%	N / A
b)	Carbon Capture Mode Thermal Input at Maximum Plant Load	MW	N / A
c)	Carbon Capture Mode Net Electrical Output at Maximum Plant Load	MW	N / A
d)	Carbon Capture Mode Net Electrical Efficiency at Maximum Plant Load	%	N / A
e)	Minimum Stable Plant Load with CCS	%	N / A
f)	Carbon Capture Mode CCS Thermal Input at Minimum Stable Plant Load	MW	N / A
g)	Carbon Capture Mode Net Electrical Output at Minimum Stable Plant Load	MW	N / A
h)	Carbon Capture Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	N / A
5.4	Heat Extraction for CHP at 100% Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at 100% Plant Load with Carbon Capture [H]	MW	N / A
b)	Maximum Heat Extraction Export Flow at 100% Plant Load with Carbon Capture	t/h	N / A
c)	Carbon Capture and CHP Mode Net Electrical Output at 100% Plant Load	MW	N / A
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at 100% Plant Load	%	N / A
e)	Carbon Capture and CHP Mode Net CHP Efficiency at 100% Plant Load	%	N / A
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at 100% Plant Load	%	N / A

5.5	Heat Extraction at Minimum Stable Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load with Carbon Capture	MW	N / A
b)	Maximum Heat Extraction Export Flow at Minimum Stable Plant Load with Carbon Capture	t/h	N / A
c)	Carbon Capture and CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	N / A
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	N / A
e)	Carbon Capture and CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	N / A
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at Minimum Stable Plant Load	%	N / A
5.6	Can the Plant with Carbon Capture supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP and Carbon Capture Envelope')?		N / A
5.7	Description of Potential Options which could be incorporated in the Plant for useful integration of any realised CHP System and Carbon Capture System		N / A
Requirement 6: Economics of CHP-R			
6.1	Economic Assessment of CHP-R		Not required for the Case Study
BAT Assessment			
	Is the new plant a CHP plant at the outset (i.e. are there economically viable CHP opportunities at the outset)?		Not required for the Case Study
	If not, is the new plant a CHP-R plant at the outset?		Not required for the Case Study

	Once the new plant is CHP-R, is it BAT?		Not required for the Case Study

CHP Envelope for Case Study 4



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Plot Date: 09/08/2012 11:49:36
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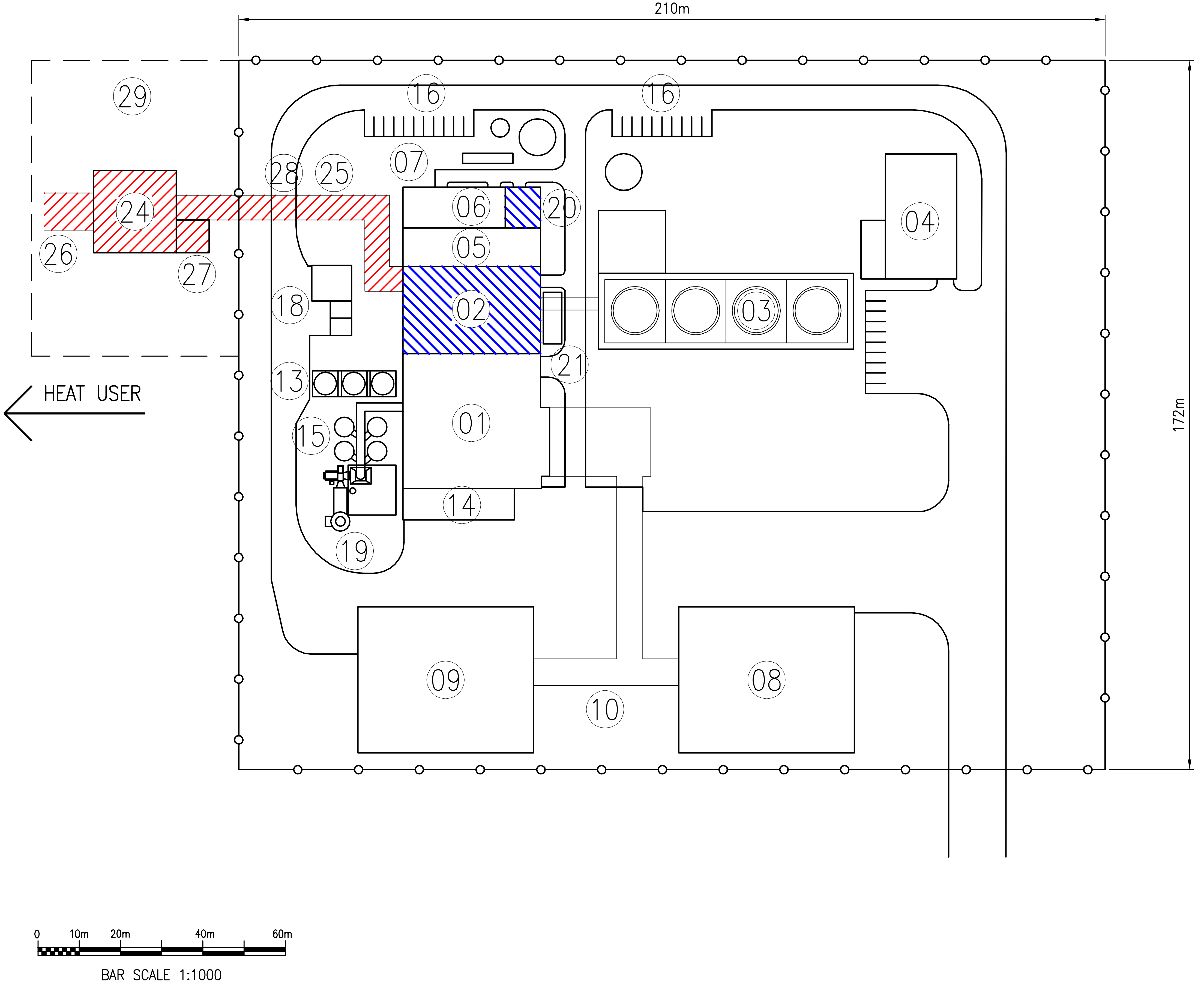
Project Number: 3511829A | Drawing Number: CS04 | Revision:



LEGEND

ENERGY FROM WASTE

- 01 BOILER BUILDING
- 02 STEAM TURBINE
- 03 COOLING TOWERS
- 04 A.I SWITCHYARD
- 05 CONTROL BUILDING
- 06 ADMINISTRATION, SHOP & WAREHOUSE
- 07 FIRE PUMP EQUIPMENT AREA
- 08 FUEL STORAGE 1
- 09 FUEL STORAGE 2
- 10 FUEL CONVEYORS
- 13 FLY ASH AND REAGENT STORAGE
- 14 SLAG STORAGE
- 15 FLUE GAS TREATMENT AREA
- 16 PARKING
- 18 TRANSFORMER
- 19 STACK
- 20 WATER TREATMENT PLANT
- 21 SEDIMENTATIONS BASIN

CHP-R PROVISIONS

- 02 STEAM TURBINE WITH PROVISIONS FOR IDENTIFIED SUITABLE EXTRACTION POINTS
- 24 OFF SITE SPACE FOR DISTRICT HEATING HEAT EXCHANGERS
- 25 OFF SITE SPACE FOR DISTRICT HEATING STEAM AND CONDENSATE RETURN PIPEWORK (PIPE CORRIDOR)
- 26 OFF SITE SPACE FOR DISTRICT HEAT WATER PIPEWORK (PIPE CORRIDOR) INCLUDES SPACE FOR PUMPS
- 27 OFF SITE SPACE FOR STANDBY BOILER
- 28 PIPEBRIDGE
- 20 POSSIBLE EXPANSION TO WATER TREATMENT PLANT
- 29 ADDITIONAL LAND TO BE PURCHASED

Rev	Date	Description	By	Chk	App

Notes:

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Client: ENVIRONMENT AGENCY

Project: CHP-R GUIDANCE

Title: SITE LAYOUT PLAN FOR CASE STUDY 4
ENERGY FROM WASTE POWER PLANT WITH 5MW OF DISTRICT HEATING

Drawn: ALM		Checked:	
Designed: EB		Approved:	
Date: 01/08/2012	Scale: 1:1000	A3	Sheet:
Project Number: 3511829A		Drawing Number: CS04	Revision:

Case Study / Worked Example 5a

#	Description	Units	Notes / Instructions
Requirement 1: Plant, Plant Location and Potential Heat Loads			
1.1	Plant Name		Case Study 5a
1.2	Plant Description		Plant comprises: • Single-shaft (1 + 1) Configuration; • No IP / LP crossover pipe present; • Hybrid Cooling; and • UK ambient conditions.
1.3	Plant Location (Postcode / GridRef)		Not required for the Case Study
1.4	Factors Influencing Selection of Plant Location		Not required for the Case Study
1.5	Operation of Plant		
a)	Proposed Operational Plant Load	%	100
b)	Thermal Input at Proposed Operational Plant Load	MW	771
c)	Net Electrical Output at Proposed Operational Plant Load	MW	446.5
d)	Net Electrical Efficiency at Proposed Operational Plant Load	%	57.9
e)	Maximum Plant Load	%	100
f)	Thermal Input at Maximum Plant Load	MW	771
g)	Net Electrical Output at Maximum Plant Load	MW	446.5
h)	Net Electrical Efficiency at Maximum Plant Load	%	57.9
i)	Minimum Stable Plant Load	%	40
j)	Thermal Input at Minimum Stable Plant Load	MW	427
k)	Net Electrical Output at Minimum Stable Plant Load	MW	215
l)	Net Electrical Efficiency at Minimum Stable Plant Load	%	50.4
1.6	Identified Potential Heat Loads		
			50 MW District Heating
1.7	Selected Heat Load(s)		
a)	Category (e.g. Industrial / District Heating)		District Heating

b)	Maximum Heat Load Extraction Required	MW	50
1.8	Export and Return Requirements of Heat Load		
a)	Description of Heat Load Extraction		Hot water
b)	Description of Heat Load Profile		Constant
c)	Export Pressure	bar a	5
d)	Export Temperature	°C	95
e)	Export Flow	t/h	1075
f)	Return Pressure	bar a	3
g)	Return Temperature	°C	55
h)	Return Flow	t/h	1075
Requirement 2: Identification of CHP Envelope			
2.0	Comparative Efficiency of a Standalone Boiler for supplying the Heat Load	90 % LHV	90
2.1	Heat Extraction at 100% Plant Load		
a)	Maximum Heat Load Extraction at 100% Plant Load	MW	151
b)	Maximum Heat Extraction Export Flow at 100% Plant Load	t/h	3249
c)	CHP Mode Net Electrical Output at 100% Plant Load	MW	386
d)	CHP Mode Net Electrical Efficiency at 100% Plant Load	%	50.1
e)	CHP Mode Net CHP Efficiency at 100% Plant Load	%	69.7
f)	Reduction in Primary Energy Usage for CHP Mode at 100% Plant Load	%	7.7
2.2	Heat Extraction at Minimum Stable Plant Load		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load	MW	77
b)	Heat Extraction Export Flow at Minimum Stable Plant Load	t/h	1651
c)	CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	184

d)	CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	43.2
e)	CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	61.2
f)	Reduction in Primary Energy Usage for CHP Mode at Minimum Stable Plant Load	%	5.4
2.3	Can the Plant supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP Envelope')?		Yes
Requirement 3: Operation of the Plant with the Selected Identified Heat Load			
3.1	Proposed Operation of Plant with CHP		
a)	CHP Mode Net Electrical Output at Proposed Operational Plant Load	MW	424
b)	CHP Mode Net Electrical Efficiency at Proposed Operational Plant Load	%	55.0
c)	CHP Mode Net CHP Efficiency at Proposed Operational Plant Load	%	61.5
d)	Reduction in Net Electrical Output for CHP Mode at Proposed Operational Plant Load	MW	22.7
e)	Reduction in Net Electrical Efficiency for CHP Mode at Proposed Operational Plant Load	%	5.1
f)	Reduction in Primary Energy Usage for CHP Mode at Proposed Operational Plant Load	%	2.1
g)	Z Ratio		2.2
Requirement 4: Technical Provisions and Space Requirements			
4.1	Description of Likely Suitable Extraction Points		Steam cannot be readily extracted from the IP turbine exit. Therefore, steam is extracted from the cold reheat pipe, passed through a let-down station and supplied to the District Heating System.

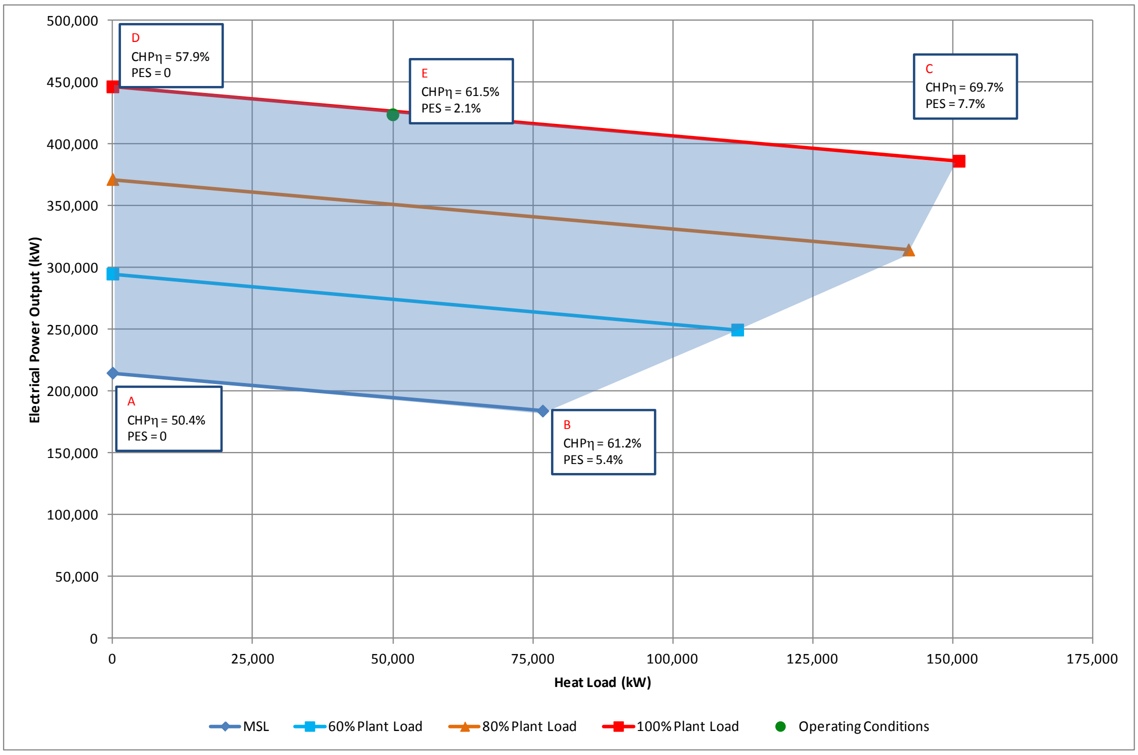
4.2	Description of Potential Options which could be incorporated in the Plant, should a CHP Opportunity be realised outside the 'CHP Envelope'		N / A (CHP opportunity lies within the CHP Envelope)
4.3	Description of how the future Costs and Burdens associated with supplying the Identified Heat Load / Potential CHP Opportunity have been minimised through the implementation of an appropriate CHP-R design		Not required for the Case Study
4.4	Provision of Site Layout of the Plant, indicating Available Space which could be made available for CHP-R		No Site Layout is provided for Case Study 5a. However, a number of points are noted. The District Heating System would (likely) include: extraction piping; control and shut-off valves, and actuators; a Pressure Reduction and De-superheating Station; District Heaters; District Heating supply and return lines; condensate return piping (to the condensate header); interconnecting piping; drains; pipe bridges / supports; and Control and Instrumentation / electrical connections. A Stand-by Boiler would also be included. Provision would also be made for possible extension of the Water Treatment Plant.
Requirement 5: Integration of CHP and Carbon Capture			
5.1	Is the Plant required to be CCR?		Yes
5.2	Export and Return Requirements Identified for Carbon Capture		
	100% Plant Load		
a)	Heat Load Extraction for Carbon Capture at 100% Plant Load	MW	117
b)	Description of Heat Export (e.g. Steam / Hot Water)		Low pressure steam
c)	Export Pressure	bar a	3.4
d)	Export Temperature	°C	150
e)	Export Flow	t/h	193

f)	Return Pressure	bar a	3.4
g)	Return Temperature	°C	137
h)	Return Flow	t/h	193
i)	Likely Suitable Extraction Points		Steam cannot be readily extracted from the IP turbine exit. Therefore, steam is extracted from the cold reheat pipe, passed through a let-down station.
	Minimum Stable Plant Load		
j)	Heat Load Extraction for Carbon Capture at Minimum Stable Plant Load	MW	65
k)	Description of Heat Export (e.g. Steam / Hot Water)		Low pressure steam
l)	Export Pressure	bar a	2.7
m)	Export Temperature	°C	150
n)	Export Flow	t/h	105
o)	Return Pressure	bar a	2.7
p)	Return Temperature	°C	130
q)	Return Flow	t/h	105
r)	Likely Suitable Extraction Points		Steam cannot be readily extracted from the IP turbine exit. Therefore, steam is extracted from the cold reheat pipe, passed through a let-down station.
5.3	Operation of Plant with Carbon Capture (without CHP)		
a)	Maximum Plant Load with Carbon Capture	%	100
b)	Carbon Capture Mode Thermal Input at Maximum Plant Load	MW	771
c)	Carbon Capture Mode Net Electrical Output at Maximum Plant Load	MW	380
d)	Carbon Capture Mode Net Electrical Efficiency at Maximum Plant Load	%	49.3
e)	Minimum Stable Plant Load with CCS	%	40
f)	Carbon Capture Mode CCS Thermal Input at Minimum Stable Plant Load	MW	427
g)	Carbon Capture Mode Net Electrical Output at Minimum Stable Plant Load	MW	177
h)	Carbon Capture Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	41.5
5.4	Heat Extraction for CHP at 100% Plant Load with Carbon Capture		

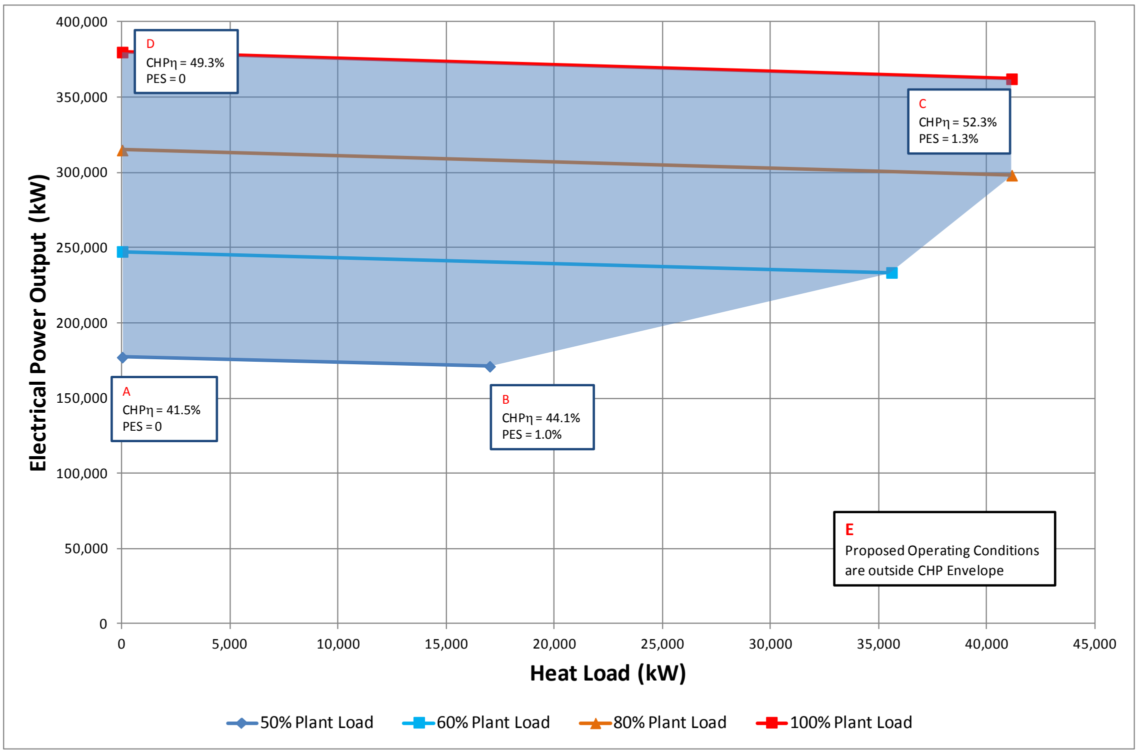
a)	Maximum Heat Load Extraction at 100% Plant Load with Carbon Capture [H]	MW	41
b)	Maximum Heat Extraction Export Flow at 100% Plant Load with Carbon Capture	t/h	879
c)	Carbon Capture and CHP Mode Net Electrical Output at 100% Plant Load	MW	362
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at 100% Plant Load	%	47.0
e)	Carbon Capture and CHP Mode Net CHP Efficiency at 100% Plant Load	%	52.3
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at 100% Plant Load	%	1.3
5.5	Heat Extraction at Minimum Stable Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load with Carbon Capture	MW	17
b)	Maximum Heat Extraction Export Flow at Minimum Stable Plant Load with Carbon Capture	t/h	366
c)	Carbon Capture and CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	171
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	40.1
e)	Carbon Capture and CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	44.1
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at Minimum Stable Plant Load	%	1.0

5.6	Can the Plant with Carbon Capture supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP and Carbon Capture Envelope')?		No
5.7	Description of Potential Options which could be incorporated in the Plant for useful integration of any realised CHP System and Carbon Capture System		In the case where the plant is required to simultaneously meet the carbon capture requirement and the identified heat load, a dedicated auxiliary boiler may form part of the CHP Plant.
Requirement 6: Economics of CHP-R			
6.1	Economic Assessment of CHP-R		Not required for the Case Study
BAT Assessment			
	Is the new plant a CHP plant at the outset (i.e. are there economically viable CHP opportunities at the outset)?		Not required for the Case Study
	If not, is the new plant a CHP-R plant at the outset?		Not required for the Case Study
	Once the new plant is CHP-R, is it BAT?		Not required for the Case Study

CHP Envelope for Case Study 5a



CHP and Carbon Capture Envelope for Case Study 5a



Case Study / Worked Example 5b

#	Description	Units	Notes / Instructions
Requirement 1: Plant, Plant Location and Potential Heat Loads			
1.1	Plant Name		Case Study 5b
1.2	Plant Description		Plant comprises: • Single-shaft (1 + 1) Configuration; • Hybrid Cooling; and • UK ambient conditions.
1.3	Plant Location (Postcode / GridRef)		Not required for the Case Study
1.4	Factors Influencing Selection of Plant Location		Not required for the Case Study
1.5	Operation of Plant		
a)	Proposed Operational Plant Load	%	100
b)	Thermal Input at Proposed Operational Plant Load	MW	771
c)	Net Electrical Output at Proposed Operational Plant Load	MW	446.5
d)	Net Electrical Efficiency at Proposed Operational Plant Load	%	57.9
e)	Maximum Plant Load	%	100
f)	Thermal Input at Maximum Plant Load	MW	771
g)	Net Electrical Output at Maximum Plant Load	MW	446.5
h)	Net Electrical Efficiency at Maximum Plant Load	%	57.9
i)	Minimum Stable Plant Load	%	40
j)	Thermal Input at Minimum Stable Plant Load	MW	427
k)	Net Electrical Output at Minimum Stable Plant Load	MW	215
l)	Net Electrical Efficiency at Minimum Stable Plant Load	%	50.4
1.6	Identified Potential Heat Loads		
			50 MW District Heating
1.7	Selected Heat Load(s)		
a)	Category (e.g. Industrial / District Heating)		District Heating
b)	Maximum Heat Load Extraction Required	MW	50

1.8	Export and Return Requirements of Heat Load		
a)	Description of Heat Load Extraction		Hot water
b)	Description of Heat Load Profile		Constant
c)	Export Pressure	bar a	5
d)	Export Temperature	°C	95
e)	Export Flow	t/h	1075
f)	Return Pressure	bar a	3
g)	Return Temperature	°C	55
h)	Return Flow	t/h	1075
Requirement 2: Identification of CHP Envelope			
2.0	Comparative Efficiency of a Standalone Boiler for supplying the Heat Load	90 % LHV	90
2.1	Heat Extraction at 100% Plant Load		
a)	Maximum Heat Load Extraction at 100% Plant Load	MW	145
b)	Maximum Heat Extraction Export Flow at 100% Plant Load	t/h	3111
c)	CHP Mode Net Electrical Output at 100% Plant Load	MW	409
d)	CHP Mode Net Electrical Efficiency at 100% Plant Load	%	53.1
e)	CHP Mode Net CHP Efficiency at 100% Plant Load	%	71.8
f)	Reduction in Primary Energy Usage for CHP Mode at 100% Plant Load	%	11.1
2.2	Heat Extraction at Minimum Stable Plant Load		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load	MW	68
b)	Heat Extraction Export Flow at Minimum Stable Plant Load	t/h	1456
c)	CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	195
d)	CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	45.6

e)	CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	61.5
f)	Reduction in Primary Energy Usage for CHP Mode at Minimum Stable Plant Load	%	13.3
2.3	Can the Plant supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the 'CHP Envelope')?		Yes
Requirement 3: Operation of the Plant with the Selected Identified Heat Load			
3.1	Proposed Operation of Plant with CHP		
a)	CHP Mode Net Electrical Output at Proposed Operational Plant Load	MW	433
b)	CHP Mode Net Electrical Efficiency at Proposed Operational Plant Load	%	56.3
c)	CHP Mode Net CHP Efficiency at Proposed Operational Plant Load	%	62.8
d)	Reduction in Net Electrical Output for CHP Mode at Proposed Operational Plant Load	MW	13.6
e)	Reduction in Net Electrical Efficiency for CHP Mode at Proposed Operational Plant Load	%	2.8
f)	Reduction in Primary Energy Usage for CHP Mode at Proposed Operational Plant Load	%	4.2
g)	Z Ratio		3.7
Requirement 4: Technical Provisions and Space Requirements			
4.1	Description of Likely Suitable Extraction Points		Steam cannot be readily extracted from the IP turbine exit. Therefore, steam is extracted from the cold reheat pipe, passed through a back pressure steam turbine and supplied to the District Heating System.
4.2	Description of Potential Options which could be incorporated in the Plant, should a CHP Opportunity be realised outside the 'CHP Envelope'		N / A (CHP opportunity lies within the CHP Envelope)

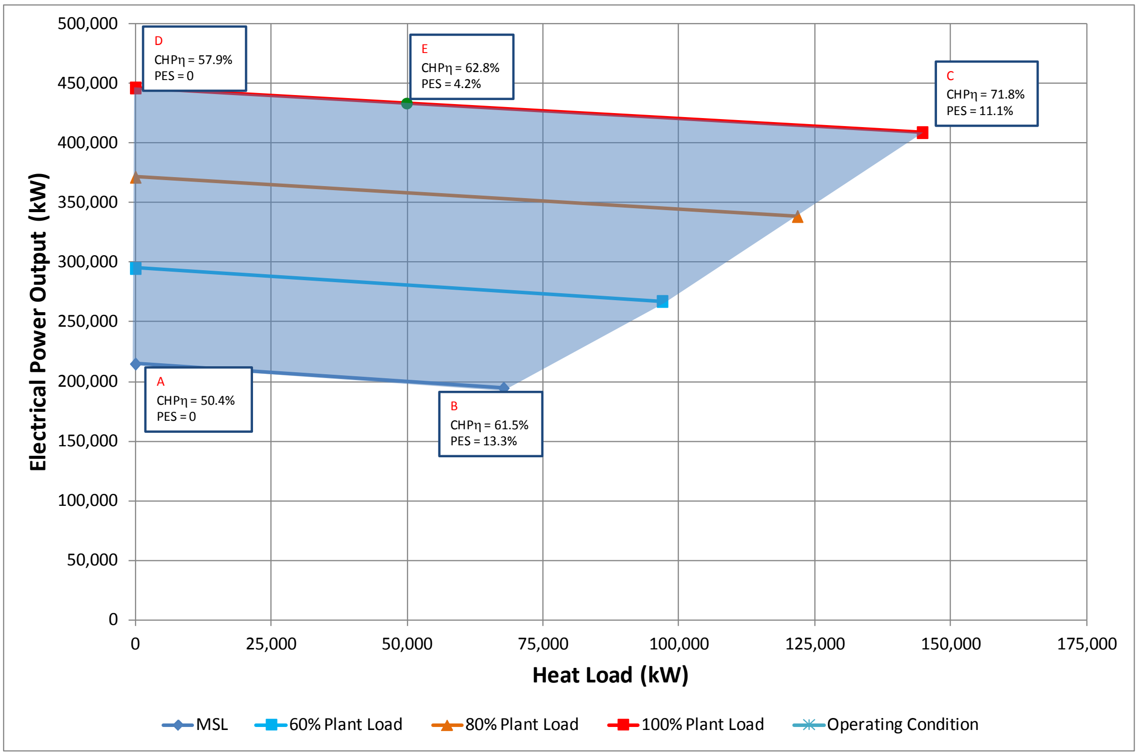
4.3	Description of how the future Costs and Burdens associated with supplying the Identified Heat Load / Potential CHP Opportunity have been minimised through the implementation of an appropriate CHP-R design		Not required for the Case Study
4.4	Provision of Site Layout of the Plant, indicating Available Space which could be made available for CHP-R		Please see Layout CS 05b. A back pressure steam turbine generator (with associated transformer) is included. The District Heating System will (likely) include: extraction piping; control and shut-off valves, and actuators; a Pressure Reduction and De-superheating Station; District Heaters; District Heating supply and return lines; condensate return piping (to the condensate header); interconnecting piping; drains; pipe bridges / supports; and Control and Instrumentation / electrical connections. A Stand-by Boiler is also included. Provision is also made for possible extension of the Water Treatment Plant.
Requirement 5: Integration of CHP and Carbon Capture			
5.1	Is the Plant required to be CCR?		Yes
5.2	Export and Return Requirements Identified for Carbon Capture		
	100% Plant Load		
a)	Heat Load Extraction for Carbon Capture at 100% Plant Load	MW	34.6
b)	Description of Heat Export (e.g. Steam / Hot Water)		Low pressure steam
c)	Export Pressure	bar a	3.4
d)	Export Temperature	°C	150
e)	Export Flow	t/h	57
f)	Return Pressure	bar a	3.4
g)	Return Temperature	°C	137
h)	Return Flow	t/h	57
i)	Likely Suitable Extraction Points		Steam is taken from the exit of the new back pressure steam turbine.
	Minimum Stable Plant Load		

j)	Heat Load Extraction for Carbon Capture at Minimum Stable Plant Load	MW	5.2
k)	Description of Heat Export (e.g. Steam / Hot Water)		Low pressure steam
l)	Export Pressure	bar a	2.7
m)	Export Temperature	°C	150
n)	Export Flow	t/h	8
o)	Return Pressure	bar a	2.7
p)	Return Temperature	°C	130
q)	Return Flow	t/h	8
r)	Likely Suitable Extraction Points		Steam is taken from the exit of the new back pressure steam turbine.
5.3	Operation of Plant with Carbon Capture (without CHP)		
a)	Maximum Plant Load with Carbon Capture	%	100
b)	Carbon Capture Mode Thermal Input at Maximum Plant Load	MW	771
c)	Carbon Capture Mode Net Electrical Output at Maximum Plant Load	MW	385
d)	Carbon Capture Mode Net Electrical Efficiency at Maximum Plant Load	%	49.9
e)	Minimum Stable Plant Load with CCS	%	40
f)	Carbon Capture Mode CCS Thermal Input at Minimum Stable Plant Load	MW	427
g)	Carbon Capture Mode Net Electrical Output at Minimum Stable Plant Load	MW	180
h)	Carbon Capture Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	42.1
5.4	Heat Extraction for CHP at 100% Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at 100% Plant Load with Carbon Capture [H]	MW	35
b)	Maximum Heat Extraction Export Flow at 100% Plant Load with Carbon Capture	t/h	739
c)	Carbon Capture and CHP Mode Net Electrical Output at 100% Plant Load	MW	375

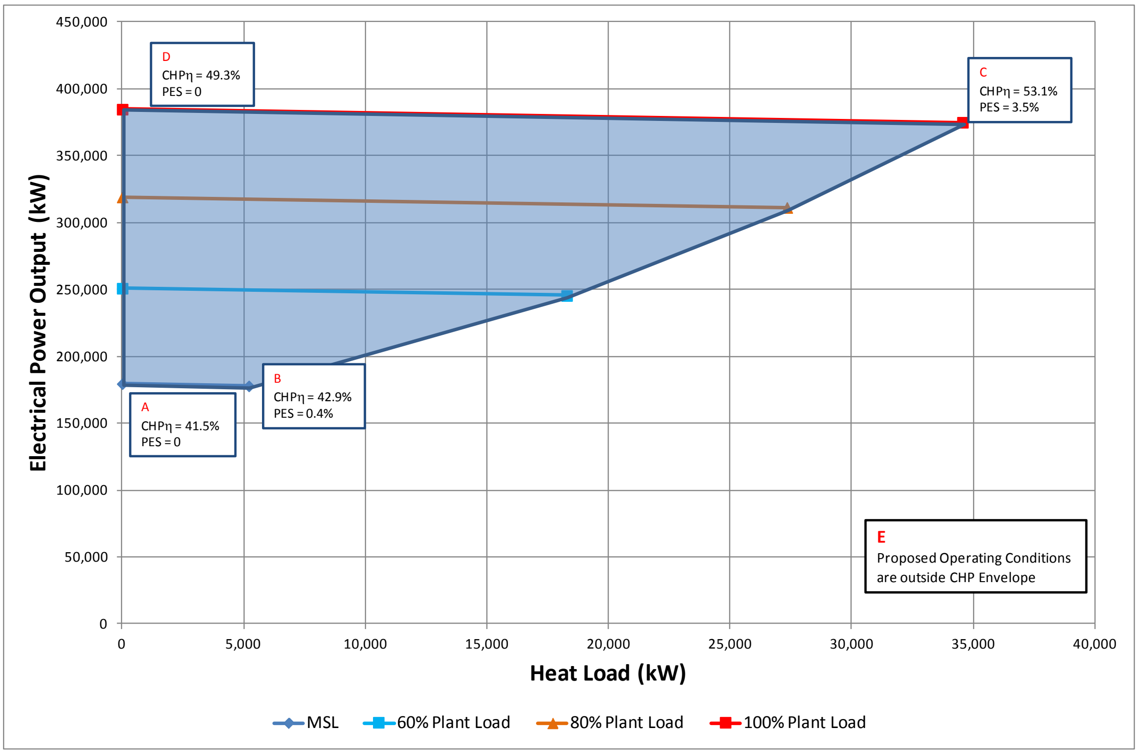
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at 100% Plant Load	%	48.6
e)	Carbon Capture and CHP Mode Net CHP Efficiency at 100% Plant Load	%	53.1
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at 100% Plant Load	%	3.5
5.5	Heat Extraction at Minimum Stable Plant Load with Carbon Capture		
a)	Maximum Heat Load Extraction at Minimum Stable Plant Load with Carbon Capture	MW	5
b)	Maximum Heat Extraction Export Flow at Minimum Stable Plant Load with Carbon Capture	t/h	112
c)	Carbon Capture and CHP Mode Net Electrical Output at Minimum Stable Plant Load	MW	178
d)	Carbon Capture and CHP Mode Net Electrical Efficiency at Minimum Stable Plant Load	%	41.7
e)	Carbon Capture and CHP Mode Net CHP Efficiency at Minimum Stable Plant Load	%	42.9
f)	Reduction in Primary Energy Usage for Carbon Capture and CHP Mode at Minimum Stable Plant Load	%	0.4
5.6	Can the Plant with Carbon Capture supply the Selected Identified Potential Heat Load (i.e. is the Identified Potential Heat Load within the ‘CHP and Carbon Capture Envelope’)?		No
5.7	Description of Potential Options which could be incorporated in the Plant for useful integration of any realised CHP System and Carbon Capture System		In the case where the plant is required to simultaneously meet the carbon capture requirement and the identified heat load, a dedicated auxiliary boiler may form part of the CHP Plant.

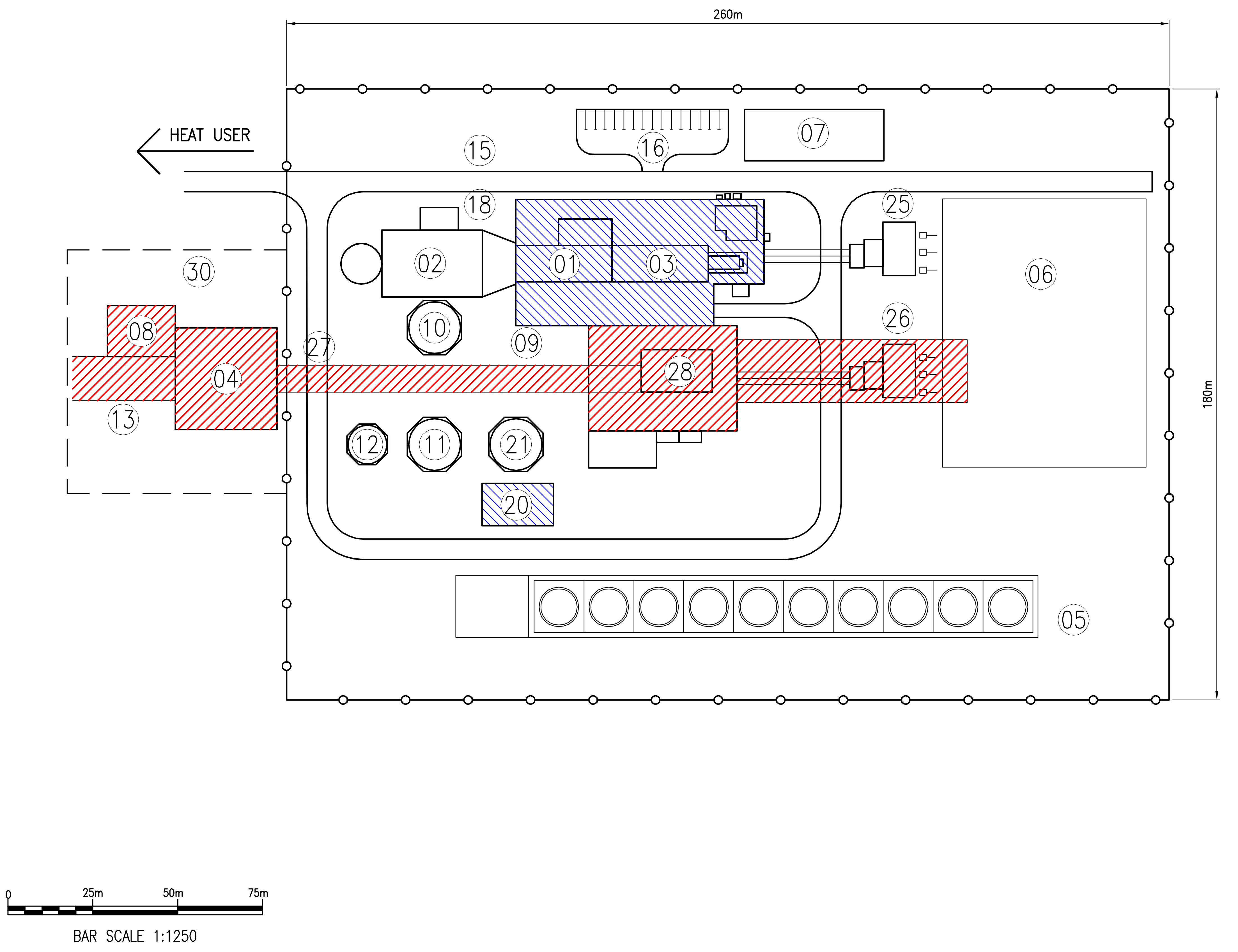
Requirement 6: Economics of CHP-R			
6.1	Economic Assessment of CHP-R		Not required for the Case Study
BAT Assessment			
	Is the new plant a CHP plant at the outset (i.e. are there economically viable CHP opportunities at the outset)?		Not required for the Case Study
	If not, is the new plant a CHP-R plant at the outset?		Not required for the Case Study
	Once the new plant is CHP-R, is it BAT?		Not required for the Case Study

CHP Envelope for Case Study 5b



CHP and Carbon Capture Envelope for Case Study 5b





LEGEND

CCGT PLANT

- 01 GAS TURBINE
- 02 HEAT RECOVERY STEAM GENERATOR
- 03 STEAM TURBINE
- 05 COOLING TOWERS
- 06 A.I. SWITCHYARD
- 07 ADMINISTRATION, SHOP & WAREHOUSE
- 10 DEMINERALISED WATER TANK
- 11 RAW WATER TANK
- 12 NEUTRALIZED WATER TANK
- 15 ROAD
- 16 PARKING
- 18 FEED PUMPS
- 20 WATER TREATMENT PLANT
- 21 FIRE PROTECTION TANK
- 25 GAS TURBINE/STEAM TURBINE TRANSFORMER

CHP-R PROVISIONS

- 03 STEAM TURBINE WITH PROVISIONS FOR IDENTIFIED SUITABLE EXTRACTION POINTS
- 04 OFF SITE SPACE FOR DISTRICT HEATING HEAT EXCHANGERS
- 08 OFF SITE SPACE FOR STANDBY BOILER
- 09 ON SITE SPACE FOR DISTRICT HEAT STEAM/CONDENSATE PIPEWORK (PIPE CORRIDOR)
- 13 OFF SITE SPACE FOR DISTRICT HEAT WATER PIPEWORK INCLUDING SPACE FOR PUMPS AND EXPANSION LOOPS ETC (PIPE CORRIDOR)
- 20 POSSIBLE EXPANSION TO WATER TREATMENT PLANT
- 26 BACK PRESSURE STEAM TURBINE TRANSFORMER
- 27 PIPEBRIDGE
- 28 BACK PRESSURE STEAM TURBINE (PROCESS)
- 30 ADDITIONAL LAND TO BE PURCHASED

Rev	Date	Description	By	Chk	App	Notes:

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Client: ENVIRONMENT AGENCY

Project: CHP-R GUIDANCE

Title: SITE LAYOUT PLAN FOR CASE STUDY 5 CCGT POWER PLANT WITH 50MW DISTRICT HEATING CHP USE

Drawn: ALM		Checked:	
Designed: EB		Approved:	
Date: 30/07/2012	Scale: 1:1250	A3	Sheet:
Project Number: 3511829A	Drawing Number: CS 05		Revision: 1

Project Number: 3511829A | Drawing Number: CS 05 | Revision: 1
File Name: K:\Projects\3511829A - CHP-R Case Study\Z. Drawings\1. Current\Civil\CS5.dwg
Login: Minikin, Sandra
Plot Date: 22/10/2012 14:15:40

Appendix C: Additional Economic Supporting Information

An integral part of any BAT test is a consideration of the economic viability of the chosen option.

Qualitative Economic Screening

Under Requirement 1, the CHP-R Assessment requires that there is a description of and search for the likely extent and nature of CHP opportunities (i.e. potential heat loads) in the area of the new plant. Following this, the CHP-R Assessment requires that there is an appropriate selection of heat loads to take forwards to the CHP-R Assessment.

In terms of the 'appropriate selection of heat loads', this should be such that, wherever possible, 10% primary energy savings could be achieved in the future. However, where this is not possible, the selection of heat loads should be such that maximum primary energy savings could eventually be achieved whilst not necessarily meeting the criteria for Good Quality CHP. Accordingly, the appropriate selection of heat loads may include a discussion with the Environment Agency, potential heat load recipient(s), and / or a degree of qualitative economic screening.

An example of a qualitative economic screening process is given here. However, it should be noted that this should not be considered to be the only way in which a qualitative economic screening can be undertaken, and therefore it would be the responsibility of the applicant / operator to justify the basis for their qualitative economic screening.

Step 1: High Level Analysis of Likely Extent and Nature of CHP Opportunities in the Area

The high level analysis of the likely extent and nature of CHP opportunities in the area should comprise a description of:

- Size / type of heat load and initial estimation of primary energy savings;
- Likelihood of CHP opportunity being realised;
- Likely requirement for on site works (giving consideration to additional land / space requirements); and
- Likely requirement for off site works (giving consideration to: additional land / space requirements; distance of CHP Load from Plant; and, terrain between CHP Load and Plant).

Step 2: Ranking of CHP Opportunities in the Area

In terms of the factors listed under Step 1, a ranking of CHP opportunities in the area should be undertaken.

The ranking (and subsequent) selection of heat loads should be such that, wherever possible, 10% primary energy savings could be achieved in the future. Therefore, where the initial estimation of primary energy savings is greater than 10%, this heat load (or heat loads) should automatically be taken forwards. However, it is accepted that this may not always be possible. In these cases, the selection of heat load (or heat loads) should be such that maximum primary energy savings could eventually be achieved whilst not necessarily meeting the criteria for Good Quality CHP.

In terms of the remaining factors, an example of additional ranking criteria which can be used is provided in Table C.1.

TABLE C.1: DESCRIPTION OF ADDITIONAL RANKING CRITERIA

	Likely High Level of Economic Viability	**Likely Medium Level of Economic Viability**	**Likely Low Level of Economic Viability**
Likelihood of CHP Opportunity being Raised	Within 5 Years	Between 5 to 10 Years	Over 10 Years
Ranking	1	2	3
Requirement for On Site Works	Minimal	Moderate	Complex
Ranking	1	2	3
Requirement for Off Site Works	Minimal	Moderate	Complex
Ranking	1	2	3

Step3: Appropriate Selection of Heat Loads

Based on Step 2, an appropriate selection of heat loads should be undertaken. A justification of this appropriate selection should be provided, which could be based on the analysis / ranking undertaken in Step 1 and Step 2.

Also, the appropriate selection of heat loads may include a discussion with the Environment Agency and potential heat load recipient, and must be agreed with the Environment Agency.

Economics of CHP-R and CHP

Further to the requirement for the new plant being CHP-R, the economic viability of actually realising a CHP scheme is an important consideration for:

- The first BAT test (i.e. when realising a CHP scheme at the outset); and
- The third BAT test (i.e. when carrying out periodic reviews of opportunities to realise CHP (both existing and new)).

For this reason, this CHP-R Guidance provides some suggestions on assessing and presenting the potential revenues and costs of the wider economics of CHP-R and CHP schemes. Accordingly, within the context of this CHP-R Guidance, the potential revenues and costs of being a CHP-R plant, converting a CHP-R plant to a CHP plant or a CHP plant are considered to include (but not necessarily be limited to):

- Revenues / benefits associated with incentives and support measures for CHP, including[17],[18]:
  - Up to 1 April 2013, exemption (via Levy Exemption Certificates) from the Climate Change Levy of all fuel inputs to (and electricity outputs from) Good Quality CHP;
  - Enhanced Capital Allowances for Good Quality CHP equipment / machinery in Non-Utility Sectors;
  - Business Rates exemption for embedded CHP equipment / machinery; and,
  - Support under the Renewables Obligation and / or Renewables Heat Incentive[19] for some types of plant that incorporate CHP. .
- Costs associated with being a CHP-R plant, including:
  - Upfront Studies;
  - Modifications to 'standard' design (i.e. providing suitable extraction points); and,
  - Additional land / space requirements.
- Costs associated with the modification / conversion to CHP plant, including:
  - Modifications to CHP-R plant (e.g. implementing suitable extraction points);
  - Modifications to existing plant items (e.g. pipe runs);
  - Expansion of existing plant items (e.g. water treatment plant);
  - Structural / civil works; and,
  - Control and Instrumentation / Electrical works.
- Costs associated with new on site CHP equipment / plant, including:
  - Additional equipment items (e.g. supply and return pipes, back-up boilers); and
  - Additional plant items (e.g. valves, pumps, heat exchangers).
- Costs associated with the new off-site CHP equipment / plant, including:
  - Additional equipment items (e.g. supply and return pipes);
  - Additional plant items (e.g. valves, pumps);
  - Structural / civil works;
  - Control and Instrumentation / Electrical works; and
  - Additional land / space requirements.

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[17] Adapted from Digest of UK Energy Statistics (DUKES) 2011 – Chapter 6 (Combined Heat and Power).

[18] However, it should be noted that these measures may be subject to change as a results of changes in Government Policy. There is may be that additional incentives and support measures for plant which incorporate CHP may be available in the future.

[19] At the time of writing, DECC are intending to consult on amendments to the Renewable Heat Incentive (RHI) tariff arrangements for renewable CHP plants which are not eligible for the "half Renewable Obligation Certificates uplift" which applies to plant accredited before 1 April 2013.

It is noted that the EED contains guidance on conducting an economic assessment (i.e. a cost-benefit analysis). This is included at Part 2 of Annex IX.

Furthermore, it is noted that there are a number of Documents available which contain guidance on conducting economic assessments. These Documents include:

- Annex K (Cost Benefit Analysis) of the Environment Agency H1 Guidance (Environmental Risk Assessment Framework);
- Appendix 4 (Appraisal of Energy Efficiency Techniques) of the Environment Agency H2 Guidance (Energy Efficiency); and,
- Paragraphs 62 to 69 of Carbon Capture Readiness (CCR): A Guidance Note for Section 36 Electricity Act, 1989 Consent Applications[20].

The following suggested proposed structure incorporates elements from the above Documents. However, it should be noted that this should not be considered to be the only way in which an economic assessment can be undertaken, and therefore it would be the responsibility of the applicant / operator to justify the basis for their economic assessment.

- **Outline**

The economic assessment should be based on the parameters provided in the technical assessments of CHP-R (i.e. those in Requirement 2 to Requirement 5).

- **Parameters taken into Account**

The parameters for the economic assessment should be described.

For the economic assessment, including the subsequent revenues and costs of the CHP scheme, the following parameters may be required: discount rate; assumed lifetime; fuel price; carbon price; heat price; amount of heat supplied; plant net electrical power output with and without CHP; proposed plant load factor; likely incentives and support measures for CHP; initial costs for the plant to be CHP-R (i.e. similar to those estimated in the second BAT test, as described in this CHP-R Guidance); subsequent costs to modify / convert the CHP-R plant to a CHP plant (including all associated on site and off site costs) (i.e. similar to those estimated in the second BAT test, as described in this CHP-R Guidance); and, reasonable estimates of when the revenues / costs would occur.

- **Estimated Costs**

Based on the above parameters, Table A4.3 (Template for the Presentation of Capital Costs) and Table A4.4 (Template for the Presentation of Operating Costs) of Appendix 4 (Appraisal of Energy Efficiency Techniques) of the Environment Agency H2 Guidance (Energy Efficiency) could be used as a template to estimate (for each identified option): the capital costs; the likely annual operating revenues; and, the average change in annual operating and maintenance costs.

In using these Tables, the capital costs / operating revenues and costs are broken down into sufficient details to allow the major influences of each option to be clearly demonstrated.

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[20] Carbon Capture Readiness (CCR): A Guidance Note for Section 36 Electricity Act, 1989 Consent Applications. Crown Copyright URN 09D/819.

- **Methodology / Determining Economic Viability**

The principles in use within the modelling should be described, and a comparison could be provided between costs of generation for the various options. Table A4.2 (Cost-Benefit Appraisal Summary) of Appendix 4 (Appraisal of Energy Efficiency Techniques) of the Environment Agency H2 Guidance (Energy Efficiency) could be used as a template.

For example:

	Non CHP Plant	CHP Plant (Option 1)	CHP Plant (Option 2)
Capital Costs (£)			
Potential Operating Revenues (£/year)			
Operating Costs (£/year)			
Life of Option			
Annual Costs / Savings with CHP[21]	N /A		
Price of Electricity			
Annual Carbon Dioxide savings with CHP	N / A		

A sensitivity analysis could then be undertaken (i.e. by varying the parameters which influence the annual costs / savings) to determine likely ranges which would ultimately allow an option to be economically viable. This could be used to give a measure of uncertainty within the modelling.

- **Economic Assessment Summary**

Based on the above, a clear summary of the economic assessment could be provided, indicating the likely ranges (in terms of costs of generation) which would ultimately allow an option for a CHP scheme to be economically viable

[21] Based on one of the support measures to incentivise CHP.

Appendix D: Additional Technical Supporting Information

Based on the CHP-R Assessment Form Point 4.1 (Description of Likely Suitable Extraction Points), it is required that likely suitable extraction points are described and a suitable method (or methods) or extraction are identified.

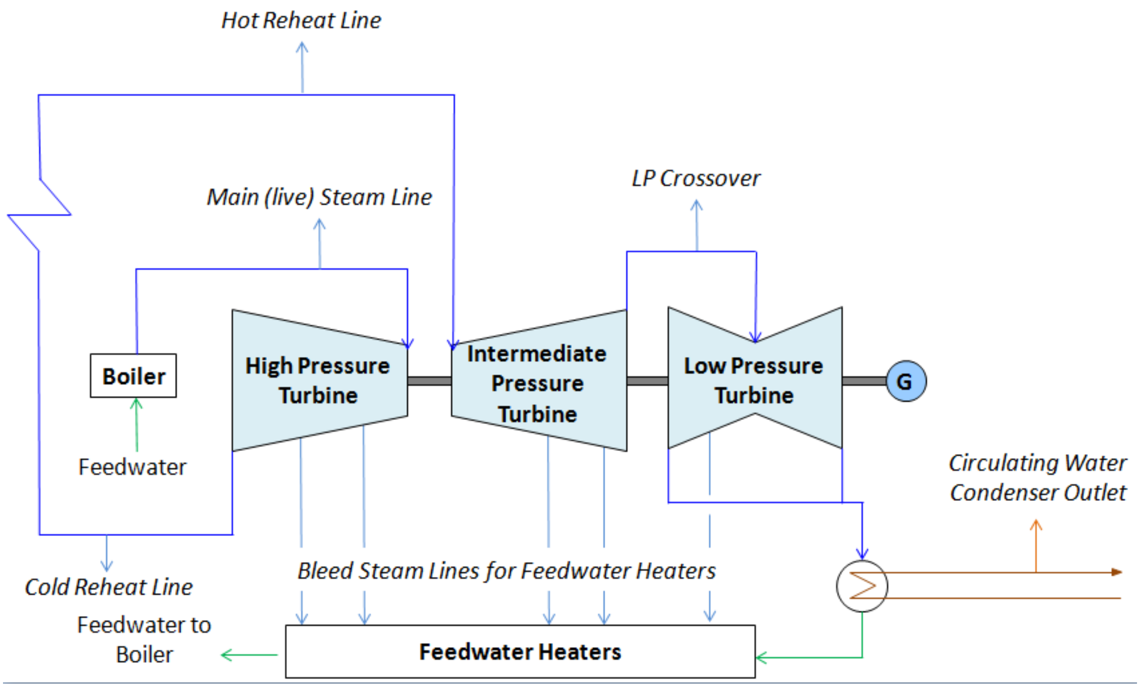
The potential for a plant to be converted to supply heat in the future (whether it is to either a district heat network or an industrial process) depends upon: the type of plant being considered (i.e. whether it is conventional steam or a CCGT); the steam cycle configuration; and, the steam turbine configuration.
For example:

- The steam cycle can be:
  - With or without reheat; and,
  - (For CCGT) it can be one, two or three pressure.
- The steam turbine can:
  - Have a lateral exhaust (side or down), or an axial exhaust;
  - Have different casing arrangements (i.e. single and multi).

The following information contains a range of examples which represent a range of configurations for illustrative purposes. However, it should be noted that this range of examples is not intended to be exhaustive.

Additionally, the potential steam sources shown are based on typical arrangements without consideration of CHP (i.e. they are representative of plants which are initially required to generate electrical power). However, the future extraction points are described for the purposes of demonstrating CHP-R.

Large Scale Conventional Steam Plant with Reheat (Water Cooled Surface Condenser)

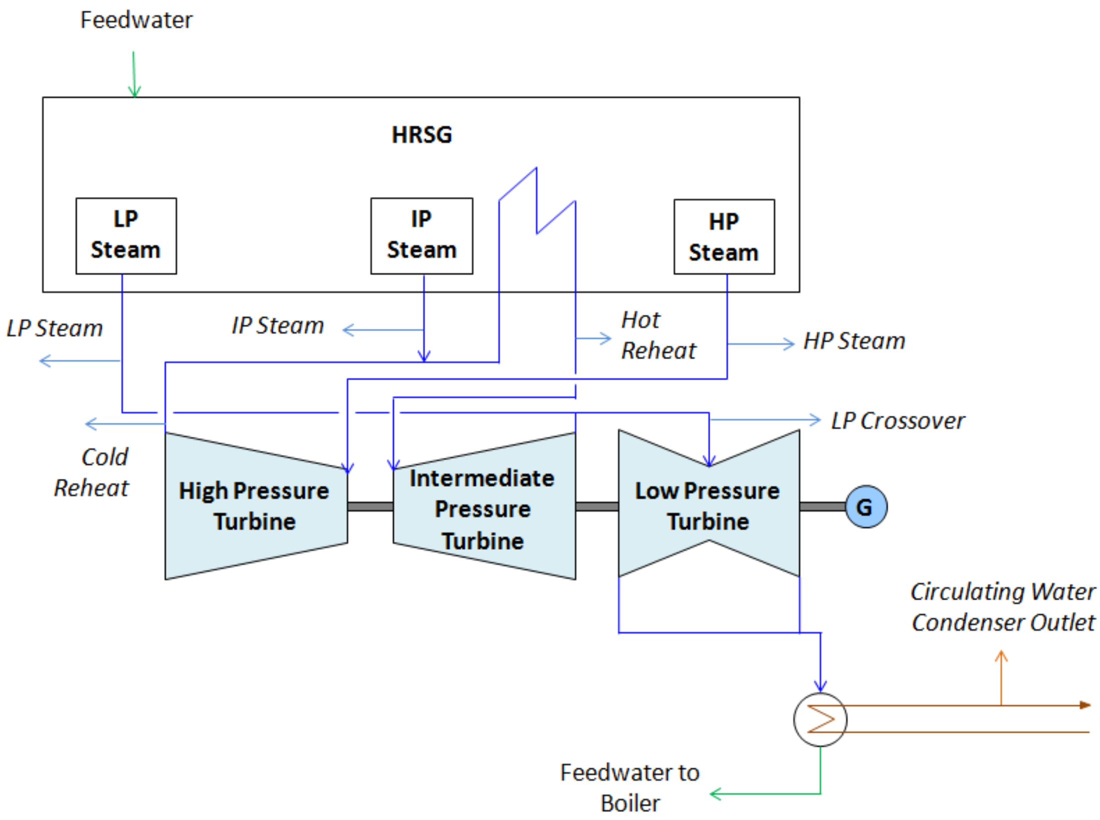


This example considers a typical large scale conventional steam plant with reheat, and a water cooled surface condenser. This is based on separate HP, IP and LP steam turbines. The LP steam turbine(s) have down exhausts, and the steam is delivered from the exhaust of the IP steam turbine to the LP steam turbine by large crossover pipes.

Potential sources of heat are:

- Main (live) steam (high pressure);
- Hot reheat (intermediate pressure);
- Cold reheat (intermediate pressure);
- LP cross over (low pressure);
- Bleed steam for feedwater heaters (high pressure / intermediate pressure / low pressure); and
- Circulating water condenser outlet (hot water).

Large Scale CCGT Plant with Reheat (Water Cooled Surface Condenser)



This example considers a typical large scale CCGT plant with a three pressure reheat, and a water cooled surface condenser. This is also based on separate HP, IP and LP steam turbines. The LP steam turbine(s) have down exhausts[22], and the steam is delivered from the exhaust of the IP steam turbine to the LP steam turbine by large crossover pipes. There are usually no feedheaters, but multiple pressures are generated in the Heat Recovery Steam Generator (HRSG).

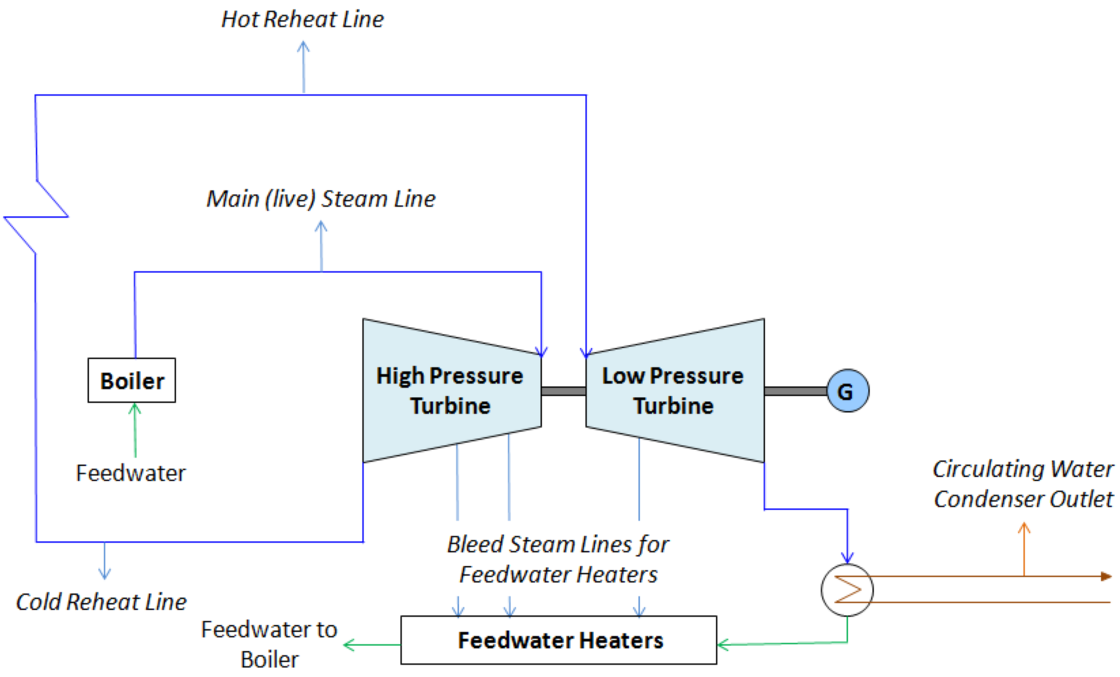
Potential sources of heat are:

- HP steam (high pressure);
- Cold reheat (intermediate pressure);
- IP steam (intermediate pressure);
- Hot reheat (intermediate pressure);
- LP steam (low pressure);
- LP cross over (low pressure); and,
- Circulating water condenser outlet (hot water).

This is considered to represent the configuration in Case Study 1 and Case Study 2.

[22] Depending on the cooling system and condenser pressure selected, steam turbines for single shaft may have a single LP turbine without a full IP / LP crossover pipe and an axial exhaust. This is considered to represent the configuration in Case Study 5.

Small Scale Conventional Steam Plant with Reheat (Water Cooled Surface Condenser)

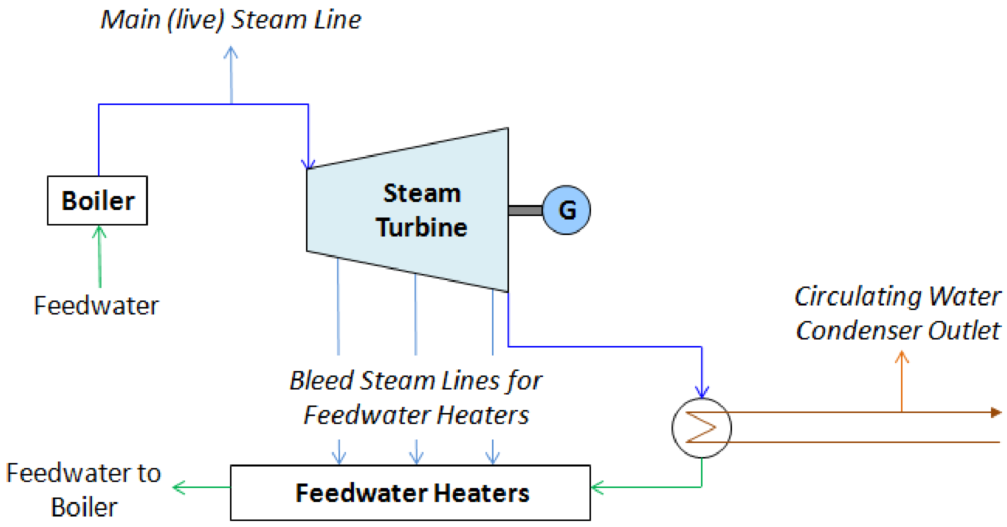


This example considers a typical small scale conventional steam plant with reheat, and a water cooled surface condenser. This is based on separate HP and LP steam turbines. The LP steam turbine could have a lateral or axial exhaust. There is no crossover pipe.

Potential sources of heat are:

- Main (live) steam (high pressure);
- Hot reheat (intermediate pressure);
- Cold reheat (intermediate pressure);
- Bleed steam for feedwater heaters (high pressure / intermediate pressure / low pressure); and
- Circulating water condenser outlet (hot water).

Small Scale Conventional Steam Plant without Reheat (Water Cooled Surface Condenser)



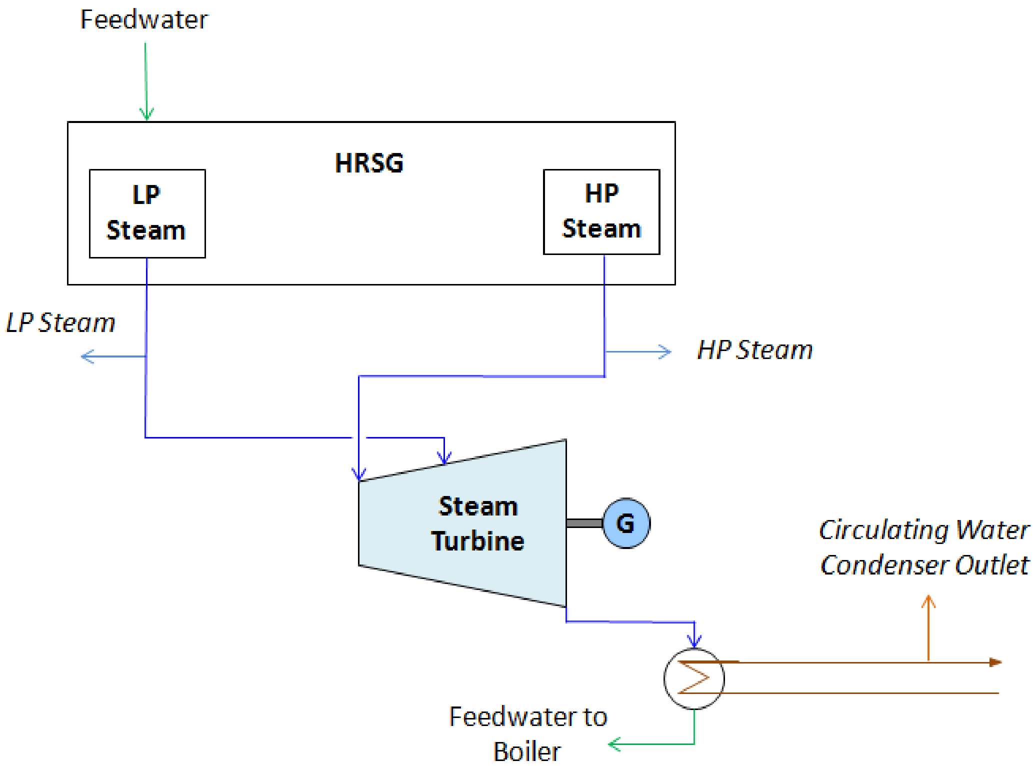
This example considers a typical small scale conventional steam plant without re-heat, and a water cooled surface condenser. This is based a single casing Steam Turbine. The Steam Turbine could have a lateral or axial exhaust. There is no crossover pipe.

Potential sources of heat are:

- Main (live) steam (high pressure);
- Bleed steam for feedwater heaters (high pressure / intermediate pressure / low pressure); and
- Circulating water condenser outlet (hot water).

This is considered to represent the configuration in Case Study 3 and Case Study 4.

Small Scale CCGT Plant without Reheat (Water Cooled Surface Condenser)



This example shows a typical small scale CCGT plant without reheat, and a water cooled surface condenser. This is based on a single case steam turbine with two pressures. The steam turbine could have a lateral or axial exhaust. There is no crossover pipe.

Potential sources of heat are:

- HP steam (high pressure);
- LP steam (low pressure); and
- Circulating water condenser outlet (hot water).

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