Department for
Business, Energy
& Industrial Strategy

SAP 10.2 – updates for heat networks

Covering proposals to natural-gas CHP, the Products Characteristics Database, Biomass and recovered heat factors

Closing date: 10 May 2021

March 2021

Any enquiries regarding this publication should be sent to us at:
SapHeatNetworksConsultation@beis.gov.uk

Contents

Scope of the Consultation

In this consultation we set out proposals for improving the latest version of SAP's (SAP 10), approach to assessing homes connected to heat networks that utilise recovered heat and to homes connected to heat networks using Combined Heat and Power (CHP). These proposals intend to address the risk that SAP does not correctly model or reflect recovered heat sources for heat networks, and to better reflect the ability of heat networks utilising natural gas CHP units to displace more carbon intensive electricity generation.

These proposals will support the development and delivery of heat networks as a key part of decarbonising heat as part of meeting 2050 net zero targets.

Consultation details

Issued: 15 March 2021

Respond by: 10 May 2021, midday
Consultation runs for 8 weeks

Enquiries to:

Email: SAPHeatNetworksConsultation@beis.gov.uk

Audiences:

This consultation is primarily aimed at:

- Heat network & property developers and builders
- Heat network owners and operators
- Property owners and occupiers
- SAP/RdSAP assessors
- Construction industry professionals
- Manufacturers and suppliers of construction materials
- Environmental organisations
- Local authorities and other building control bodies
- Consumer groups

Specific elements may be of interest to members of the public.

Territorial extent:

The Standard Assessment Procedure is a calculation methodology used across the United Kingdom.

How to respond

We strongly encourage responses via Citizen Space, particularly from organisations with access to online facilities such as local authorities, representative bodies, and businesses. Consultations receive a high-level of interest across many sectors. Using the online service greatly assists our analysis of the responses, enabling more efficient and effective consideration of the issues raised.

Respond online at:
https://beisgovuk.citizenspace.com/heat/heat-network-updates-sap10

or

Email to: SAPHeatNetworksConsultation@beis.gov.uk

or

Write to:

SAP Heat Networks Consultation
Department for Business, Energy and Industrial Strategy
2nd Floor, Orchard 1
1 Victoria Street
Westminster
London
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When responding, please state whether you are responding as an individual or representing the views of an organisation.

If you are responding in writing, please make it clear which questions you are responding to. Your response will be most useful if it is framed in direct response to the questions posed, though further comments and evidence are also welcome.

Please include:

- your name
- your position (if applicable)
- the name of organisation (if applicable)
- an address (including post-code)
- an email address, and
- a contact telephone number

Confidentiality and data protection

Information you provide in response to this consultation, including personal information, may be disclosed in accordance with UK legislation (the Freedom of Information Act 2000, the Data Protection Act 2018 and the Environmental Information Regulations 2004).

If you want the information that you provide to be treated as confidential please tell us, but be aware that we cannot guarantee confidentiality in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not be regarded by us as a confidentiality request.

We will process your personal data in accordance with all applicable data protection laws. See our privacy policy.

We will summarise all responses and publish this summary on GOV.UK. The summary will include a list of names or organisations that responded, but not people's personal names, addresses or other contact details.

Quality assurance

This consultation has been carried out in accordance with the government's consultation principles.

If you have any complaints about the way this consultation has been conducted, please email: beis.bru@beis.gov.uk.

Introduction

The Government is committed to achieving net zero greenhouse gas emissions by 2050. Meeting this legal commitment will require virtually all heat in buildings to be decarbonised, and heat in industry to be reduced to close to zero carbon emissions. Presently, heat is responsible for a third of the UK's greenhouse gas emissions[1]. Heat networks are a crucial aspect of the path towards decarbonising heat. Whilst heat networks currently provide only 2% of the UK's heat, in their net zero modelling, the Climate Change Committee assumes that 18% of the UK's heat demand will be met by heat networks in 2050.[2] In the right circumstances, they can reduce bills, support local regeneration and can be a cost-effective way of reducing carbon emissions from heating.

Compared to individual home or building heating systems, heat networks are uniquely able to unlock otherwise inaccessible larger scale renewable and recovered heat sources, such as waste heat, industrial heat, and heat from rivers and mines. For the purposes of this document we have defined 'recovered heat' as heat which is produced or generated by a process for which heat generation is not a primary purpose, and which would otherwise not be used.

Decarbonising heat as part of meeting 2050 net zero targets will require increasing uptake and utilisation of recovered and waste heat sources in heat networks. It is critical therefore that we recognise the benefits of using recovered and waste heat in heat networks during the development and design of those networks. This includes reflecting these benefits in the Standard Assessment Procedure (SAP), the energy modelling tool used across the UK to assess compliance with Building Regulations and produce Energy Performance Certificates (EPCs).

This consultation proposes changes to SAP to update our list of waste-heat technologies, one of the key heat sources for low-carbon heat networks in the future. It also suggests updates for natural gas Combined Heat and Power. These units produce heat and electricity and are an important technology for many district heating schemes. The proposals reflect updated analysis of the carbon and primary energy performance of this important technology.

[1] BEIS. Clean Growth -Transforming Heating. Overview of Current Evidence. December 2018

[2] Element Energy for the CCC, "Research on District heating and local approaches to heat decarbonisation,"https://www.theccc.org.uk/publication/element-energy-for-ccc-research-on-district-heating-and-local-approaches-to-heat-decarbonisation/

The consultation has two parts:

1. **Proposed updates to recovered heat and biomass:** We are proposing updates to SAP Appendix C: *Heat networks, including those with Combined Heat and Power (CHP) and those that recover heat from power stations*. We are seeking views on proposals for:

    - An expanded categorisation of recovered heat sources in SAP Appendix C4: *Heat networks that recover waste heat from power stations*;
    - An updated approach to Primary Energy factors for recovered heat sources used in heat networks;
    - Updates to Appendix C5: *Permutations of heat generators*, including clarification on the use of the Products Characteristics Database (PCDB)
    - Whether biomass Primary Energy factors are appropriate for heat networks

    Alongside this consultation we have included a revised Appendix C for information, which includes our proposed changes.

2. **Gas fired CHP approach:** We are proposing some changes to SAP to more accurately reflect the ability of natural gas CHP units to displace more carbon intensive electricity generation. Gas CHP is a common technology for heat networks but the way that SAP models the carbon performance of these units requires updating to better reflect that it currently saves carbon by displacing more carbon dioxide intensive electricity generation. We are also updating the approach to reflect the declining carbon savings from gas CHP as the UK's electricity grid decarbonises.

In this technical consultation we set out proposals for improving the latest version of SAP's (SAP 10) approach to assessing homes connected to heat networks that utilise recovered heat and to homes connected to heat networks using CHP. SAP 10 will be used to assess compliance with the 2021 version of Part L of the Building Regulations (see Government response to the standards in this consultation here). It will also be used to produce EPCs from 2021/22.

We intend to respond to this consultation in summer 2021 and incorporate any changes to SAP 10 before the SAP 10.2 is implemented in summer 2022 in line with updates to Building Regulations.

Part 1: Recovered Heat Proposals and Biomass

SAP Appendix C – recovered heat sources

The current guidance in SAP Appendix C describes ‘*waste heat from power stations*’ (Appendix C4 and C5), ‘*geothermal heat (or other natural sources)*’ (Appendix C5), and ‘*heat pumps utilising recovered sources*’ (Appendix C5) as the primary recovered heat sources for heat networks. We consider that this list does not truly reflect the range of sources of recovered heat available to heat networks. As a result, there is a risk that SAP inaccurately models other recovered heat sources.

Heat recovered from Energy from Waste (EfW) plants is a common large-scale recovered heat source for heat networks but up until this point SAP has not included it as a heating technology. This consultation builds on some previous updates. On 16th March 2020 BRE published a technical note[3] for SAP 2012 that provided distinction between heat networks that use recovered heat from EfW combustion and heat networks that recover ‘waste heat from power stations’. Prior to this technical note, EfW would typically be entered in SAP as ‘*Community heating schemes that recover waste heat from power stations*’ which can be inaccurate[4]

Following publication of the technical note, we have worked with industry to further expand the types of recovered heat sources for SAP 10 (including EfW), the proposed categories for which are listed and described below. In defining the below categories (as listed and described in the accompanying proposed SAP Appendix C), and recognising that the ‘grade’ of heat can vary across recovered heat types, we have broadly considered heat to be ‘high-grade’ where no additional energy input is required to elevate fluid temperature before delivery to a heat network. This can typically mean delivery to a network at higher than the network return temperature. ‘Low-grade’ heat requires boosting (e.g. by a heat pump) either in the dwelling or before delivery to a heat network.

Heat recovered from waste combustion *[New recovered heat category]* – this specifically refers to EfW facilities where the primary purpose of the plant is to dispose of municipal waste. High-grade heat can be recovered for district heating from the power generation process.

Heat recovered from power stations *[Updated recovered heat category]* – this specifically relates to plants where the primary purpose is to generate electricity (plants rated at more than 10MWe and operating at a gross power

[3] https://files.bregroup.com/SAP/BRE_Technical_Note-Energy_from_Waste_Facilities_%28ERF%29_1.0.pdf

[4] From BRE technical note: “…the methodology states that a system that recovers waste heat should be modelled as a CHP where the electrical efficiency is less than 35% and the electrical output is less than 10MW. However, modelling EfW facilities as CHPs can be inaccurate since the primary function of these facilities is the burning of waste at a rate determined by the amount of waste received, whereas the primary function of CHP is to meet the heat needs of the attached buildings by burning a high grade fuel and in the process providing electricity to the grid.”

efficiency below 35%, otherwise it is considered as CHP[5]). High-grade heat can be recovered for district heating from the process of generating power.

Heat recovered from other industrial processes *[New recovered heat category]* – this relates to industrial/other facilities where the process would have happened with or without heat being recovered. Examples include recovering heat from glass manufacturing, cement manufacturing or chemical processing. High-grade heat can be recovered for district heating.

Heat recovered from other commercial processes *[New recovered heat category]* – this relates to commercial/other facilities where the process would have happened with or without heat being recovered. Examples include recovering heat from data centre cooling, refrigeration processes, waste-water processing etc. Low-grade heat can be recovered for district heating.

Heat recovered from geothermal or other natural sources *[Updated recovered heat category]* – this category relates to instances where natural/ambient heat can be recovered. Examples include solar thermal heat. High- or low-grade heat can be recovered for district heating.

Question 1 – Do you agree with the proposed additional recovered heat categories? If you disagree, please provide reasoning, including alternative approaches.

Question 2 – Do you agree with the description of each of the proposed categories? If you disagree, please provide reasoning, including alternative descriptions.

Question 3 – Are there any recovered heat sources not covered by the proposed categories which are likely to contribute to decarbonising heat networks? Please state which.

Primary Energy factors for recovered heat sources

The recent Future Homes Standard consultation[6] proposed the introduction of a Primary Energy target as a part of compliance with Part L of the Building Regulations. The purpose of this was to transpose a requirement of the revised Energy Performance of Buildings Directive (EPBD). SAP has historically calculated Primary Energy, but with the proposed changes to Part L, this output has gained more importance.

Primary energy use is a measure of the energy regulated by the energy efficiency requirements of the Building Regulations, such as lighting, heating and hot water. The calculation takes account of efficiencies and energy uses such as:

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[5] See SAP Appendix C. General Electric research shows that the average efficiency of coal-fired power plants in the UK is 38%. Gas-fired power plants are typically more efficient than coal-fired power plants. (From 'GE Global Power Plant Efficiency Analysis, GE', available at: https://www.ge.com/reports/wp-content/themes/ge-reports/ge-power-plant/dist/pdf/GE%20Global%20Power%20Plant%20Efficiency%20Analysis.pdf)

[6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/956094/Government_response_to_Future_Homes_Standard_consultation.pdf

• The efficiency of the property's heating system;

• Power station efficiency for electricity; and

• The energy used to produce the fuel and deliver it to the property.

A primary energy metric therefore provides a measure of the energy use in dwellings and takes account of upstream energy uses. This will ensure that new homes are energy efficient and making good use of our nation's energy resources regardless of our wider progress towards decarbonising the electricity grid. 38 3.56. More information on primary energy, including an explanation of what primary energy is and how it is calculated, can be found in the Briefing Note – Derivation and use of primary energy factors in SAP, which is available on the SAP website: https://www.bregroup.com/sap/sap10/

The SAP specification assigns carbon dioxide emissions and primary energy factors for different energy sources in Table 12 of SAP documents[7]. These factors are updated shortly before each new publication of SAP to ensure that changes in the energy system, e.g reductions in the average emissions of electricity production, are up to date.

The SAP 2016 consultation information paper *CONSP:07 –* CO2 *and Primary Energy Factors for SAP 2016 Version 1.0*[8] outlines provisional carbon emissions and primary energy factors for SAP, including methodology and data sources. This paper notes that "*waste used to produce energy should also be assigned a primary energy factor of 1, with any subsequent energy use or losses that occur prior to delivery added*".

However, following engagement with industry, and to better align approaches to recovered heat sources, we are proposing to assign a Primary Energy factor of 0 to all recovered heat sources. We are also proposing to add values for (outlined in the table below):

Pumping energy, to reflect the electrical energy required to transport the heat from its source;

Where relevant (i.e. in cases where heat is recovered from an electricity generation process), offsetting downturn in power generation which is subsequently made up elsewhere. This is known as the 'z-factor' approach, consistent with the existing carbon dioxide emission factor calculation for 'waste heat from power station'.

We believe that this approach will better reflect the 'recovered' nature of these heat sources and bring the Primary Energy approach for recovered heat sources for heat networks in line with existing approaches to other recovered heat sources in SAP. The main examples of existing approaches are solar thermal and Wastewater Heat Recovery Systems (WWHRS), both of which are implemented as an offset to domestic hot water demand. In each case we consider 0 to be an appropriate Primary Energy factor because the primary energy used to generate that heat is

[7] The most recent SAP publication was SAP 10.1 published here: https://www.bregroup.com/wp-content/uploads/2019/11/SAP-10.1-08-11-2019_1.pdf
[8] https://www.bre.co.uk/filelibrary/SAP/2016/CONSP-07---CO2-and-PE-factors---V1_0.pdf

typically assigned to the original purpose, e.g. heating water for a shower, or generating electricity by burning municipal waste.

Our proposals for recovered heat relate to the approach to Primary Energy factors for recovered heat sources used in heat networks only. The Primary Energy approach to renewable power is not part of the proposals in this document.

Our proposed approach for the categorisation of recovered heat sources is outlined below.

Proposed recovered heat category	Primary Energy pumping energy addition	Primary Energy 'z-factor' addition	Proposed Primary Energy Factor (kWh/kWh)[9]
Heat recovered from waste combustion	Yes	Yes	0.063
Heat recovered from power stations	Yes	Yes	0.063
Heat recovered from other industrial processes	Yes	No	0.051
Heat recovered from other commercial processes[10]	Yes, or bespoke PCDB calculation	No	1.501, or bespoke PCDB calculation
Heat recovered from geothermal or other natural sources	Yes	No	0.051

We think that it is important that primary energy factors are up to date, if necessary, we will consider updating primary energy factors when the implementation version of SAP 10 is published.

Biomass

There are over 4 million homes in Great Britain and around 200,000 non-domestic buildings that are not connected to the gas grid. Many of these buildings will transition to using heat pumps, but we expect other technologies to play a role for some harder to treat buildings such as limited biomass and efficiencies could potentially be made by using heat networks. Biomass is an important optional fuel source for some heat networks, typically in rural locations and where there can be a sustainable supply of feedstock.

We recognise high primary energy factors of biomass can impact how biomass heat networks are treated in SAP and we are interested in gathering views on how the

[9] Illustration based on SAP10.1 factors – to be updated for SAP10.2.
[10] See section 4.4 in accompanying Appendix C

biomass factors could be amended to better enable use of this fuel where it is sustainable.

Question 4 – Do you agree with the proposed approach to Primary Energy factors for recovered heat sources for heat networks? If you disagree, please outline why.

Question 5 – If you disagree with the proposed approach to Primary Energy factors for recovered heat sources for heat networks, please outline your views on alternative approaches, including relevant evidence?

Question 6 – How could the SAP methodology recognise the potential role of biomass in decarbonising rural, harder to decarbonise areas?

Product Characteristics Database (PCDB) approach

Our proposals for expanding the categorisation of recovered heat sources for heat networks in SAP, is described above and is also outlined in the attached draft SAP Appendix C (section C4). To ensure consistency across the SAP Appendix C document, we have also proposed drafting changes to section C5 of SAP Appendix C, which lists and describes the permutations/configurations of heat generators for heat networks in SAP.

The primary drafting updates include:

- Updating wording to reflect expanded categorisation of recovered heat sources, referencing SAP Appendix C section C4;
- Clarifying wording regarding the different ambient and recovered sources of heat for heat pumps;
- Clarifying that permutations of heat sources not covered by SAP Appendix C section C5 should be inputted by a PCDB entry.

These drafting changes are largely to ensure that the new categories of waste-heat sources are referenced consistently and accurately throughout the SAP document. The final bullet point on adding heat sources through the PCDB is to ensure that there is a opportunity for new and innovative heat sources to be referenced in SAP before the document is formally updated. At the moment new arrangements of heat sources which do not have an existing category either have to pick an inaccurate heat source classification or go through a lengthy and difficult process by submitting calculations to the PCDB. We want to clarify and streamline this latter process so that new and innovative heat sources are not held up by Building Regulations approval. We will be updating document[s] *Application Form: APPF:01 – Application guide for entry of heat network performance data in SAP Products Characteristics*

Database[11] and the *Application workbook for entry of heat networks in SAP PCDB*[12] for issue. This will be published after SAP10.2 publication.

Question 7 – Do you agree with the approach of using PCDB entries for permutations of heat generators not covered in proposed Appendix C5 bullets 1-6? If you disagree, please state why, providing alternative approaches.

Part 2: Gas CHP Proposal

One of the common technologies for heat networks, particularly larger district schemes, is natural-gas Combined Heat and Power (CHP) turbines. These generate both heat and power, with the revenues from electricity sales being particularly important for the finances of many schemes. The power generated by gas CHP displaces power produced by the grid, which is a carbon saving for gas CHP schemes. In SAP, a carbon factor is used to represent the carbon intensity of the power which is displaced by gas CHP. The higher carbon the grid generation displaced by gas CHP, the higher the carbon factor and the greater the carbon saving.

Feedback from industry has revealed concerns regarding how the carbon emissions of the power that gas CHP displaces on the grid are calculated in SAP. The calculation in SAP uses average emissions factors, rather than marginal emissions factors, to calculate the carbon content of the displaced power (carbon factor). Average emissions factors are lower than marginal emissions factors and therefore using them underestimates the carbon saved due to the power produced by gas CHP plants. According to the Green Book[13], analysis on changes in energy use should use marginal emissions factors.

Gas CHP heat networks have historically been carbon saving as the UK's electricity production has relied on higher carbon generation. However, as the UK's electricity has become greener over the last decade, particularly with the shift away from coal power generation, these carbon savings have declined to such an extent that we now believe natural gas CHP units installed in heat networks are no longer carbon saving.

This is for three main reasons. Firstly, as the proportion of electricity produced by burning coal becomes ever smaller, gas CHP is increasingly displacing generation from efficient gas Combined Cycle Gas Turbines and electricity imported from the continent through our interconnectors. Secondly, gas CHP units installed in heat networks typically make use of private wire arrangements to sell electricity directly to consumers on-site. Whilst this is financially advantageous to the network, this electricity is increasingly more carbon-intensive than electricity that comes from the national grid. Thirdly, unlike natural gas CHP units that are used for industrial purposes, the units that produce heat for heat networks typically lose a portion of

[11] https://www.ncm-pcdb.org.uk/sap/filelibrary/pdf/Applications/APPF-01---Application-guide-for-entry-of-heat-network-performance-data-in-SAP-PCDB---V1.1.pdf
[12] https://www.ncm-pcdb.org.uk/sap/filelibrary/pdf/Applications/Application-workbook-for-entry-of-heat-networks-in-SAP-PCDB-Format-1.2.xls
[13] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

their heat as it is being distributed to the consumer. This ‘lost heat’ has to be replaced by more generation by the plant, further adding to carbon emissions.

The updates we are proposing in this technical consultation, detailed below, show that gas CHP installed in 2020 is 25% more carbon intensive than individual gas boilers over their expected lifetime (15 years), when considering both heat and power production.[14]

Gas CHP Analysis

As part of regular updates to analytical assumptions we have revisited analysis that the Department commissioned in 2014 to update our evidence base on how gas CHP interacts with the power sector.[15] This analysis seeks to understand what power generation on the grid is displaced by gas CHP, and how it differs from analysis carried out in 2014. Further, the analysis assesses how the displacement differs between power generation by gas CHP which is exported to the grid and used onsite. Further information is provided in the technical annex attached to this consultation.

Using outputs of this analysis, we calculated the carbon factors and primary energy factors which are set out below. Details of how these were calculated are set out in the technical annex to this consultation. Carbon factors and primary energy factors are presented separately for existing and new gas CHP plants, as analysis suggests that the carbon emissions of existing plants will be lower over their lifetime than for new plants. New gas CHP plants will have higher carbon emissions over time as they will displace lower carbon grid generation towards the end of their lives relative to existing gas CHP plants. Our classification of existing and new plants is as follows:

- **Existing** – heat networks with existing gas CHP plants that are seeking to connect to new buildings. For the purposes of the analysis, it is assumed that the gas CHP plants were built from 2015 – 2021.
- **New** – new gas CHP plants that are going to be constructed when Part L 2021 of the Building Regulations is in force (from June 2022), until the Future Homes Standard comes into force (expected to be 2025). We are proposing that these are included in Table 12 of SAP 10.2 under the category ‘Electricity generated by CHP’:

	Current (kgcO2e/KWh)	Proposed (kgcO2e/KWh)
Carbon factor (new)	0.136	0.221
Carbon factor (existing)		0.286
Primary energy factor (new)	1.501	1.754

[14] This calculation assumes 20% thermal losses in the distribution network, and a 15 year lifetime for gas CHP plants

[15] Bespoke natural gas CHP analysis (2014), https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis

Primary energy factor (existing)		1.849

The lower carbon and primary energy factors for new gas CHP plants, rather than existing, represent the fact that the grid power that is displaced by these plants will tend to be lower carbon towards the end of their lives. Existing gas CHP plants will displace more higher carbon generation at the beginning of their lives, which can be seen in the correspondingly higher carbon factor.

Question 8 – Do you agree with the proposed factors for CO2e & Primary Energy? If not, why not, and what would be a more accurate approach to natural gas CHP in SAP?

Question 9 – Do you agree with the assumptions described in the technical annex to this consultation? Please provide evidence to support your response.

Question 10 – Do you agree with our proposed classification of new and existing gas CHP plants?

Question 11 – Do you agree with our assumption that gas CHP plants tend to operate under a 'mixed exposure' commercial arrangement? If not, please provide any evidence to support your response.

Question 12 – Are respondents more likely to be building new or expanding existing gas CHP? If new gas CHP, what heating technologies would gas CHP be used in conjunction with? Would it be primary heating plant, or used alongside something else?

Consultation questions

Question 1 – Do you agree with the proposed additional recovered heat categories? If you disagree, please provide reasoning, including alternative approaches.

Question 2 – Do you agree with the description of each of the proposed categories? If you disagree, please provide reasoning, including alternative descriptions.

Question 3 – Are there any recovered heat sources not covered by the proposed categories which are likely to contribute to decarbonising heat networks? Please state which.

Question 4 – Do you agree with the proposed approach to Primary Energy factors for recovered heat sources for heat networks? If you disagree, please outline why.

Question 5 – If you disagree with the proposed approach to Primary Energy factors for recovered heat sources for heat networks, please outline your views on alternative approaches, including relevant evidence?

Question 6 – How could the SAP methodology recognise the potential role of biomass in decarbonising rural, harder to decarbonise areas?

Question 7 – Do you agree with the approach of using PCDB entries for permutations of heat generators not covered in bullets 1-6? If you disagree, please state why, providing alternative approaches.

Question 8 – Do you agree with the proposed factors for CO2e & Primary Energy? If not, why not, and what would be a more accurate approach to natural gas CHP in SAP?

Question 9 – Do you agree with the assumptions described in the technical annex to this consultation? Please provide evidence to support your response.

Question 10 – Do you agree with our proposed classification of new and existing gas CHP plants?

Question 11 – Do you agree with our assumption that gas CHP plants tend to operate under a 'mixed exposure' commercial arrangement? If not, please provide any evidence to support your response.

Question 12 – Are respondents more likely to be building new or expanding existing gas CHP? If new gas CHP, what heating technologies would gas CHP be used in conjunction with? Would it be primary heating plant, or used alongside something else?

Technical Annex – Gas CHP Carbon Displacement Analysis

Introduction

We have revisited analysis that the Department commissioned in 2014 to understand how gas CHP interacts with the power sector. In 2014, LCP were commissioned to complete a study titled "Modelling the impacts of additional Gas CHP capacity in the GB electricity market."[16] The analysis looked to assess the type of generation that would be displaced by the operation of gas CHP and the resulting impact on net carbon emissions over the 2018-45 period.

The grid has decarbonised more rapidly than was assumed in 2014. Therefore, we have updated the analysis carried out in 2014 using BEIS' current assumptions regarding the grid's decarbonisation trajectory. This analysis seeks to understand what power generation on the grid is displaced by gas CHP, the carbon intensity of that displaced power generation, and how this differs from the analysis carried out in 2014. This is then used to calculate the carbon and PE factors which are proposed in this consultation.

Results of 2014 Analysis

The carbon displacement analysis showed that additional gas CHP capacity, relative to the baseline, provides annual power sector carbon savings through to 2032 under BEIS' central grid decarbonisation trajectory assumptions. After which, additional gas CHP leads to a net increase in annual emissions. The 2014 analysis concluded that gas CHP would stop saving carbon over its lifetime from around 2023.

Update to Analysis

This is a partial update of the grid generation displacement analysis LCP provided in 2014. The present analysis is focused on gas CHP for district heating only, whereas the 2014 analysis included other types of gas CHP. In the LCP analysis, different gas CHP deployments were also modelled, within a selected range of 0.5GW to 3.0 GW of additional capacity. The present analysis is focused on gas CHP for district heating in a scenario of 2GW of additional capacity[17]. Both of the analyses use BEIS' Dynamic Dispatch Model (DDM).[18]

[16] Bespoke natural gas CHP analysis (2014), https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis
[17] We assume 2GW additional CHP for district heating capacity is deployed in 2018 for consistency with previous analysis.
[18] The DDM is a comprehensive fully integrated power market model covering the GB power market over the medium to long term. The model is used for analysis of electricity dispatch from GB power

The analysis seeks to answer four inter-related questions:

- What power generation on the grid does gas CHP displace when it is running, and what is the carbon intensity of it? Has this changed since 2014?
- How does the power displacement differ between generation which is exported and used onsite?
- Can we determine a new set of bespoke gas CHP marginal emissions factors for the electricity displaced by gas CHP?
- What are the relative carbon emissions of gas CHP to a gas boiler, and how does this vary over time?

Methodology

The grid generation displacement analysis was carried out by running the DDM with 2GW of additional gas CHP capacity and assessing the grid's power generation which is displaced by the additional capacity. The analysis was carried out using BEIS' 'Net Zero Higher Demand' and 'Net Zero Lower Demand' reference cases. Each of the reference cases represents a different decarbonisation pathway for the grid. 'Higher Demand' represents a pathway where transport and heating are electrified which results in higher demand on the grid, whereas the 'Lower Demand' reference case represents a pathway with large scale role out of hydrogen and therefore lower demands on the grid.

Separate runs of the DDM were also carried out based on different potential operating regimes of the gas CHP plant. The runs were as follows:

- All the power was exported to the grid;
- All the power was used onsite.

The displacement analysis presented the different generation on the grid that was displaced by gas CHP, broken down by generation type – this is presented in figures 1 and 2 below for the 'Net Zero Higher Demand' reference case only. From this it is possible to work out the carbon intensity of the power which is displaced in terms of marginal emissions factors (MEFs). The MEFs represent the carbon intensity of the power displaced, measured in kgCO2e/KWh.

The displacement analysis was carried out separately for the two runs described above and using the two Net Zero consistent reference cases for the grid generation. Using the MEFs for the export and onsite analyses, and assumptions regarding the amount of power which gas CHPs export and use onsite, it is possible to create a blended MEF series for the power displaced by gas CHP. The blended MEFs are calculated for the two reference cases, and ultimately an average is taken of the two to calculate the carbon factor to use in SAP. This is to reflect the uncertainty regarding the decarbonisation pathway that we will follow. The blended MEF series is therefore a weighted average of the results of the export and onsite only analyses.

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generators and investment decisions in generating capacity over the next 30 years. It considers electricity demand and supply on a half hourly basis for sample days.

Assumptions

There are a number of key assumptions in this analysis:

- Approach to accounting for **traded sector emissions** in the analysis. In our approach to calculating a carbon factor for gas CHP in SAP, we have included all of the carbon emissions associated with the energy use of a heat network with a gas CHP plant. This includes calculating the carbon content of the power displaced by gas CHP on the UK grid, including power imported from interconnectors. We consider that this approach most accurately reflects the carbon emissions associated with the impact of gas CHP on a building's energy use and resulting emissions.
    - An alternative approach to accounting for traded sector emissions, used in cost benefit analysis, is described in the Green Book.[19] Emissions trading schemes, such as the UK ETS and the EU ETS, governs the total level of traded sector emissions, and the power produced by gas CHP will have no impact on overall net global emissions due to this binding constraint. Following this approach, the carbon factor for the power displaced by gas CHP would be 0. However, given we are primarily concerned about the impact of a given heating technology on the overall emissions from buildings, we consider that it is more appropriate to include the indirect power emissions in the carbon factor.

- The **commercial arrangements of gas CHP**. In line with the 2014 analysis, we have assumed that gas CHP operates under a 'mixed exposure' commercial arrangement. Our understanding – based on the original LCP study and industry engagement – is that this assumption continues to be the most accurate representation of how the market operates. Under a mixed exposure operating regime, gas CHP exports power at wholesale prices, while the plant imports power at retail prices. Under this operating regime, the power used onsite is not sensitive to the generation on the grid. This is because the retail price is greater than the wholesale price, and high enough that even if low carbon generation is on the margin, it would still be cheaper for the plant to use its own power than to import it from the grid. In the sensitivity analysis we test how the results change if all the power was either used onsite or exported to the grid, to test the impact of this assumption.

- The **decarbonisation trajectory of the grid**. The analysis is carried out using the department's Net Zero scenarios. The scenarios represent two illustrative net zero electricity demand and generation scenarios. They are not forecasts nor do they indicate preferred outcomes, instead they illustrate the mix of properties required for a Net Zero consistent power system. This has been published as part of the Energy and Emissions Projections 2019[20]. The analysis has been carried out separately on each of the reference cases, and

[19] Green Book Supplementary Guidance: valuation of energy use and greenhouse gas emissions for appraisal, 2020 https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal
[20] Energy and Emissions Projections, 2019 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019

an average of the results used to calculate the carbon and primary energy factors.

- The proportion of **power used onsite and exported to the grid**. We have based this assumption from the CHPQA dataset[21], for the current year. The proportion of power which is exported is assumed to change over time in proportion to the amount of gas generation on the grid. Gas CHP will tend to export mainly against gas generation on the grid, since the wholesale price is greater for gas generation. Due to the commercial arrangements outlined above, we expect the hours in a year where CHP can export against gas generation will decrease as the grid decarbonises.
    - In the reference case, 8% of the grid's generation in 2050 is natural gas or gas CCS in the Net Zero Higher Demand scenario. In 2018, the start year for the analysis, it was 36%. Our assumption is that the proportion of gas CHP power which is exported to the grid reduces linearly from the current level to 8% by 2050. The pattern is similar in the Net Zero Lower Demand scenario.
    - This assumption is uncertain and tested in the sensitivity analysis.

- The carbon intensity of **imported electricity from interconnection**. The assumption is based on the National Grid's estimates regarding the proportion of zero carbon imports on their interconnectors.[22] The National Grid estimate that 65% of their imports are zero carbon in 2020, increasing to 85% in 2025 and 90% in 2030. For the proportion of carbon intensive imports, we assume they have a carbon intensity consistent with generation from gas plants. There is significant uncertainty around this approach. The estimates do not cover all current or future interconnector capacity, as the National Grid do not own all of the interconnectors in the pipeline. Since the approach to estimate the carbon intensity of imports is highly uncertain, two different approaches for calculating the value are presented in the sensitivity analysis.

Results – Grid Generation Displacement Analysis

The results are presented separately for each model run. As expected, the results differ significantly between the two. The total generation is lower in the scenario where power is all exported to the grid, than the scenario where it is used onsite. This is because onsite generation does not respond to price signals due to different marginal generation on the grid. As a result, the power that is used onsite displaces a greater proportion of lower carbon generation on the grid.

As can be seen from Figure 1 below, the additional gas CHP capacity displaces mainly generation from natural gas sources to 2026 in the onsite only series. After 2026, gas CHP generation starts displacing an increasing proportion of imports and low carbon generation. Gas CHP, therefore, provides power sector carbon savings up to 2026, thereafter it starts displacing lower carbon generation on the grid.

[21] CHPQA Programme, https://www.gov.uk/guidance/combined-heat-power-quality-assurance-programme
[22] National Grid, 2020, https://www.nationalgridcleanenergy.com/

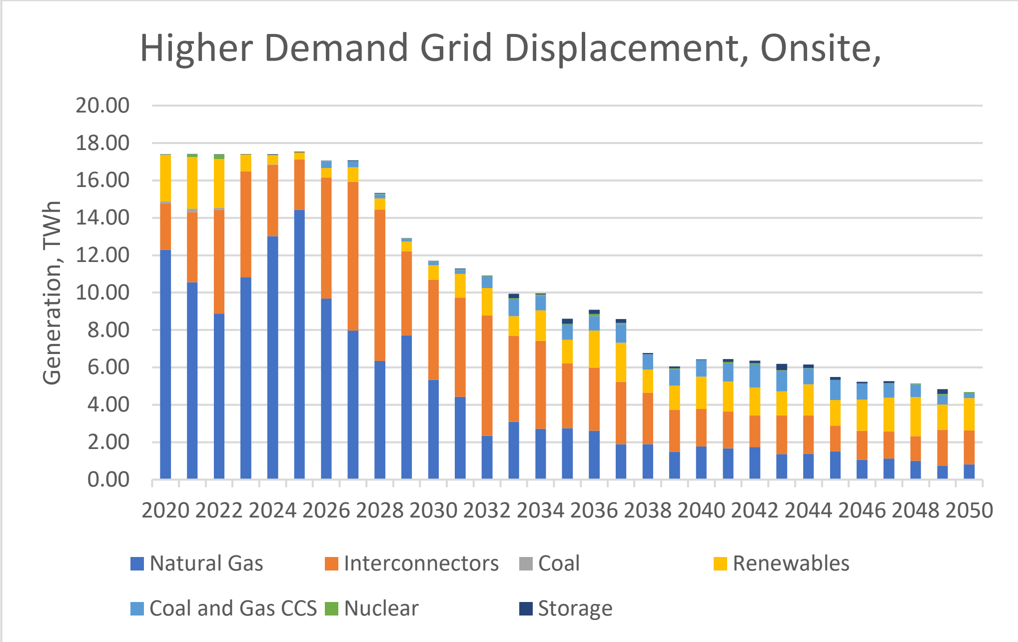

Figure 1: Higher demand grid displacement, onsite

The results for the exporting only series are presented below. As expected, there is a greater proportion of natural gas generation relative to the onsite series, which reflects that exported power responds to wholesale prices. However, there is still an increasing displacement of power imported from interconnectors from the late 2020s.

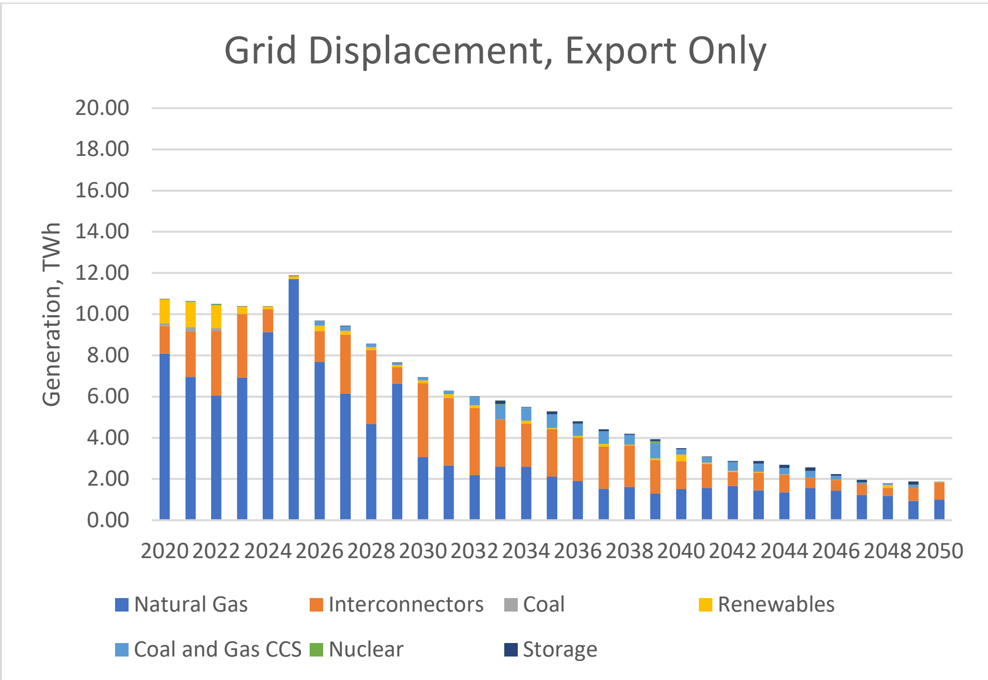

Figure 2 Grid displacement, export only[23]

[23] The decrease in renewables generation is a result of less onshore and solar capacity due to the increased gas CHP capacity.

Results – Blended MEF

As described above, the blended MEF is calculated assuming a proportion of the gas CHP's power is exported and used onsite. The proportion of power exported to the grid in 2020 is based on CHPQA data. It is assumed that the proportion will change over time as the amount of gas generation on the grid changes. As there is less gas generation, there will be less exported power. In 2018, 36% of the grid generation is gas, falling to 8% in 2050. The MEF series are presented graphically in Figure 3 below.

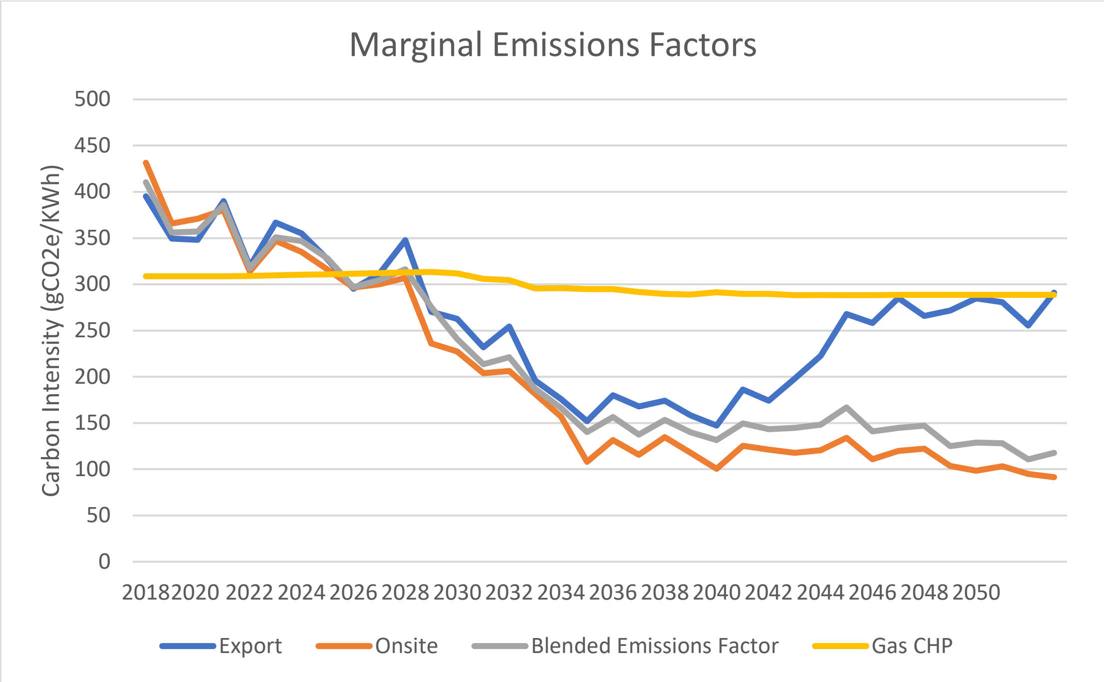

Figure 3 Marginal emissions factors

Carbon and Primary Energy Factors

The carbon and primary energy factors will be updated in Table 12 of SAP. The values are calculated based on the analysis presented above.

Carbon Factor

The carbon factor is calculated as the average carbon intensity of the displaced electricity over the lifetime of gas CHP plants - 15 years – installed over the SAP period. That is, the average of the blended marginal emissions factor presented in Figure 3.

We are proposing including different carbon factors for new, and existing gas CHP plants in SAP.

- For **new** gas CHP plants, the carbon factor is calculated as the average of the blended emissions factors over the period from 2022 – 2039 This reflects the 15-year lifetime of gas CHP plants installed over the building regs period, 2022 – 2025.

- For **existing** gas CHP plants, the carbon factor is calculated as the average of the blended emissions factors over the period 2015 – 2035. This reflects the 15-year lifetime of gas CHP plants installed from 2015 up to 2021.

The proposed carbon factors are below:

Table 1:

	Current (kgcO2e/KWh)	Proposed (kgcO2e/KWh)
Carbon factor (new)	0.136	0.221
Carbon factor (existing)		0.286

Primary Energy Factor

SAP uses primary energy factors to convert the energy requirements of a dwelling into a primary energy demand figure. The definition of primary energy used in SAP is ‘energy from renewable and non-renewable sources which has not undergone any conversion of transformation process.’ The primary energy factor calculation uses information from the Digest of UK Energy Statistics (DUKES)[24] regarding the upstream activities involved in the production of the fuel. BRE published a briefing note on the derivation of primary energy factors[25], this consultation follows the same methodology to work out the energy content of the power which is displaced by gas CHP.

The primary energy factor represents the kWh of primary energy which is used to generate a kWh of power. In this case, the primary energy factor represents how much primary energy is required to generate a unit of power which is displaced by gas CHP. In a similar manner to the carbon factor, the primary energy factor for new gas CHP plants is calculated over the period 2022 – 2039 to reflect the 15-year lifetime of gas CHP plants that would be installed under SAP up to 2025. The primary energy factor is also calculated as a blend between the exporting only and onsite only displacement analysis.

For existing gas CHP plants, the primary energy factor is calculated for gas CHP plants installed from 2018, rather than 2015. We do not have evidence on the primary energy displacement from the years prior to 2018 to develop an assumption for gas CHP plants installed from 2015.

Table 2:

[24] https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes
[25] https://www.bregroup.com/wp-content/uploads/2019/10/Briefing-note-on-derivation-of-PE-factors-V1.3-01-10-2019.pdf

	Current (KWh /KWh)	Proposed (KWh/ KWh)
Primary energy factor (new)	1.501	1.754
Primary energy factor (existing)		1.849

Sensitivity Analysis

Due to the uncertainty in the analysis, sensitivity analysis has been carried out on key assumptions to understand how they influence the results. The sensitivity analysis will assess how the carbon and primary energy factors change with changes to certain assumptions. The main sources of uncertainty in the analysis relate to:

- the proportion of power that gas CHP plants export to the grid (operating regime);
- the carbon intensity of imported power; and
- the decarbonisation trajectory of the grid.

Operating Regime

To test the impact of varying the assumed **commercial arrangements of gas CHP (proportion of power exported to the grid)**, the analysis was carried out assuming that either all of the power was exported to the grid or used onsite. The displacement is anticipated to vary between power which is used onsite or exported due to how the CHP plant responds to wholesale prices.

We have also presented a sensitivity where gas CHP displaces only CCGT generation on the grid.

Table 3

Sensitivity	Carbon Factor (kgCO2e/KWh)	PE Factor (KWh/ KWh)
All gas CHP power exported to the grid	0.237	1.865
All gas CHP power used onsite	0.207	1.689
Constant Proportion of power exported	0.226	1.797
Gas CHP displaces CCGT Only	0.420	2.369

Carbon Intensity of Imported Power
Our central approach to calculating the carbon content of imported power is to estimates from the National Grid regarding the amount of imported power which is

zero carbon, we assume the non-zero carbon imports are CCGT. This approach is highly uncertain. The sensitivity analysis carried out here tests the impact of different methods of calculating the carbon intensity of imports. Each of the methods come with their own uncertainties:

One approach is to assume that the carbon intensity of imported power is the same as the **domestic generation displaced** by gas CHP. This can reasonably be assumed when carbon prices between markets are aligned. However, having similar carbon prices between markets is one of many factors that will determine interconnector flows. Others include – levels of decarbonisation in the UK and EU grids, fossil fuel prices, interconnector capacity in the UK and EU.

Using domestic generation displaced by gas CHP is likely to overstate the carbon intensity of imported power. For instance, in the exporting only series, the implicit assumption would be that the power imported through interconnectors is generated by natural gas generation, with a carbon intensity of around 400gCO2e/KWh. In the onsite series, this approach results in a carbon intensity of imports that is slightly lower, but still significant. Evidence from the recent Aurora study into the decarbonisation impact of interconnection[26], and the National Grid[27] evidence base, suggest that increased interconnector capacity would decarbonise both the UK and EU power grids.

Another approach is to base the carbon intensity of imported power on the average emissions intensities of the grids that the UK imports from. The values for the average emissions intensities of EU grids are taken from a study BEIS commissioned from Aurora into the impact of interconnectors on decarbonisation.[28] The main limitation of this approach is that assumes constant carbon intensities over time which is not consistent with EU decarbonisation plans. It may also underestimate the current emissions intensity since the imported energy might have higher carbon intensity than the average.

Table 4

Sensitivity	**Carbon Factor (kgCO2e/KWh)**	**PE Factor (KWh/ KWh)**
Domestic Generation Displaced	0.323	1.778
Average Emissions Intensity	0.251	1.778

[26] Impact of Interconnectors on Decarbonisation, 2020 https://www.gov.uk/government/publications/impact-of-interconnectors-on-decarbonisation
[27] National Grid, 2020, https://www.nationalgridcleanenergy.com/
[28] Impact of Interconnectors on Decarbonisation, 2020 https://www.gov.uk/government/publications/impact-of-interconnectors-on-decarbonisation

Net Zero Reference Cases

The analysis is carried out by taking an average of the two BEIS Net Zero reference cases for the grid. The results of using the two reference cases separately are also presented below.

Table 5 - Higher Demand:

Sensitivity	Carbon Factor (kgCO2e/KWh)	PE Factor (KWh/ KWh)
New	0.230	1.778
Existing	0.294	1.866

Table 6 - Lower Demand:

Sensitivity	Carbon Factor (kgCO2e/KWh)	PE Factor (KWh/ KWh)
New	0.212	1.730
Existing	0.278	1.832

This consultation is available from: www.gov.uk/government/consultations/standard-assessment-procedure-sap-102-proposals-for-updates-for-heat-networks

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