

Design Note

Project Lea Valley Heat Network
Subject Carbon Factor of Heat: Methodology, inputs and assumptions
Project no 0042616
Date 5 November 2019

Revision	Description	Issued by	Date	Approved (signature)
00	Issue for comment and agreement	LB	06.11.19	

1 Introduction

The purpose of this design note is to explain options available to Energetik in setting a carbon factor for heat associated with the proposed heat network from the Edmonton Energy Recovery Facility (ERF).

The scope for this piece of work is:

1. Review policy updates to Part L / SAP 10 / SAP10.1 and impacts on
 - a. Gas and electric carbon factors
 - b. Update waste heat carbon factor to the latest SAP / BEIS factors
 - c. Part L baseline for establishing target carbon factors
2. Outline key assumptions / changes on the regulations, ERF and plant efficiencies in advance of commencing modelling / report updates
3. Carbon modelling calculations to be updated to reflect fuel emission factors and district heat network efficiency modelling as identified in the above
4. Update 'Energetik Carbon Factor of heat' design note and carbon factor modelling to incorporate the above changes
5. Prepare 'Carbon Factor of DHN Delivered Heat Calculation Method' note (as per example for CHP / Heat Pumps issued on 26/04/19) to set out how designers / developers should input SAP factors for ERF network connection.

This note has been prepared in response to points (1) and (2) of the above, to explain the policy updates and gain agreement on key assumptions to be used in carbon modelling calculations. Four potential methodologies for calculating the carbon factor of the network are set out:

1. Current default SAP rule, which would mandate the CHP method be used as the electrical efficiency of the plant is less than 35%
2. SAP waste heat from power station, if there was no threshold of 35% electrical efficiency
3. Method 5 as per BuroHappold's previous report '160106 CC 033993 Heat Network Carbon Factor 02', denoted 'Reduced electrical efficiency method'
4. Displaced electricity method

2 Assumptions

2.1 Technical assumptions

Assumptions made in calculations are currently based on those extracted from the Arup document 'Interim_chp_development-strategy_may-2015', summarised in Table 2-1.

Table 2-1 Technical assumptions

Heat Output (MWth)	0	10	20	30	35	160
Gross Electricity Output (MW e)	70.6	68.5	66.4	64.3	63.2	15
Auxilliary Power Allowance (MW e)	9	9	9	9	9	9
Net Power (MW e)	61.5	59.4	57.3	55.2	54.2	6

Paragraph 2.1.2 of the Arup report states that an efficiency of 29% of the ERF could be achieved in power-only mode, however it is not known if this is net or gross. Efficiencies have therefore been calculated assuming the efficiency is net to give a worst-case scenario, however this assumption needs to be checked and agreed with Energetik.

It is understood that if Energetik sign a commercial agreement to take heat from the ERF, it will be for a 35MW heat supply to be taken as and when required. Therefore the efficiencies at 35 MW heat offtake have been taken for calculation of the heat carbon factor within this note.

It is recommended that the assumptions in Table 2-1 are checked and verified to ensure that up-to-date figures are being used to calculate the carbon factor.

Within this note, the calculations of heat carbon factor do not include losses from distribution to give a clear comparison between methodologies. However, when Energetik reports carbon factors to developers, losses in the network and energy used for pumping will also need to be considered.

3 SAP carbon factors

An updated version of the Standard Assessment Procedure (SAP), SAP 10.0¹, was published for consultation in July 2018. More recently, a further updated version, SAP 10.1, has been published in October 2019² to coincide with the publication of the Government's Future Homes Standard consultation, which discusses proposed changes to Building Regulations Approved Document L1, which makes reference to SAP.

It should be noted that both SAP 10.0 and SAP 10.1 are consultation versions only and are not used for any official purpose. SAP 2012³ continues to be the version used for all official purposes. The Building Research Establishment (BRE) expects a further update to SAP, SAP 10.2, to be published before it is brought into official use⁴. Building Regulations Part L is usually updated once every four years, meaning that SAP 10 could be in use in 2020.

Amongst other changes within these new versions of SAP, carbon emissions factors have been updated for a number of key fuels including grid electricity, waste heat from power stations and heat from waste combustion boilers. These carbon factors are summarised in Table 3-1 and Figure 3-1.

Table 3-1 Carbon factor by version of SAP

	SAP 2012 version 9.92	SAP 2016	SAP 10	SAP 10.1
Heat from boilers - waste combustion	0.047	0.074	0.074	0.074
Waste heat from power station	0.058	0.044	0.026	0.015
Mains gas	0.216	0.208	0.210	0.210
Electricity, any tariff	0.519	0.398	0.233	0.136

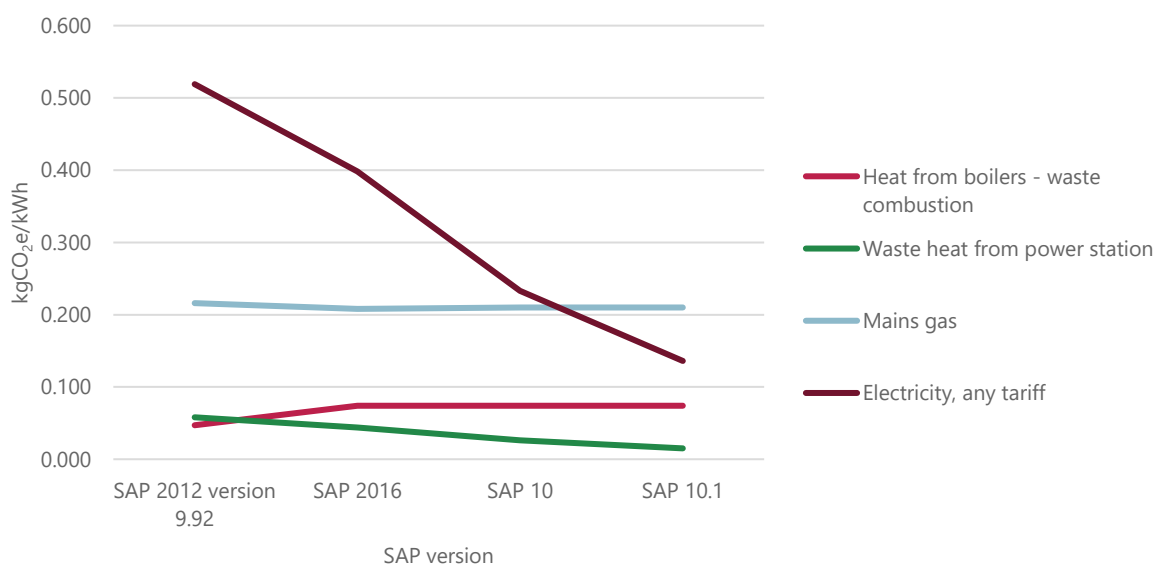


Figure 3-1 Carbon factor by version of SAP

Heat from boilers – waste combustion

There was an increase in carbon factor associated with heat from waste combustion boilers between SAP 2012 and SAP 2016, which has been maintained through SAP 10.0 and SAP 10.1.

The Consultation Paper for SAP 2016⁵ notes that the emission factor for heat from waste combustion is derived from Defra's Biomass Environmental Assessment Tool (BEAT)⁶. The carbon factor is based on 'Lifecycle greenhouse gas emissions for production of heat by combustion of high biomass refuse derived fuel (RDF) from municipal solid waste using the Fairport process'.

¹ [SAP 10.0 specification \(superseded\)](#)

² [SAP 10.1 specification](#)

³ [SAP 2012 document](#)

⁴ [SAP 10 hosting site](#)

⁵ [Consultation Paper: CONSP:07 CO₂ and Primary Energy Factors for SAP 2016](#)

⁶ [BEAT v2.1 download](#)

The following definition is given to High Biomass RDF: "Within BEAT2 the term high biomass refuse derived fuel is used to refer to any potential fuel resulting from the processing of mixed waste streams to a fraction with a biomass content >90% and a low fossil derived content. This fuel may be available as a floc or as a pellet. In this tool, only the pelletised version is considered."

File Name	Biomass Source	Harvesting	Intermediate Product	Processing Technology	End Product(s)	Reference System	Allocation Procedures	Key Assumptions	Data Gaps
rdf_p_cb_e.xls	Municipal solid waste	Collection	RRBF pellets	Combustion	Electricity	Disposal of municipal solid waste to landfill with energy recovery	Price	Use of Fairport process, and option for Waste Incineration Directive compliance	None but direct emissions based on combustion of old paper

Figure 3-2 Excerpt from BEAT v2 User Guide

Waste heat from power station

Capturing waste heat from power stations requires heat to be produced at a higher temperatures than would otherwise be the case, resulting in a reduction in electricity generation when the power station is producing heat at a high enough temperature to provide district heating.

SAP 2012 assumed that a 1kW reduction in electricity output was experienced for every 7kW of heat generated, thereby setting the emissions factor of waste heat from a power station to one seventh of the emission factor of grid electricity.

The SAP emission factor since the 2016 consultation version has now been based on the assumption that there is a 1kW reduction in electricity output for every 9kW of heat generated, reflecting higher efficiency of the process. Therefore the emission factor for waste heat is set to one ninth of the emission factor for grid electricity, as shown in Figure 3-3.

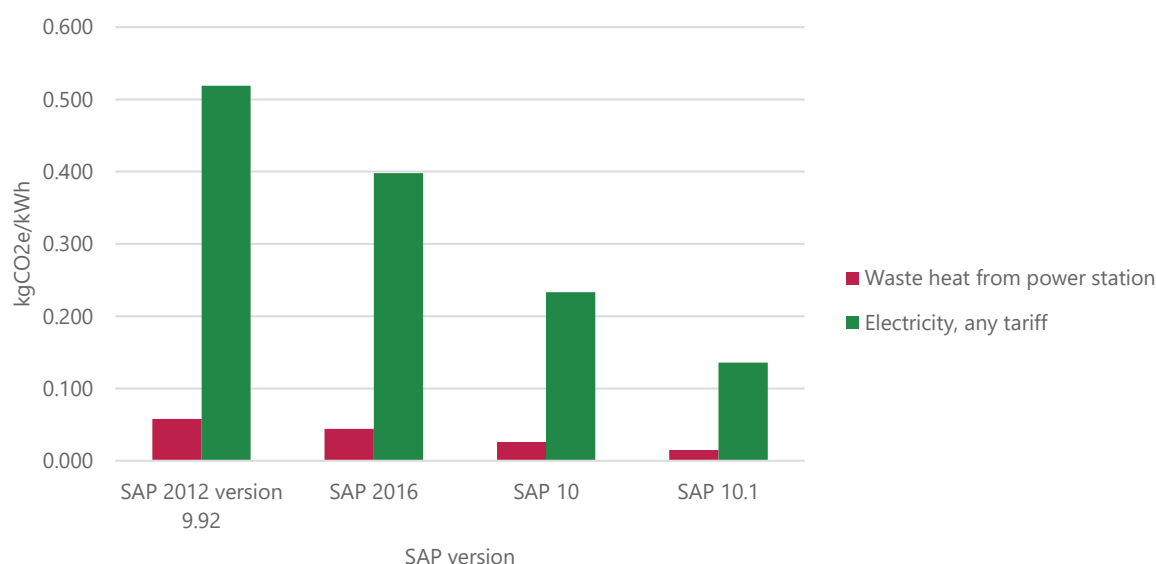


Figure 3-3 Electricity and waste heat from power station carbon factor by SAP version

CHP

It has been noted by BuroHappold that there is an error in the SAP 10.1 Table 12, which states a carbon factor for "Heat from CHP" as 0.011, as shown in Figure 3-4. This would not consider the fuel source for CHP and therefore is considered to be an error in the consultation document.

Table 12: Fuel prices, emission factors and primary energy factors

Fuel	Standing charge, £ (a)	Unit price p/kWh	Emissions kg CO ₂ per kWh ^(b)	Primary energy factor	Fuel code
Heat networks: ^(k)	87 ^(l)				
waste heat from power station		3.35	0.015	1.063	45
geothermal heat source		3.35	0.011	1.051	46
heat from CHP		3.35	0.011	1.051	48
electricity generated by CHP			0.136	1.501	49
electricity for pumping in distribution network			0.136	1.501	50

Figure 3-4 Excerpt from SAP 10.1, showing presumed typo in "heat from CHP" carbon factor

Figure 3-5 shows where this error may have arisen from. In the SAP 2012 document, the carbon factor for CHP is noted "as above" with Note (q) referenced.

Table 12: Fuel prices, emission factors and primary energy factors

Fuel	Standing charge, £ (a)	Unit price p/kWh	Emissions kg CO ₂ per kWh ^(b)	Primary energy factor	Fuel code
Community heating schemes: ^(k)	120 ^(l)				
waste heat from power station		2.97	0.058 ^(p)	1.34	45
geothermal heat source		2.97	0.041	1.24	46
heat from CHP		2.97	as above ^(q)	as above ^(q)	48
electricity generated by CHP			0.519 ⁽ⁱ⁾	3.07 ⁽ⁱ⁾	49
electricity for pumping in distribution network			0.519	3.07	50

Figure 3-5 Excerpt from SAP 2012 showing "Heat from CHP" aligning to Note (q)

Note (q) in SAP 2012 states:

Use factor for community heat from boilers according to fuel used.

Note (q) in SAP 10.1 states:

Use factor for heat network with boilers according to fuel used.

Appendix C of each version of SAP describes in detail the process to be used for calculating emissions associated with CHP. For CHP units, the efficiency to be used is the actual efficiency (if known) of the heat generator.

Section 4.1 describes the methodology that should be followed if calculating emissions from CHP in SAP.

4 Methodology options

4.1 SAP CHP method

As the ERF cannot be considered “Waste heat from power station” in SAP 10.1 (or any of the previous versions) as the electrical efficiency of the plant falls below 35%, SAP defaults to the methodology used to calculate emissions from CHP. Figure 4-1 describes the default methodology that would be followed in SAP, if following the guidance exactly as written.

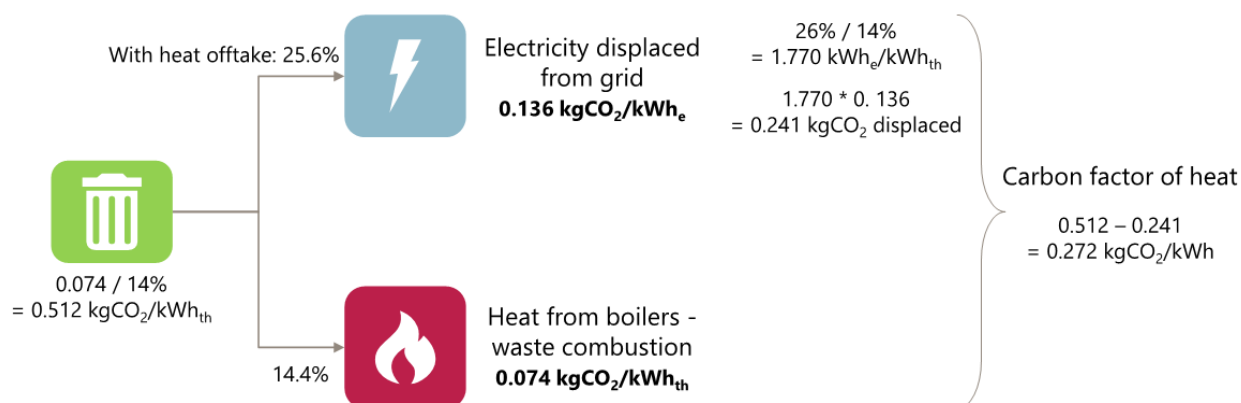


Figure 4-1 CHP calculation methodology, with SAP 10.1 figures

This methodology assumes that the heat from waste combustion is generated at 14.4% efficiency, resulting in 0.512 kgCO₂ of emissions arising from the combustion of fuel for every kWh of heat produced. Using an electrical efficiency with heat offtake of 25.6%, this means that 1.770 kWh of electricity are produced for every kWh of heat whilst the plant is in heat offtake mode. Using a grid carbon factor of 0.136 kgCO₂/kWh, this means that 0.241 kgCO₂ is displaced for every kWh of heat offtake.

In CHP, the emissions associated with the fuel consumption (in this case, 0.512 kgCO₂/kWh) are partly offset by displacement of electricity from the grid (0.241 kgCO₂/kWh), resulting in a carbon factor of heat of 0.272 kgCO₂/kWh.

Table 4-1 describes key considerations of such an approach.

Table 4-1 Methodology appraisal - SAP CHP method

Positive	Negative
Default method in SAP when calculating emissions associated with heat offtake from a power station with electrical efficiency of less than 35%.	Low power efficiency of the ERF is a function of the technology, which means that it is penalised in SAP despite being a key part of the UK's waste strategy going forward.
	As grid carbon factor decreases, the emissions of heat from CHP increase, as the electricity being displaced is increasingly low carbon.
	Emissions factor for fuel is based on “Heat from boilers – waste combustion”. Need to question whether this carbon factor is appropriate as in this scenario, heat is being taken from the steam turbine, not boilers.
	The ERF is expected to still be built as a means to generate electricity, whether there is heat offtake or not. Therefore, penalising the facility for the low thermal efficiency is not seen as an approach that is representative of the proposal to take waste heat from the facility.

4.2 SAP Waste heat from power station

It is BuroHappold's understanding that the Association for Decentralised Energy (ADE) has responded to the SAP consultation with concerns about the threshold of 35% power efficiency before heat offtake from a power station can be considered as the default SAP fuel "Waste heat from Power Station".

This requirement has been part of the methodology since at least SAP 2012, and there are currently no signs that the threshold will change. However, should the next official version of SAP remove the 35% threshold, the ERF may become eligible to use the default value from Table 12 of the document, which currently means a carbon factor of 0.015 kgCO₂/kWh.

As described in Section 3, SAP 2012 assumes a 1kW reduction in electricity output for every 7kW of heat generated, whilst subsequent consultation versions have increased the efficiency to a 1kW reduction in electricity output for every 9kW of heat generated.

Table 4-2 describes key considerations in pursuing this approach to calculation of heat carbon factor.

Table 4-2 Methodology appraisal – Waste heat from power station method

Positive	Negative
As emissions factor of grid electricity decreases, the carbon factor for SAP Waste Heat from Power Station continues to decrease.	The underlying methodology assumes that there is a 1kW reduction in electricity output for every 9kW of heat generated in SAP 10.1. However, the technical data for the Edmonton ERF currently shows that the efficiency is lower, with a drop of 1kW electricity output for every 5kW of heat generated. The actual technical specification are used in the methodology described in Section 4.4
Fuel as "Waste heat from power station" would be the closest description to the process proposed for the ERF.	This methodology would not currently be allowable under the C4 note in SAP 10.2, which states that where power station electrical efficiency is less than 35%, the plant must be considered as CHP. This is, however, being challenged by the ADE.

4.3 Reduced electrical efficiency method

This method, as proposed by the BuroHappold report '160106 CC 033993 Heat Network Carbon Factor 02' as Method 5, assigns only the emissions associated with the reduction in ERF electrical efficiency to the heat offtake.

Figure 4-2 describes the calculation process as followed in the 160616 carbon factor report.

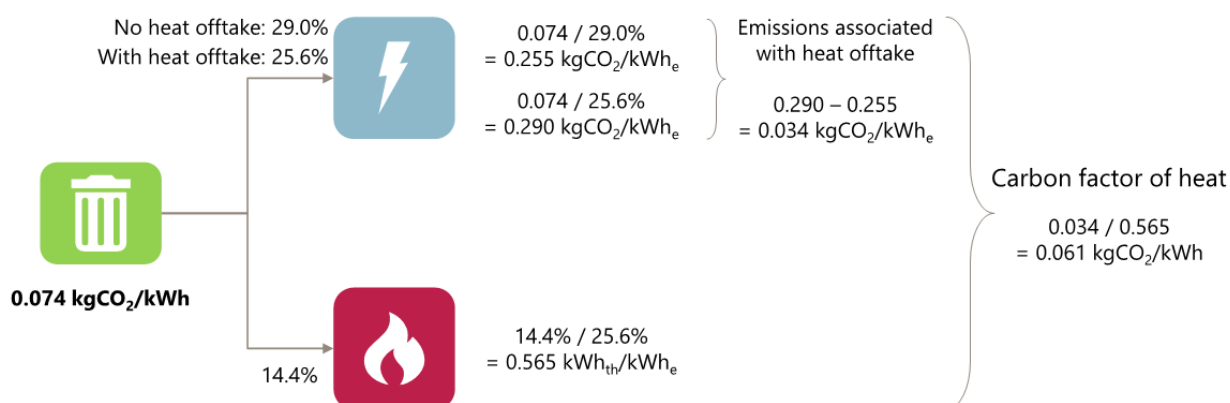


Figure 4-2 Reduced electrical efficiency method

Assuming a carbon factor of $0.074 \text{ kgCO}_2/\text{kWh}$, which aligns with the SAP "Waste heat from boilers – waste combustion" fuel, there are 0.255 kgCO_2 emissions for every kWh of electricity generated when the plant is running with no heat offtake. When the ERF electrical efficiency drops with heat offtake, there are 0.290 kgCO_2 emissions for every kWh electricity generated. Therefore, heat offtake can be considered to result in an additional 0.034 kgCO_2 emissions for every kWh generated by the ERF.

Assuming a thermal efficiency of 14.4% in heat offtake mode, there is 0.565 kW of heat generated for every kW of electricity. Therefore, the carbon factor of heat can be considered to be $0.061 \text{ kgCO}_2/\text{kWh}$.

Table 4-3 sets out key considerations in using such an approach.

Table 4-3 Methodology appraisal – Reduced electrical efficiency method

Positive	Negative
BuroHappold considers this to be a robust approach as it considers the whole ERF system and compares emissions from the plant prior to conversion to CHP to emissions post-conversion.	The input factor for combustion of waste should be reviewed and agreed, requiring agreement from both the BRE and the ERF operator – as the factor may need to be aligned with other reporting sources. It should be noted that the BEIS emissions factor ⁷ for waste ('Domestic refuse (raw)') is $0.16 \text{ kgCO}_2/\text{kWh}_{th}$ which would result in a heat carbon factor of $0.132 \text{ kgCO}_2/\text{kWh}_{th}$ using this methodology.
	Question of whether "heat from boilers – waste combustion" is applicable to this case, where heat is taken from the turbine, not boilers.

⁷ [BEIS Greenhouse gas reporting: conversion factors 2019](#)

4.4 Displaced electricity method

This method, as proposed by the BuroHappold report '160106 CC 033993 Heat Network Carbon Factor 02' as *Method 1*, follows a similar methodology to the SAP Waste heat from power station carbon factor. This aligns with Note (p) to Table 12 of SAP, which states that the emissions factor for "Waste heat from power station" takes account of the reduction in electricity generation that occurs where heat is produced at a high enough temperature to supply a community heat network.

As described in Section 3, SAP 2012 assumes a 1kW reduction in electricity output for every 7kW of heat generated, whilst subsequent consultation versions have increased the efficiency to a 1kW reduction in electricity output for every 9kW of heat generated.

However, the technical specifications received by BuroHappold suggest that this figure should be 1 kW reduction in electricity output for every 5kW of heat generated.

Figure 4-3 describes the calculation process.

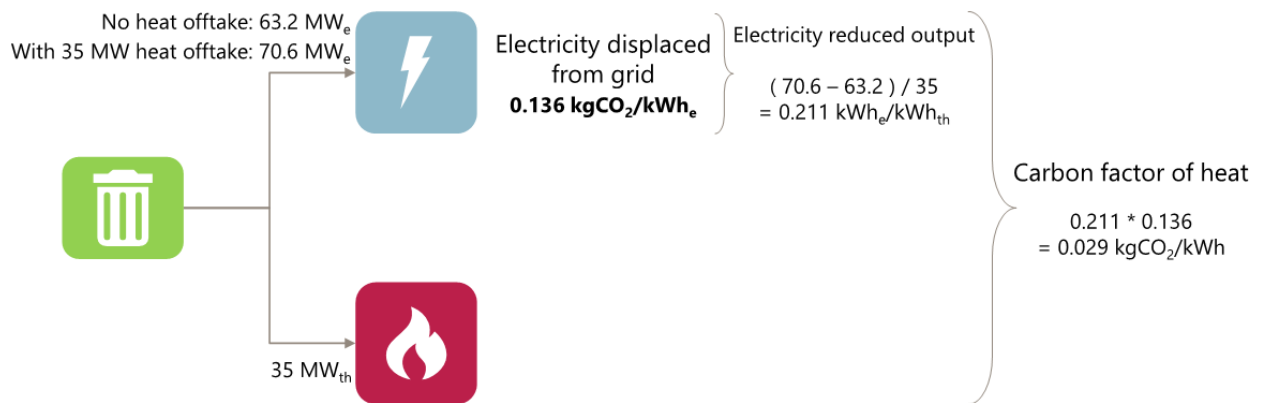


Figure 4-3 Displaced electricity method

Using the technical data for a 35 MW heat offtake, a reduction in output of 0.211 kW of electricity is experienced for every kW of heat. Therefore, it could be considered that the carbon factor of heat is 0.029 kgCO₂/kWh.

Table 4-4 sets out the major considerations in using this approach in calculating the heat carbon factor from the ERF.

Table 4-4 Methodology appraisal – Displaced electricity method

Positive	Negative
Follows the methodology as for SAP "Waste Heat from Power Station", but is bespoke to the ERF plant in terms of heat offtake per unit decreased electricity output.	The methodology for SAP "Waste Heat from Power Station", which closely mirrors this approach, is currently only allowable for cases where electrical efficiency of the plant is greater than 35%.
Does not rely on input of fuel carbon factor, which is uncertain and may need agreement between the BRE and ERF operator.	Does not consider the emissions associated with fuel consumption.
As grid carbon factor continues to decrease, emissions associated with heat offtake from ERF will also decrease.	SAP carbon factors for electricity are the same for consumption and displacement, whereas in reality a "marginal" electricity emissions factor would be used to represent the generation that is generally displaced by additional generation on the grid.

4.5 Summary

This report has considered four distinct methodologies for calculating the carbon factor for heat from the ERF. Results of heat carbon factor for each method are shown in Figure 4-4.

1. Current default SAP rule, which would mandate the CHP method be used as the electrical efficiency of the plant is less than 35%
2. SAP waste heat from power station, if there was no threshold of 35% electrical efficiency
3. Method 5 as per BuroHappold's previous report '160106 CC 033993 Heat Network Carbon Factor 02', denoted 'Reduced electrical efficiency method'
4. Displaced electricity method

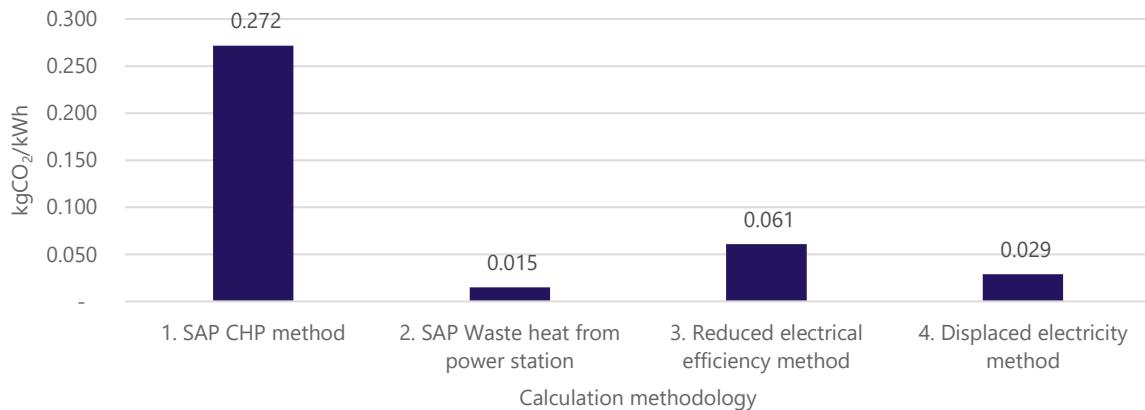


Figure 4-4 Comparison of methodologies, using SAP 10.1 emissions factors

Figure 4-5 shows the emissions factor from each calculation methodology using each of the previous versions of SAP described in this report. For both the SAP "Waste heat from power station" and 'Displaced electricity method', the carbon factor decreases as it is calculated as a fraction of the grid electricity carbon factor, which has been continually decreasing.

The SAP CHP method using waste combustion as fuel resulted in zero emissions in SAP 2012 and SAP 2016, as the carbon factor for electricity was high, meaning that the amount of displaced emissions was large for each unit heat generated.

The carbon factor from the 'Reduced electrical efficiency method' has remained constant since SAP 2016, when the carbon factor for waste combustion increased from 0.047 to 0.074 kgCO₂/kWh.

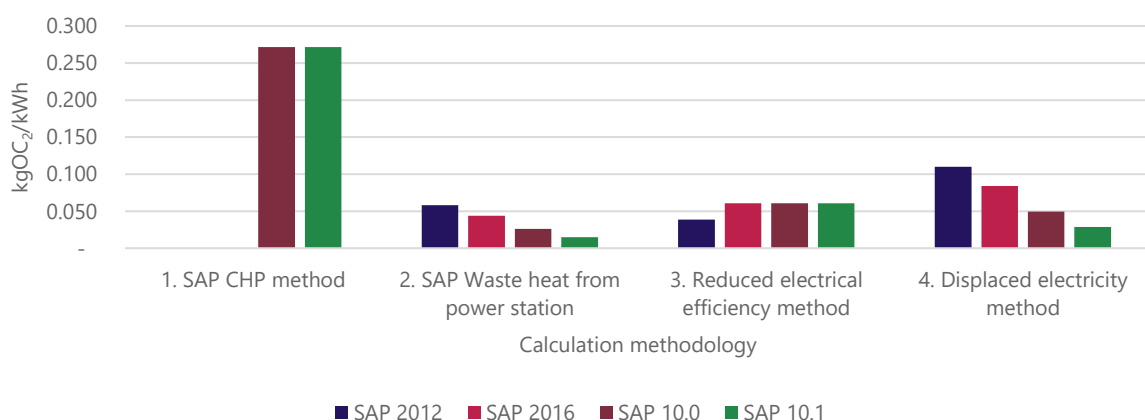


Figure 4-5 Comparison of methodologies, using previous versions of SAP

BuroHappold considers neither the SAP CHP method nor the SAP "Waste heat from power station" to be representative of the compliance carbon factor to be used for the ERF.

We recommend that both the "Reduced electrical efficiency method" and the "Displaced electricity method" are brought to the BRE for consideration in order to confirm the approach to be taken in reporting a carbon factor for the purposes of developers' compliance calculations.

5 Further work

Prior to final reporting, the technical assumptions described in Section 2 need to be verified by Energetik to ensure that they represent the most recent design of the ERF.

It is also recommended that Energetik keep abreast of the ongoing consultation response from ADE on the “Waste heat from power station” threshold in SAP, which could affect the approach used to calculate the carbon factor of the network if reduced or removed.

Should Energetik wish to provide a carbon factor to developers for use in compliance calculations, it is strongly recommended that the methodology used be agreed and verified with the BRE, who administer the technical assumptions behind SAP.

Should the “Reduced electrical efficiency method” be followed, the input waste emission factor needs to be carefully considered. By default, it is recommended that the SAP carbon factor for waste combustion be used – however, if available, plant-specific waste emissions factors may be appropriate. This would need to be agreed between the BRE and ERF operator.

Appendix C3 of each version of SAP describes in detail the process to be used for calculating emissions associated with heat networks. This includes consideration of:

- Distribution loss
- Energy for pumping

The Distribution Loss Factor (DLF) of the network will therefore also need to be provided to developers. This factor represents heat produced divided by heat delivered.

- The default in SAP 10.1 will be 1.5 if the network is designed and commissioned to CIBSE CP1, 2.0 if not. Existing dwellings have other default DLFs depending on building age
- Defaults will be used until the network registers under the Product Characteristics Database (PCDB), in which case the DLF is based on actual measured data

Energy for pumping should also be added to the carbon factor of heat for the network. According to Appendix C3.2 of SAP 10.1, CO₂ emissions associated with electricity used for pumping water through the distribution system are allowed for by adding electrical energy equal to 1% of the energy required for space and water heating. For heat networks recorded in the PCDB, actual pumping energy will be included in the data record (though this may be an estimate).

In reporting carbon factors of heat to developers, Energetik needs to also include:

- Version of SAP under which emissions factors have been calculated
- Any correspondence with the BRE confirming approach to carbon factor calculation
- Clarity that the network is not yet registered under the PCDB and that operational data may result in changes to the carbon factor