

COMBINED HEAT AND
POWER (CHP) GENERATION

Directive 2012/27/EU of the European
Parliament and of the Council

Commission Decision 2008/952/EC

May 2017

The reporting template combined heat and power generation allows for data transmission starting with reference year 2016.

According to DIRECTIVE 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC the deadline for providing data is the 30st of April the second year after the reference year (T+2).

Please send your reporting template to:

- European Commission, Eurostat, Energy Statistics (*for Member States of the European Union, EU Candidate Countries and EFTA Countries*)

Transmission details are provided below:

The completed reporting template should be transmitted to Eurostat via the Single Entry Point (SEP) following the implementing procedures of eDAMIS (electronic Data files Administration and Management Information System), selecting the electronic data collection ENERGY_CHP_A and indicating the submission year.

E-MAIL ADDRESS estat-energy@ec.europa.eu

NOTE

For questions regarding the questionnaire, contact Mr Michael Goll
e-mail: michael.goll@ec.europa.eu Telephone: + 352 4301 32782

Foreword

The purpose of these Reporting Instructions is to help statisticians in EU Member States and in other countries to fill the CHP reporting template correctly. It is written in a way as to make also non-CHP experts understand the basic ideas and concepts behind the data collection. Therefore, certain aspects are described in a simplified manner and are probably from a technical perspective not always 100% correct. This is done to keep these instructions manageable.

Contents

Foreword	2
1. Introduction	4
1.1. Purpose of the data collection	5
1.2. Different CHP technologies	6
1.2.1. Mode of production.....	6
1.2.2. Type of technologies.....	7
1.2.3. 'Normal' setup of a CHP installation (Commission Decision 2008/952/EC)	7
2. Definitions.....	8
Heat	8
Electricity	9
Fuel.....	9
Efficiencies.....	10
Power-to-heat ratio (= C)	11
Capacities	12
Other definitions.....	14
3. Assumptions	15
3.1. Overall efficiencies and full cogeneration mode	15
3.2. What should the operator of a CHP unit know?	15
3.3. Which parameters are measured?	16
4. The CHP reporting template	17
5. The whole data treatment process can be divided into five major steps:	18
Flowchart for the CHP reporting template.....	19
Step 1: Check system boundaries and calculate the overall efficiency of the CHP unit:	20
Step 2: Distinguish E_{CHP} from $E_{\text{non-CHP}}$	21
Step 3: Determination of fuel consumption for non-CHP-electricity	21
Step 4: Calculation of Primary Energy Savings (= PES).....	22
Step 5: Aggregation of fuels by fuel type for the generation of CHP products	24
6. References	26
Annex 1: Explanations regarding dual purpose boilers and reduction heat.....	27
Annex 2: Calculation of reference values for separate production of electricity and heat	28
Annex 3: Practical examples	29
Table 1: different CHP technologies	6
Table 2: default power-to-heat values (C_{default})	12
Table 3: indicative default values for β if it is not known or cannot be calculated.....	14
Table 4: For data reporting according to Directive 2012/27/EU excel tables (reporting templates) are provided.....	17

1. Introduction

Energy included in fuels is converted into electricity in conventional thermal power stations with a relatively low efficiency. The amount of generated electrical energy is typically 30 – 40 % of the energy content of the fuel consumed, and even in the most modern power plants it is 'only' around 60%. The rest of the thermal energy is emitted into the environment.

The principle of combined heat and power production (CHP) is to use the remaining heat from the power generation for example for heating of buildings or in industrial processes as process heat.

By doing so primary energy can be saved by this simultaneous production of heat and electricity. This means that less fuel is used than in separated generation processes (electricity only, heat only). CHP units have the potential to work with high total efficiency and the amount of losses can be reduced even down to 10 – 20 % of the used fuel.

CHP technologies are typically used for district heating networks or to supply industries with process heat, but CHP is also used in agriculture, the residential sector and the tertiary sector.

However, the dissemination of the generated heat is a challenge due to the distribution losses. But also other obstacles for the heat distribution exist.

As a consequence of these losses when transporting heat in pipes or networks, CHP installations should be established as near as possible to the consumers of the heat.

Therefore, big electrical power plants (e.g. nuclear power plants, power plants using lignite) are very often not equipped with a CHP technology due to their distance to the consumers of the heat. However, some exceptions exist.

Power plants can consist of several units, which may or may not be CHP units. It is therefore important to identify the CHP unit and to respect the CHP system boundaries (Commission Decision 2008/952/EC).

Different CHP technologies have been developed. They can be split into two major groups:

- Flexible units, which can adapt to the heat demand (adjustable power-to-heat ratio). These are installations using steam to run a turbine. At certain locations in the turbine (some) steam is extracted from the turbine and used to provide heat. The extracted steam can of course not be used for electricity generation. This leads to a loss of (potential) electricity generation but to the generation of useful heat within the same process. These technologies can be operated in full cogeneration mode (maximum heat generation) but also in full condensing mode (no useful heat generation at all but maximum electricity generation). The power-to-heat ratio varies along these extremes. The way these installations are operated depends on the demand for heat.
- CHP units which cannot adjust to the heat demand. The heat production is constant. If there is no heat demand, they simply release the generated heat to the environment.

District heating plants produce heat as a priority product. Nowadays many of them do this using one of the existing CHP technologies, but pure heat plants are still very common for district heating systems. However, CHP equipped district heating plants are often also

equipped with heat only boilers, which might be used instead of the CHP unit e.g. in summer time when there is little heat demand or in winter when the heat demand cannot be satisfied by the CHP unit alone.

1.1. Purpose of the data collection

The purpose of the CHP statistics is to collect data in a harmonised manner on this specific technology for policy makers allowing them to understand easily how this field develops. The collected data are not collected to build up CHP quality schemes and will also not be used to see which operator can claim subsidies for its CHP products.

The method for collecting CHP statistics must be able to cope with all the variable technical and operational features of CHP production in order to separate the CHP generation from the total production in a consistent and accurate manner.

Three general principles are to be followed:

- a) All useful heat generated in CHP units regardless whether it is used in industry, district heating etc. and whether it is sold or not **is to be reported**. This is different from the reporting of the Annual Electricity and Heat Questionnaire, where only heat sold has to be reported.
- b) As many parameters as possible should be measured. If this is not possible, some parameters have to be calculated following the descriptions below.
- c) Keep the reporting template as simple as possible. The practical data collection on the CHP units involves sending reporting templates to power plants requesting capacity and production data. The information asked for has to be clear and readily available at the plants, since the plant operators may not have enough resources to find out all the data requested in complicated forms.

For most of the plants it is not a difficult task to fill in the reporting template, but **for units producing both CHP-electricity and non-CHP-electricity** the reporting templates to be completed are not necessarily straightforward. The accurate calculation of the real CHP-electricity generation in these units would require day-to-day data on generation and on the thermodynamics of the system, for example temperature and mass flow measurements. The process computers are not necessarily designed for producing and storing data for statistical purposes, and often the distinction between the CHP production and non-CHP production has to be done by some other method.

The probability of not receiving data or obtaining data of poor quality increases if the method is too complicated. Therefore, the method has to be simple enough and unequivocal to avoid possible misinterpretations. The calculations on the real CHP production must be possible by knowing the annual production, electricity and heat, and fuel input.

1.2. Different CHP technologies

The following list gives an overview of different CHP technologies as laid down in Directive 2012/27/EU:

Table 1: different CHP technologies

Numbering in the legislation	Numbering in the reporting template rows	Name of the technology
a)*	1 and 8	Combined cycle gas turbine with heat recovery including a steam condensing extraction turbine– flexible power-to-heat ratio
a)**	1 and 8	Combined cycle gas turbine with heat recovery without a condensing extraction turbine
b)	4 and 11	Steam back pressure turbine
c)	5 and 12	Steam condensing extraction turbine - flexible power-to-heat ratio
d)	2 and 9	Gas turbine with heat recovery
e)	3 and 10	Internal combustion engine
f)	6 and 13	Microturbines
g)	6 and 13	Stirling engines
h)	6 and 13	Fuel cells
i)	6 and 13	Steam engines
j)	6 and 13	Organic Rankine cycles
k)	6 and 13	Any other type of technology or combination thereof falling under the definition laid down in Article 2(30)

In the reporting template technologies listed under f) to k) are to be aggregated under 'f) others'.

1.2.1. Mode of production

Full cogeneration mode (full CHP mode): a CHP unit operating with maximum technically possible heat recovery from the CHP unit itself is said to be operating in full cogeneration mode. This means that all electricity generated during this period is considered to be CHP-electricity. If a CHP unit is not operated in full cogeneration mode, in addition to CHP-electricity and CHP heat also non-CHP-electricity is generated.

Full condensing mode: a CHP unit operating with no useful heat production at all is only generating non-CHP-electricity. It is said to be operating in full condensing mode. This is only possible for certain CHP technologies ((a)* Combined cycle gas turbine with heat recovery – and (c) Steam condensing extraction turbine), in which for the generation of useful heat steam is extracted from the turbine. If there is no demand for useful heat, no steam is extracted but all steam is condensed to generate electricity. In a way this is the opposite situation of the full cogeneration mode.

1.2.2. Type of technologies

Technologies mentioned in table 1 under a)* and c) work on the basis of steam condensation. By extracting more or less steam from the turbine they can adjust their heat and electricity generation. They can be operated in full CHP mode (maximum useful heat production) or in the other extreme, in full condensing mode which means maximum electricity generation and no useful heat production.

Therefore, they can adapt to the useful heat demand. Full CHP mode means a maximum production of CHP products (CHP-electricity and useful heat), while the condensing mode means only non-CHP-electricity generation.

These technologies represent a compromise:

In full CHP mode they produce a maximum of useful heat (the limitation is often the capacity of the heat exchanger) and less electricity (but CHP-electricity) than they could generate in full condensing mode. The electricity generated in full condensing mode is only non-CHP-electricity. In other words in full CHP mode the electricity generation is sacrificed for the sake of useful heat production.

Technologies mentioned in table 1 under a)**, b), d), e), f), g), h), i), j) and k) cannot adjust their heat production when generating electricity. If heat is needed (= useful), it is collected and used e.g. for heating of houses. If no heat is needed, the heat accumulated during electricity generation is just released to the environment.

1.2.3. 'Normal' setup of a CHP installation (Commission Decision 2008/952/EC)

Elements needed to run a steam driven CHP installation (Table 1, a) to d)) are, for example:

- a boiler to produce steam
- a turbine using the steam to produce kinetic energy
- a generator to convert the kinetic energy into electrical energy
- a heat exchanger to provide the useful heat to a district heating network
- in industrial use exhaust gases can be used directly

Often there are additional boilers installed as back-up or as supporting elements (e.g. in winter when there is a high demand for heat). These additional boilers don't belong to the CHP units.

In special cases the boiler to produce the steam for the CHP unit could be used for dual purpose and produce steam for the CHP unit and e.g. for industrial customers (dual purpose boiler). For more details please see Annex I.

2. Definitions

Heat

- a) Useful heat (H_{CHP})(= CHP heat): this is the central product of any CHP unit and it is defined as 'heat from a CHP scheme delivered to satisfy an economically justifiable demand for heat or cooling. Heat that is used for process or space heating and/or delivered for subsequent cooling purposes. Heat delivered to district heating/cooling networks; exhaust gases from a cogeneration process that are used for direct heating and drying purposes'.

The demand is very important in this case because the electricity generated at the same time as the heat can only be qualified as being CHP-electricity if the heat is used in a meaningful way. If, because there is no demand for the heat, the heat is just released to the environment, this heat is non-CHP heat and consequently the electricity generated at the same time cannot be labelled as being CHP-electricity, because it is non-CHP-electricity.

Useful heat is measured normally at the heat exchanger to the network / distribution infrastructure. This quantity is net.

Examples for heat which is not useful: heat rejected to the environment, lost from chimneys or exhausts; heat rejected in equipment (condensers, heat dump radiators). More in Commission Decision 2008/952/EC, annex, Part I, point 5.7.

H_{CHP} is to be reported in column F of tables EU-1B and EU1C

- b) Supplementary heat (H_{suppl}) is heat which is produced outside of the cogeneration system boundaries or the CHP unit (e.g. heat produced in a conventional or in an auxiliary boiler). This supplementary heat is either measured or calculated by measuring the fuel used multiplied with the reference (heat) efficiencies for the fuel used (see Commission Delegated Regulation (EU) 2015/2402).

Heat production in auxiliary boilers might happen at times when there is only little heat demand from district heating plants i.e. in summer time, when there is only demand for hot tap water but not for space heating purposes. Also in winter when the heat demand cannot be satisfied by the CHP unit alone heat is produced in auxiliary (heat only) boilers. Other reasons for alternative heat production in heat only boilers might be: during maintenance of the CHP installation, when the CHP installation breaks down (back-up) or when electricity generation is not profitable.

- c) Total heat (H_{total}) is the heat produced by the boiler of the installation of which the CHP unit might be only a part.

$$H_{total} = H_{CHP} + H_{suppl} \text{ [equation 1]}$$

- d) Reduction heat (H_{reduct}) is heat produced in dual purpose boilers also supplying CHP units with heat. For more details please see Annex I.

Electricity

- e) Total electricity generated (E_{total}) is the total gross amount of electricity generated in a CHP unit regardless whether it is CHP-electricity or not.
- f) CHP-electricity (E_{CHP}): electrical energy generated in a process related to the production of useful heat.
- g) Non-CHP-electricity ($E_{non-CHP}$): electrical energy generated by a CHP unit at times when the CHP unit doesn't generate useful heat or part of the heat is not useful (rejected to the environment because there is no demand etc.).

$$E_{total} = E_{CHP} + E_{non-CHP} \text{ [equation 2]}$$

E_{total} is to be reported in column E of tables EU-1B and EU-1C

E_{CHP} is to be reported in column D of tables EU-1B and EU-1C

Fuel

- h) The total fuel (F_{total}) used is subdivided into fuel used in the CHP unit ($F_{CHPunit}$) and fuel used for supplementary (e.g. auxiliary boiler) heating (F_{suppl}). The latter is fuel used outside the boundary of the CHP unit.

$$F_{CHPunit} = F_{total} - F_{suppl} \text{ [equation 3]}$$

- i) $F_{CHPunit}$ can be further split into fuel used for CHP products (F_{CHP}) and fuel used for the generation of non-CHP-electricity in a CHP unit ($F_{non-CHP}$). For dual purpose boilers please see Annex I.

$$F_{CHPunit} = F_{CHP} + F_{non-CHP} \text{ [equation 4]}$$

$F_{CHPunit}$ is to be reported in column G of tables EU-1B and EU-1C

F_{CHP} is to be reported in column H of tables EU-1B and EU-1C

- j) To distinguish fuel used for CHP products from fuel used for non-CHP products F_{CHP} and $F_{non-CHP}$ need to be calculated according to the CHP technology used:

- CHP units without steam condensation (table 1: technologies a)**, b), d), e), f) etc.)

$$F_{CHP} = F_{CHPunit} - \frac{E_{non-CHP}}{\eta_{total-E}} \text{ [equation 5]}$$

where: $\eta_{total-E}$ is the efficiency of electricity generation of the CHP unit.

- CHP units with steam condensation (table 1: technologies a)* and c))

$$F_{CHP} = F_{CHPunit} - \frac{E_{non-CHP}}{\eta_{non-CHP-E}} \text{ [equation 6]}$$

where: $\eta_{non-CHP-E}$ is the efficiency of electricity generation of the CHP unit in full condensation mode.

Efficiencies

The relation of products generated and the fuel invested is called efficiency (η). Efficiencies can be calculated for different processes

- k) Overall efficiency of a CHP unit

$$\eta_{overall} = \frac{E_{total} + H_{CHP}}{F_{CHPunit}} \quad [\text{equation 7}]$$

- l) Efficiency of useful heat production defined as annual useful heat output divided by the fuel input used to produce the sum of useful heat output and CHP-electricity

$$CHP \ H_{\eta} = \frac{H_{CHP}}{F_{CHP}} \quad [\text{equation 8}] \quad \text{or} \quad \eta_{CHP-H} = \frac{H_{CHP}}{F_{CHP}}$$

- m) Efficiency of total electricity generation of the CHP unit for CHP units without steam condensation (table 1: technologies a)**, b), d), e), f) etc.)

$$\eta_{total-E} = \frac{E_{total}}{F_{CHPunit}} \quad [\text{equation 9}]$$

- n) Efficiency of CHP-electricity generation defined as annual CHP-electricity divided by the fuel input used to produce the sum of useful heat output and CHP-electricity

$$CHP \ E_{\eta} = \frac{E_{CHP}}{F_{CHP}} \quad [\text{equation 10}] \quad \text{or} \quad \eta_{CHP-E} = \frac{E_{CHP}}{F_{CHP}}$$

- o) Efficiency of total electricity generation of the CHP unit for CHP units with steam condensation (table 1: technologies a)* and c)) (to simulate the efficiency of the unit running in full condensing mode) see also example c) in Annex 3 (page 31).

$$\eta_{non-CHP-E} = \frac{E_{total} + \beta * H_{CHP}}{F_{CHPunit}} \quad [\text{equation 11}]$$

where:

E_{total} is the measured electricity generated and is composed of $E_{non-CHP}$ and E_{CHP}

$\beta * H_{CHP}$ represents the additional electricity which could have been generated if no heat was extracted

β is the loss coefficient (see also point y) on page 14)

In case of CHP units with technologies a)* or c) but operating without heat extraction (i.e. in full condensing mode) β is equal to 0 so that

$$\eta_{non-CHP-E} = \eta_{total-E}$$

Power-to-heat ratio (= C)

The Power-to-heat ratio (= C) is a characteristic of each CHP unit. It represents the ratio between electricity from cogeneration and useful heat when operating in full cogeneration mode.

- p) if the unit operates in full cogeneration mode during certain periods, the plant operator can measure actual heat and electrical energy output from the cogeneration unit. These data will allow him to determine the actual 'power-to-heat-ratio'.

$$C_{actual} = \frac{E_{CHP}}{H_{CHP}} \quad [\text{equation 12}]$$

In Commission Decision, Annex, Point 7.2 it is stipulated: For the CHP part of a CHP unit, the plant operator shall check the load pattern (useful heat demand) and evaluate whether the unit operates in full cogeneration mode during certain periods. If this is the case, the plant operator shall measure actual heat and electrical energy output from the cogeneration unit for this situation and during these periods. These data will allow him to determine the actual 'power to heat ratio' (C_{actual}).

- q) alternatively C can also be calculated

1. For CHP units without steam condensation C is calculated using the following expression:

$$C = \frac{\eta_{total-E}}{\eta_0 - \eta_{total-E}} \quad [\text{equation 13}]$$

where:

$\eta_{total-E}$ is the efficiency of total electricity (E_{total}) generation, dividing electrical power generated by the fuel consumed by the CHP unit ($F_{CHPunit}$).

η_0 is the overall efficiency threshold established by Directive 2012/27/EC:
- 75% for technologies as listed in table 1 under b), d), e), f), g), h), i), j) and k)
- 80 % for technologies as listed in table 1 under a) and c).

2. For CHP units with steam condensation C is calculated using the following expression:

$$C = \frac{\eta_{non-CHP-E} - \beta^* \eta_0}{\eta_0 - \eta_{non-CHP-E}} \quad [\text{equation 14}]$$

Where:

$\eta_{non-CHP-E}$ efficiency of total electricity generation of the CHP unit for CHP units with steam condensation (table 1: technologies a)* and c))

η_0 is the overall efficiency threshold established by Directive 2012/27/EC:
80 % for technologies as listed in table 1 under a) and c).

β loss coefficient (see also point y) on page 14)

- r) The design power-to-heat ratio ($= C_{\text{design}}$) is the power-to-heat ratio, which was used for the planning of the CHP unit. It can be used in the beginning of the operational phase replacing C_{actual} until this is known.
- s) If neither C_{actual} nor C_{design} values are known C_{default} values have to be used. But this should be the absolute exception. C_{default} values are available from table 2 (Annex I of Directive 2012/27/EU).

Table 2: default power-to-heat values (C_{default})

Numbering in the legislation	Name of the technology	Default power to heat ratio, C
a)	Combined cycle gas turbine with heat recovery	0,95
b)	Steam back pressure turbine	0,45
c)	Steam condensing extraction turbine	0,45
d)	Gas turbine with heat recovery	0,55
e)	Internal combustion engine	0,75

Capacities

- t) The useful heat capacity ($CAP_{\text{CHP}_{\text{heat}}}$) in a well-designed CHP unit is characterised by the capacity of the heat exchanger which is located at the handover from the CHP unit to the district heating network or the pipe to the industrial process.

In case direct heat is used from exhausts, a heat exchanger is not used or necessary. In these cases $CAP_{\text{CHP}_{\text{heat}}}$ is characterised by the capacity recoverable from exhausts. The heat capacity is always the net heat capacity.

$CAP_{\text{CHP}_{\text{heat}}}$ is to be reported in column C of tables EU-1B and EU-1C

- u) The maximum total electrical capacity (CAP_{elec}) is limited by the capacity of the generator (= plate capacity), which is the gross electrical capacity. In the reporting template also the maximum CHP electrical capacity ($CAP_{\text{CHP}_{\text{elec}}}$) is to be reported.

For tables EU-1B1 and EU-1C1 the following applies:

1. For CHP units without steam condensation operated in full CHP mode the following applies:

$$CAP_{\text{elec}} = CAP_{\text{CHP}_{\text{elec}}}$$

2. For CHP units with steam condensation operated in full CHP mode the following applies:

$$CAP_{\text{elec}} \geq CAP_{\text{CHP}_{\text{elec}}}$$

$CAP_{\text{CHP}_{\text{elec}}}$ fully depends on the heat extracted from the turbine (heat produced) and can be determined when operating the CHP unit in full CHP mode.

$CAPCHP_{elec}$ is calculated as follows:

$$CAPCHP_{elec} = CAP_{elec} - \beta_{design} \times CAPCHP_{heat} \text{ [equation 15]}$$

Alternatively, for CHP units with steam condensation $CAPCHP_{elec}$ is to be determined under test conditions (full CHP mode) by the operator of the CHP unit.

$CAPCHP_{elec}$ is to be reported in column A of tables EU-1B and EU-1C

CAP_{elec} is to be reported in column B of tables EU-1B and EU-1C

For tables EU-1B2 and EU-1C2 the following applies:

1. For all CHP units **not** operated in full CHP mode the following applies:

The CHP electrical capacity ($CAPCHP_{elec}$) might be calculated using the formula:

$$CAPCHP_{elec} = CAPCHP_{heat} * C \text{ [equation 16]}$$

In the extreme case (full non-CHP mode):

$$CAP_{elec} = CAP_{non-CHPelec}$$

$CAPCHP_{elec}$ is to be reported in column A of tables EU-1B and EU-1C

- v) For CHP units, without generation of CHP products (CHP electricity and useful heat) in the reference year, $CAPCHP_{elec}$, CAP_{elec} and $CAPCHP_{heat}$ are to be reported in Table EU-1D (underneath table EU-1C2) in columns A, B and C respectively.

These CHP units could also be called 'dormant CHP units'.

Other definitions

- w) CHP products are sometimes also called cogeneration products. These are those products generated in cogeneration mode of the CHP units: useful heat (= CHP heat) and CHP-electricity.
- x) In contrast to this are the non-CHP products, which are also generated in a CHP unit when it is not operated in cogeneration mode. The non-CHP product generated is mainly non-CHP-electricity.
- y) Loss coefficient β . This value is only applicable for CHP units with steam condensation in cogeneration mode. It reflects the effect of steam extraction on the electricity generation. It is expressed as the loss of electricity generation per unit of extracted heat.
- z) In case β is not known, and if it is not possible to calculate it, the following indicative default values can be used:

Table 3: indicative default values for β if it is not known or cannot be calculated

Size of the steam turbine	2-5 MWe	5-10 MWe	10-25 MWe	25-50 MWe	> 50 MWe
Extraction pressure (bar(a))	β	β	β	β	β
21,7	0,200	0,213	0,227	0,244	0,256
14,8	0,185	0,200	0,213	0,227	0,238
11,4	0,175	0,189	0,204	0,217	0,227
7,9	0,164	0,175	0,189	0,200	0,213
3,8	0,139	0,149	0,159	0,169	0,179
2,4	0,123	0,133	0,143	0,152	0,159

3. Assumptions

3.1. Overall efficiencies and full cogeneration mode

After some modifications of the proposed Protermo statistical methodology the following was agreed:

- a) If a CHP unit using a technology as specified in table 1 under b), d), e), (f), (g), (h), (i), (j) or (k) reaches a minimum overall efficiency of equal or more than 75% it can be assumed that it was operated in full cogeneration mode over the observed / measured time period. Therefore, it can be assumed that all electricity measured at the generator clamps is in fact CHP-electricity.
- b) If a CHP unit using a technology as specified in table 1 under a) or c) reaches a minimum overall efficiency of equal or more than 80% it can be assumed that it was operated in full cogeneration mode over the time period. Therefore, it can be assumed that all electricity measured at the generator clamps is in fact CHP-electricity.
- c) Should the overall efficiency of the CHP unit be below these minimum limits, it can be assumed that the CHP unit was not operated in full cogeneration mode during the observation period. Therefore, it is assumed that apart from CHP-electricity also non-CHP-electricity was generated.

3.2. What should the operator of a CHP unit know?

- d) Commission Decision 2008/952/EC illustrates in its figures which installations belong to the CHP unit and which don't (auxiliary boilers, etc.)?
- e) What is the electrical capacity of the CHP unit (CAP_{elec})?
- f) What is the capacity (thermal) of the heat exchanger ($CAP_{CHP_{heat}}$)?
- g) How much fuel was used by the installation of which the CHP unit is an integral part in the last year ($F_{chp\ unit}$)?
- h) How much electricity was generated by the CHP unit last year (E_{total})?
- i) How much useful heat was generated by the CHP unit last year (H_{CHP})?
- j) What is the actual power-to-heat value (C_{actual}) of the CHP unit?
- k) How much electricity was injected to the grid (needed to calculate PES)?
- l) What was the supply voltage (= connection voltage level) (needed to calculate PES)?
- m) What is the age of the CHP installation (needed to calculate PES)?
- n) If the CHP installation uses waste steam, the fuel used to generate the steam needs to be known (needed to calculate PES).
- o) Way of heat use (Hot water, steam or direct use of exhaust gases).

3.3. Which parameters are measured?

- p) The fuel used by the CHP unit (F_{CHPunit}) is normally metered at the entry of the burner / boiler of the CHP unit. If only the total fuel consumed by the plant (F_{total}) of which the CHP unit is an integral part is known, this can be calculated if the efficiency of the auxiliary boiler (η_{boiler}) and the heat produced (H_{suppl}) is known.
- q) Total gross electricity generated (measured at the clamps of the generator).
- r) Total useful heat (H_{CHP}) produced (measured at the heat exchanger to the network / pipe).

4. The CHP reporting template

Table 4: For data reporting according to Directive 2012/27/EU excel tables (reporting templates) are provided.

Table	Reasoning / purpose
EU-1A	Giving national total figures against which the CHP data can be compared. The aim is to express i.e. the share of electricity produced from CHP in relation to the total gross electricity production in a country. These comparisons are very important for policy makers. These figures can be taken from your annual questionnaires. No need for Member States to work on this table
EU-1B	Reporting for high efficiency CHP units ($\geq 10\%$ PES)*
EU-1B1	For CHP units with an efficiency ≥ 75 resp. 80 %
EU-1B2	For CHP units with an efficiency < 75 resp. 80 %
EU-1C	Reporting for low efficiency CHP units ($< 10\%$ PES)**
EU-1C1	For CHP units with an efficiency ≥ 75 resp. 80 %
EU-1C2	For CHP units with an efficiency < 75 resp. 80 %
EU-1D	For CHP units without generation of CHP products in the reference year
EU-2	Energy input to CHP units by fuel
Remarks	e.g. to inform about negative PES values

* for installations with an electrical capacity of less than 1 MW_{elec} PES has to be bigger than 0%

** for installations with an electrical capacity of less than 1 MW_{elec} PES is 0% or less

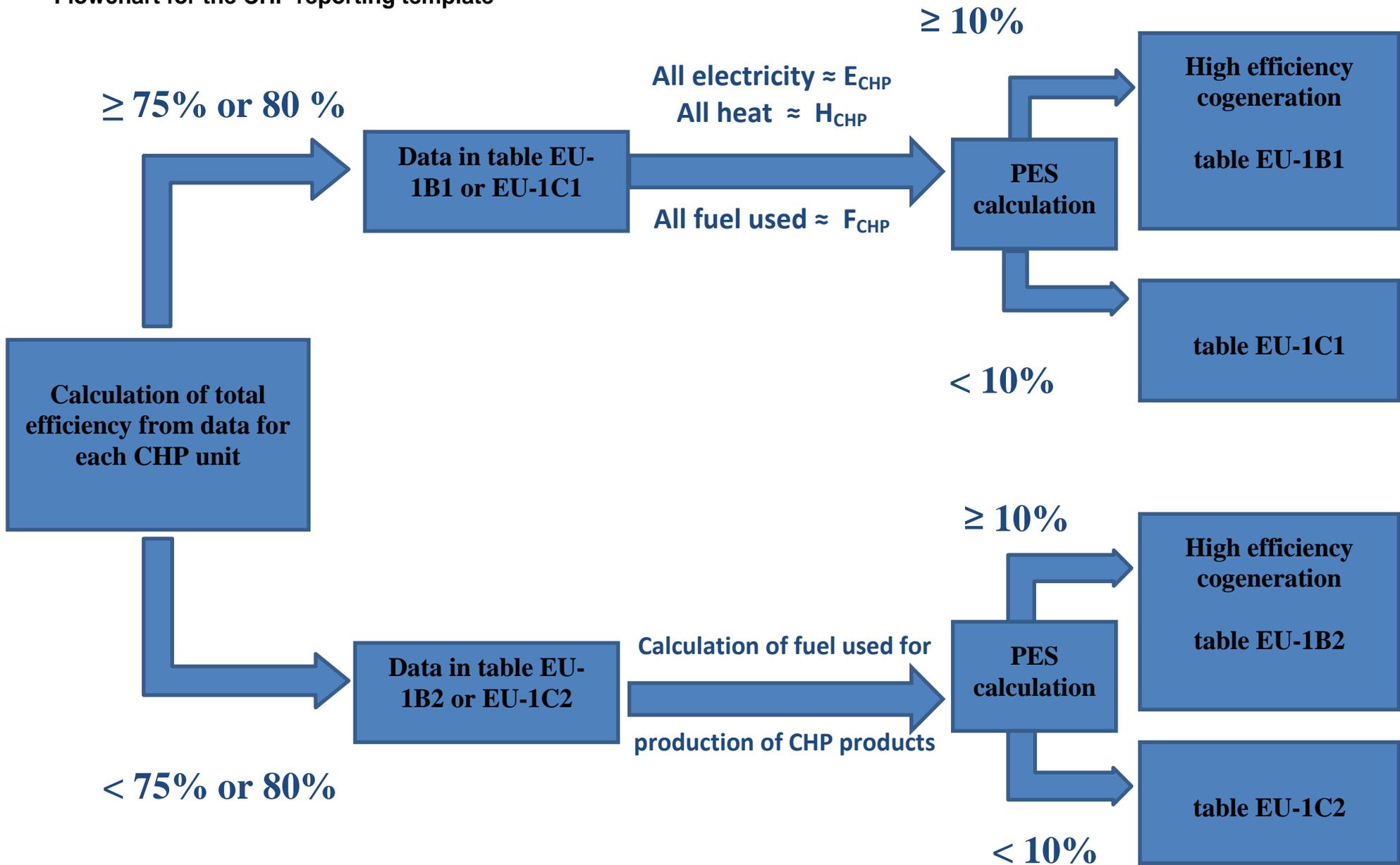
As mentioned, table EU-1A will for the time being be filled in by the Commission with available data. If Member States have other data at hand, which could fill some of the gaps (fields with the remark: 'not easily available') they are invited to make them available and fill them in.

5. The whole data treatment process can be divided into five major steps:

In the following chapter information is given to fill in table EU-1B, EU-1C and EU-2.

- Step 1 Checking carefully the system boundaries of the CHP unit and then calculating the overall efficiency. If a given CHP unit reaches the minimum threshold of 75 or 80% efficiency, the data of the CHP unit have to be reported using either table EU-1B1 or EU-1C1, i.e. not much more needs to be done.
- Step 2 If data on useful heat produced by the CHP unit are provided, CHP-electricity produced can be calculated if needed (for tables EU-1B2 and EU-1C2).
- Step 3 For CHP units reported in tables EU-1B2 and EU-1C2 the fuel used for the generation of CHP products has to be distinguished from the total fuel input (for CHP and non-CHP products).
- Step 4 The percentage of 'Primary Energy Savings' has to be calculated. Based on this it is decided whether a CHP unit belongs to table EU-1B or EU-1C. Please report the capacities (electrical and thermal) of CHP units in which no CHP products have been produced during the reference year in table EU-1D.
- Step 5 The fuel used as input for the generation of CHP products should be aggregated by specific fuel/by fuel group used in table EU-2.

Flowchart for the CHP reporting template



Step 1: Check system boundaries and calculate the overall efficiency of the CHP unit:

1. The first step is to make sure that one looks only at the CHP unit, e.g. additional or auxiliary boilers (heat only) are excluded in terms of their heat production and their fuel consumption. Respecting the cogeneration system boundaries is essential.

$$H_{CHP} = H_{total} - H_{suppl} \text{ [from equation 1]}$$

$$F_{CHPunit} = F_{total} - F_{suppl} \text{ [equation 3]}$$

2. Overall efficiency of the CHP unit is calculated by dividing the energy output (all electricity and useful heat generated) by the fuel used in the CHP unit

$$\eta_{overall} = \frac{E_{total} + H_{CHP}}{F_{CHPunit}} \text{ [equation 7]}$$

E_{total} is the gross annual electricity output of the CHP unit, H_{CHP} the annual useful heat production of the unit and $F_{CHPunit}$ is the fuel consumed for producing the electricity and useful heat.

3. If the result of this calculation is

- a) that the overall efficiency of the CHP unit is equal or bigger than 75% (80% for....) it can be assumed that all electricity generated is CHP-electricity. In this case no further calculations are needed for the moment. The measurements of F_{CHP} , H_{CHP} and E_{total} are either filled in in Table EU-1B1 or EU-1C1 depending on the outcome of the PES calculations. In this case please proceed with step 4 (calculation of PES).

- b) that the above thresholds are not reached, non-CHP-electricity generation took place and needs to be calculated. To do so the CHP unit needs to be divided into two virtual parts:

- the part generating CHP electricity (E_{CHP})
- and the part generating non-CHP electricity ($E_{non-CHP}$)

Step 2: Distinguish E_{CHP} from $E_{non-CHP}$

This is only necessary for CHP units to be reported either in tables EU-1B2 or EU-1C2.

The power-to-heat ratio of the CHP unit (C_{actual}) in question is to be used to distinguish CHP-electricity (E_{CHP}) from total electricity (E_{total}).

$$E_{CHP} = H_{CHP} \times C_{actual} \quad [\text{from equation 12}]$$

$$E_{total} = E_{CHP} + E_{non-CHP} \quad \rightarrow \quad E_{non-CHP} = E_{total} - E_{CHP}$$

If C_{actual} is not known, the following sequence has to be followed:

1. it can be calculated (see point 2.q)
2. the design power-to-heat ratio ($= C_{design}$) is to be used (see point 2.r)
3. the default power to heat ratios $C_{default}$ (see table 2).

Step 3: Determination of fuel consumption for non-CHP-electricity

This is only necessary for CHP units to be reported either in Tables EU-1B2 or EU-1C2.

The fuel used for the generation of CHP products (F_{CHP}) has to be distinguished from the total fuel input for the generation of CHP and non-CHP products ($F_{CHPunit}$).

$$\eta_{total-E} = \frac{E_{CHP} + E_{non-CHP}}{F_{CHPunit}} \quad [\text{from equation 9}]$$

The calculated non-CHP-electricity is divided by the efficiency for electricity generation (unit specific), depending on the technology used (with or without steam condensation), the formulas to be used vary (see point 2.j):

1. For CHP units without steam condensation

$$F_{CHP} = F_{CHPunit} - \frac{E_{non-CHP}}{\eta_{total-E}} \quad \rightarrow \quad F_{non-CHP} = \frac{E_{non-CHP}}{\eta_{total-E}} \quad [\text{equation 5}]$$

2. For CHP units with steam condensation

$$F_{CHP} = F_{CHPunit} - \frac{E_{non-CHP}}{\eta_{non-CHP-E}} \quad [\text{equation 6}] \quad \rightarrow \quad F_{non-CHP} = \frac{E_{non-CHP}}{\eta_{E-non-CHP}}$$

Step 4: Calculation of Primary Energy Savings (= PES)

The amount of primary energy savings in % provided by cogeneration production shall be calculated on the basis of the following formula:

$$PES = \left[1 - \frac{1}{\frac{CHP H\eta}{Ref H\eta} + \frac{CHP E\eta}{Ref E\eta}} \right] \times 100\% \text{ [equation 17]}$$

where:

PES is primary energy savings.

CHP H η is the heat efficiency of the cogeneration (= useful heat) production defined as annual useful heat output divided by the fuel input used to produce the sum of useful heat output and CHP-electricity.

Ref H η is the efficiency reference value for separate heat production.

CHP E η is the electrical efficiency of the cogeneration production defined as annual CHP-electricity divided by the fuel input used to produce the sum of useful heat output and CHP-electricity. Where a cogeneration unit generates mechanical energy, the annual CHP-electricity may be increased by an additional element representing the amount of electricity which is equivalent to that of mechanical energy.

Ref E η is the efficiency reference value for separate electricity production.

The reference values mentioned above (Ref H η and Ref E η) are shown in Commission Delegated Regulation (EU) 2015/2402 Annex I for separate production of electricity and in Annex II separate production of heat. If needed values from Annex I have to be corrected to the applicable climatic situation using values from Annex III and for avoided grid losses (Annex IV).

Alternatively the calculation as specified in Directive 2012/27/EU, Annex II, point c) can be used.

In case a CHP unit is operated using more than one fuel the reference values for electricity (Ref E η) and for heat (Ref H η) have to be calculated first. Two examples for such a calculation are shown in Annex 2 of this document.

To express the PES in energy units (TJ), the following equation can be used:

$$PES(TJ) = \frac{F_{CHP}}{1 - PES(\%)} - F_{CHP} \text{ [equation 18]}$$

Where:

$\frac{F_{CHP}}{1 - PES(\%)}$ expresses the amount of fuel, which would be needed for separate production

PES (TJ) is to be reported in column I of tables EU-1B2 and EU1C2

Negative PES values

Under certain circumstances (e.g. for very old CHP units etc.) it might happen that the calculated PES is negative. This is also because over time the harmonised efficiency reference values for separate production of heat and for electricity are raised continuously. Please add these negative values to the relevant table in one sum with the positive values.

We decided for this procedure after intensive discussions where we tried to weigh advantages and disadvantages (e.g. confidentiality) carefully. As long as we don't know enough about the frequency of this phenomenon please simply add up PES values. To learn more about the occurrence of negative PES values Member States are invited to inform Eurostat in the 'Remarks' page of the reporting template if they found negative PES values at all (yes/no) and in how many CHP units (number).

On the basis of collected data this procedure of reporting negative PES values will be reviewed after two reporting cycles.

Step 5: Aggregation of fuels by fuel type for the generation of CHP products

In table EU-2 the fuel used for the generation of CHP products (useful heat and CHP-electricity) is to be aggregated for 22 different fuel groups.

Operational CHP units, fuel used for CHP production

1) Hard coal:

consists of coking coal, anthracite, subbituminous coal and other bituminous coal. Its gross calorific value is greater than 20.000 kJ/kg on an ash-free but moist basis.

2) Sub-bituminous coal:

non-agglomerating coal with a gross calorific value between 20.000 kJ/kg and 24.000 kJ/kg containing more than 31 % volatile matter on a dry mineral matter free basis

3) Brown coal / lignite:

- Lignite and brown coal: Non-agglomerating coal with a gross calorific value less than 20.000 kJ/kg and greater than 31% volatile matter on a dry mineral matter free basis.
- Brown coal briquettes: a composition fuel manufactured from lignite or subbituminous coal, produced by briquetting under high pressure without the addition of a binding agent, including dried lignite fines and dust.

4) Peat:

a combustible soft, porous or compressed, fossil sedimentary deposit of plant origin with high water content (up to 90 % in the raw state), easily cut, of light to dark brown colour.

5) Peat products:

products such as peat briquettes derived directly or indirectly from sod peat and milled peat.

6) Coke-oven gas:

obtained as a by-product of the manufacture of coke oven coke for the production of iron and steel.

7) Blast furnace and oxygen steel furnace gas:

Gas recovered as by-product of blast furnaces and oxygen steel furnaces.

8) Other solid coal products:

Any other solid coal products not mentioned separately

9) Residual fuel oil:

this covers all residual (heavy) fuel oils (including those obtained by blending). Kinematic viscosity is above 10 cSt at 80°C. The flash point is always above 50°C and density is always more than 0.90 kg/l.

10) Refinery gas:

refinery gas includes a mixture of non-condensable gases mainly consisting of hydrogen, methane, ethane and olefins obtained during distillation of crude oil or treatment of oil products (e.g. cracking) in refineries. This also includes gases which are returned from the petrochemical industry.

11) Other liquid fossil fuels:

Any other liquid fossil fuels not mentioned separately, like gasoil, motor spirit, kerosenes and jet fuels etc.

12) Natural gas and gas works gas:

natural gas consists mainly of methane occurring naturally in underground deposits. This includes colliery gas. Gas works gas covers all types of gases produced in public utility or private plants, whose main purpose is manufacture, transport and distribution of gas.

13) Solid biomass:

covers organic, non-fossil material of biological origin which may be used as fuel for heat production or electricity generation. It comprises wood, wood residues and other solid wastes: covers purpose-grown energy crops (poplar, willow etc.), a multitude of woody materials generated by an industrial process (wood/paper industry in particular) or provided directly by forestry and agriculture (firewood, wood chips, bark, sawdust, shavings, chips, black liquor etc.) as well as wastes such as straw, rice husks, nut shells, poultry litter, crushed grape dregs etc.

14) Industrial waste:

wastes of industrial non-renewable origin (solids or liquids).

15) Municipal solid waste (renewable):

wastes produced by households, industry, hospitals and the tertiary sector which are biodegradable materials incinerated at specific installations.

16) Municipal solid waste (non-renewable):

wastes produced by households, industry, hospitals and the tertiary sector which are non-biodegradable materials incinerated at specific installations.

17) Biogases:

gas composed principally of methane and carbon dioxide produced by anaerobic digestion of biomass or by thermal processes from biomass and including biomass in waste. Biogas is a product aggregate equal to the sum of landfill gas, sewage sludge gas, other biogases from anaerobic digestion and biogases from thermal processes.

a) Landfill gas: Biogas produced from the anaerobic digestion of landfill waste.

b) Sewage sludge gas: Biogas produced from the anaerobic fermentation of sewage sludge.

c) Other biogases from anaerobic digestion: Biogas produced from the anaerobic fermentation of animal slurries and of waste in abattoirs, breweries and other agro-food industries.

d) Biogases from thermal processes: Biogas produced from thermal processes (by gasification or pyrolysis) of biomass.

18) Other renewables:

any other renewables and wastes not mentioned explicitly.

19) Nuclear heat:

heat released as a result of fission of the nuclear fuel inside the reactor.

20) Solar thermal:

heat from solar radiation for solar thermal-electric plants

21) Geothermal:

Energy available as heat emitted from within the earth's crust, usually in the form of hot water or steam. Used for electricity generation using dry steam or high enthalpy brine after flashing

22) Other fuels not mentioned above for example waste heat etc.

6. References

IDAE: Guía Técnica para la medida y determinación del calor útil, de la electricidad y del ahorro de energía primaria de cogeneración de alta eficiencia

http://www.idae.es/uploads/documentos/documentos_guia_calculo_calor_util_hchp-echp-pes_c24e48c1.pdf - an English version is also available – Spanish authorities informed that these instructions are reworked at the moment and promised to inform Eurostat once a new version is available

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC

Commission Decision 2008/952/EU of 19 November 2008 establishing detailed guidelines for the implementation and application of Annex II to Directive 2004/8/EC of the European Parliament and of the Council

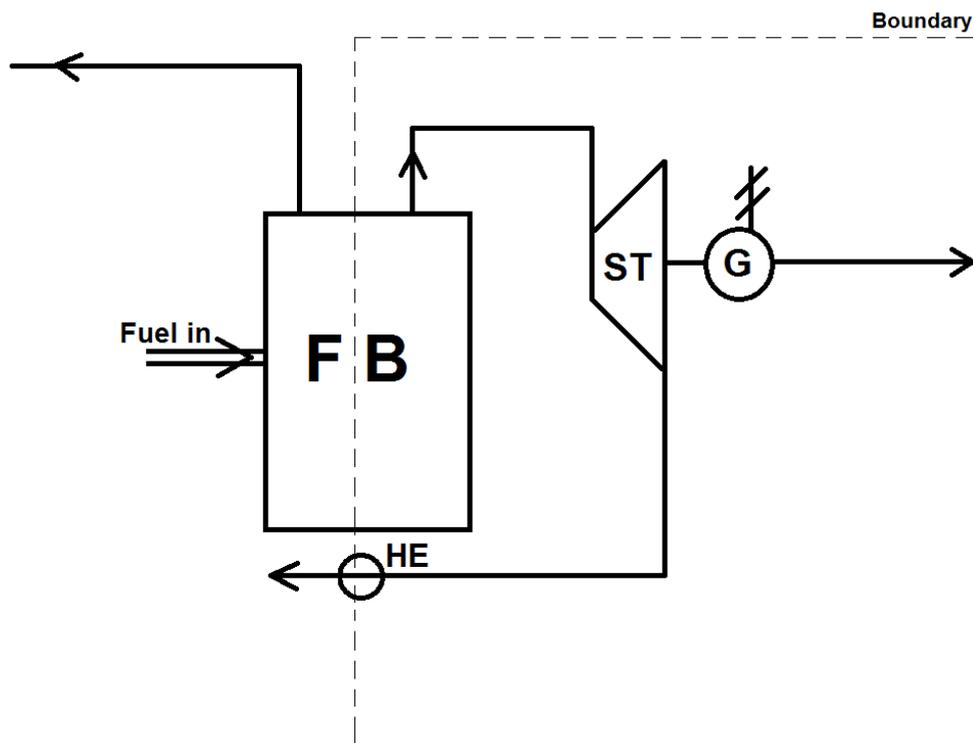
Commission delegated regulation (EU) 2015/2402 of 12 October 2015 reviewing harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2012/27/EU of the European Parliament and of the Council and repealing Commission Implementing Decision 2011/877/EU

Annex 1: Explanations regarding dual purpose boilers and reduction heat

This is a special case of a boiler which partly belongs to the CHP unit but partly has to be also recognized to be outside the boundaries of the CHP unit.

Figure 1: Boundary of a CHP unit for a dual purpose boiler (partly used for the CHP unit, partly used as a heat source for activities outside the CHP unit)

----- = boundary of the CHP unit; FB = fuel boiler; G = generator; HE = heat exchanger; ST = steam turbine



The boiler feeding heat or steam into the CHP unit is also providing heat or steam for an installation outside the CHP unit (e.g. steam for industrial customers). As this heat/steam never enters the turbine of the CHP unit, this heat/steam is called reduction heat ($H_{reduction}$). The relevant fuel ($F_{reduction}$) to create this heat/steam needs to be excluded from the CHP unit.

To calculate this, the efficiency of the boiler needs to be known:

$$\eta_{boiler} = \frac{H_{boiler}}{F_{total}}$$

where:

$$H_{boiler} = H_{turbine} + H_{reduction} \quad \text{or} \quad H_{turbine} = H_{boiler} - H_{reduction}$$

$$F_{total} = F_{CHPunit} + F_{reduction} \quad \text{or} \quad F_{CHPunit} = F_{total} - F_{reduction}$$

To calculate the proportion of the fuel used for the CHP unit:

$$F_{CHPunit} = \frac{H_{turbine}}{\eta_{boiler}}$$

Annex 2: Calculation of reference values for separate production of electricity and heat

The proportion of electricity generated by the different fuels should be known. On this basis the reference values for electricity (Ref E_η) and for heat (Ref H_η) are calculated.

In principle also the proportion of the fuel input in TJ could be used, instead of the electricity generation.

Power plant	Fuel used by CHP unit	Electricity production		Electricity production reference value (Ref E _η) calculated for each CHP unit		Heat production reference value (Ref H _η) calculated for each CHP unit	
		kWh	%	by fuel*		by fuel**	
CHP unit 1 (year 2008)	Biogas	3,379,020	60 %	42	46.16	70	77.92
	Natural gas	2,216,450	40 %	52.5		90	
CHP unit 2 (year 2008)	Biogas	4,568,670	76 %	42	44.51	70	74.78
	Natural gas	1,434,140	24 %	52.5		90	

* value from Annex I of Commission Delegated Regulation (EU) 2015/2402

** value from Annex II of Commission Delegated Regulation (EU) 2015/2402

Annex 3: Practical examples

a) Unit without steam condensation and overall efficiency above the threshold value

Plant data				
Type of cycle	Internal Combustion engine			
Year of construction	2013			
Type of fuel	natural gas			
Location	Northern Italy			
CAP _{elec} - maximum electrical capacity	1.48	MW	gross	
CAPCHP _{heat} - maximum useful heat capacity	N.A.	MW	net	
CAPCHP _{elec} - CHP electrical capacity	1.48	MW	If overall efficiency \geq threshold value	
	equation 16	MW	If overall efficiency $<$ threshold value	
Annual average temperature	11,31	°C		
Use of heat	Hot water			
Voltage	22	kV		

2013 data				
F _{CHP-unit} – fuel consumed in the CHP unit	9.0	GWh		
E _{total} – total electricity production	3.6	GWh	in this case: E _{total} = E _{CHP}	
H _{chp} - Useful heat production	3.4	GWh		
Energy consumed on site	74.4 %			

Calculation				
$\eta_{overall}$ – overall efficiency	78.1 %		$\eta > 75\% \rightarrow E_{total} = E_{CHP}$	equation 7
PES calculation				
CHP H η	38%			equation 8
Ref H η	90.0 %		Commission Delegated Regulation 2015/2402	
CHP E η	40%			equation 9
Ref E η	48.6 %		Commission Delegated Regulation 2015/2402	
PES	19.70%			equation 17
PES	2.2	GWh	= 8.0 TJ	equation 18

b) Unit without steam condensation and overall efficiency below the threshold value

Plant data				
Type of cycle	Internal Combustion engine			
Year of construction	2013			
Type of fuel	biogas			
Location	Northern Italy			
CAP _{elec} - maximum electrical capacity	0.3	MW	gross	
CAPCHP _{heat} - maximum useful heat capacity	N.A.	MW	net	
CAPCHP _{elec} - CHP electrical capacity	0.3	MW	If overall efficiency \geq threshold value	
	equation 16	MW	If overall efficiency $<$ threshold value	
Annual average temperature	11,31	°C		
Use of heat	Hot water			
Voltage	20	kV		

2013 data				
F _{CHP-unit} – fuel consumed in the CHP unit	12.1	GWh		equation 7
E _{total} – total electricity production	2.3	GWh		
H _{chp} - Useful heat production	1.5	GWh		
Energy consumed on site	9.9 %			

Calculation				
$\eta_{overall}$ – overall efficiency	31.0 %			
Virtual CHP unit				
η_0 – overall efficiency threshold	75.0 %		According to Directive 2012/27/EC	
$\eta_{E-total}$	18.7 %			equation 9
C _{actual}	0.33			equation 13
E _{chp}	0.49	GWh		equation 12
F _{CHP}	2.64	GWh		equation 5
PES calculation				
CHP H η	56.3 %			equation 8
Ref H η	70.0 %		Commission Delegated Regulation 2015/2402	
CHP E η	18.7 %			equation 9
Ref E η	39.3 %		Commission Delegated Regulation 2015/2402	
PES	21.9 %			equation 17
PES	0.7	GWh	= 2.6 TJ	equation 18

c) Unit with steam condensation and overall efficiency below the threshold value

Plant data			
Type of cycle	Combined cycle - condensing turbine		
Year of construction	2006		
Type of fuel	natural gas		
Location	Northern Italy		
CAP _{elec} - maximum electrical capacity	132.8	MW	gross
CAPCHP _{heat} - maximum useful heat capacity	N.A.	MW	net
CAPCHP _{elec} - CHP electrical capacity	132.8	MW	If overall efficiency \geq threshold value
	equation 16	MW	If overall efficiency $<$ threshold value
Annual average temperature	11,31	°C	
Use of heat	Hot water		
Voltage	220	kV	

2013 data			
F _{CHP-unit} – fuel consumed in the CHP unit	479.5	GWh	
E _{total} – total electricity production	244.8	GWh	
H _{chp} - Useful heat production	19.8	GWh	
Energy consumed on site	71.0 %		

Calculation			
$\eta_{overall}$ – overall efficiency	55.17 %		equation 7
Virtual CHP unit			
η_0 – overall efficiency threshold	80.0 %		According to Directive 2012/27/EC
β - loss factor	15.8 %		
$\eta_{E-non-CHP}$	51.7 %		equation 11
C _{actual}	1.38		equation 14
E _{chp}	27.3	GWh	equation 12
F _{chp}	58.8	GWh	equation 6
PES calculation			
CHP H η	33.6 %		equation 8
Ref H η	90.0 %		Commission Delegated Regulation 2015/2402
CHP E η	46.4 %		equation 9
Ref E η	52.3 %		Commission Delegated Regulation 2015/2402
PES	20.7 %		equation 17
PES	15.3	GWh	= 55.1 TJ equation 18