How-To-Guide

Carbon and primary energy calculation

energyPRO

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About energyPRO

energyPRO is a Windows-based modeling software package for combined techno-economic analysis and optimisation of complex energy projects with a combined supply of electricity and thermal energy from multiple different energy producing units.The unique programming in energyPRO optimises the operations of the plant including energy storage (heat, fuel, cold and electrical storages) against technical and financial parameters to provide a detailed specification for the provision of the defined energy demands, including heating, cooling and electricity use.energyPRO also provides the user with a detailed financial plan in a standard format approved by international banks and funding institutions. The software enables the user to calculate and produce a report of the emissions by the proposed project.energyPRO is very user-friendly and is the most advanced and flexible software package for making a combined technical and economic analysis of multi-dimensional energy projects.For further information concerning the applications of energyPRO please visit www.emd.dk.

Terms of application

EMD International A/S, March 21

Content

This How-To-Guide is giving an overview about the new features in energyPRO 4.7.282 regarding carbon and primary energy calculations. All possibilities and methods will be explained in detail and should allow every user to set up carbon and primary energy calculations in every energyPRO project.

List of figures:

1 Introduction

A huge reduction of greenhouse gas emissions in a short period is essential to meet the Paris agreement. As a result, calculating carbon emissions and saving potentials is becoming more and more important. This How-To-Guide explains the different options for accessing emission calculations in energyPRO. Further it focusses the different methods to allocate the combined heat and power production of units, which is necessary to calculate the intensity of CO_2 or primary energy factors.

Based on the guidelines of the European Union (EU) all member states must set up country specific CO_2 calculations. Those calculations need a standard for how cogeneration of heat and power is divided and normalized.

The EU Directive on energy efficiency (2012/27/EU) [1] is using the **reference efficiency method** for determining the efficiency of cogeneration processes. The reference values were set out in an updated EU regulation 2015/2402 [2]. Another method for the allocation of CHP is the **Carnot method** [3]. This method is used in Germany in a working paper (FW 309 part 6) of the German district heating association AGFW [4] to set up specific CO_2 emission factors for district heating. More relevant in Germany is the “**electricity credit method**” which is used for calculating the primary energy factor (PEF) of heating systems. Electricity generated is subtracted from the primary energy demand of the fuels. For district heating systems the method is also used in working papers (FW 309 part 1) of the German district heating association AGFW [4] and you can also find it in the German norm DIN V 18599 [5] which is relevant for the German building energy regulation (GEG) [6]. The GEG regulates by law that new buildings must have a primary energy demand less than a reference value. The energy demand for heating and cooling is multiplied with a specific primary energy factor based on the fuel which is used. If the dwelling is connected to district heating, the energy demand is multiplied with an individual primary energy factor of the heating network. The German district heating association provides a list with all district heating systems [7]. If there is a CHP unit in the building itself the DIN V 18599 is used for calculating the primary energy factor.

2 Input data

Depending on the purpose it is possible to define emissions and carbon calculations in different ways. These are detailed below.

2.1 Fuels and markets

The input of emission data in energyPRO can now be done in fuels and markets. Adding a fuel to a project gives the possibility to define a CO_2 factor beside the heat value. This specific factor can be defined as a pure CO_2 factor or for CO_2 equivalents. The units can be selected by the user, so it is possible to base it on the upper or lower heating value for example.

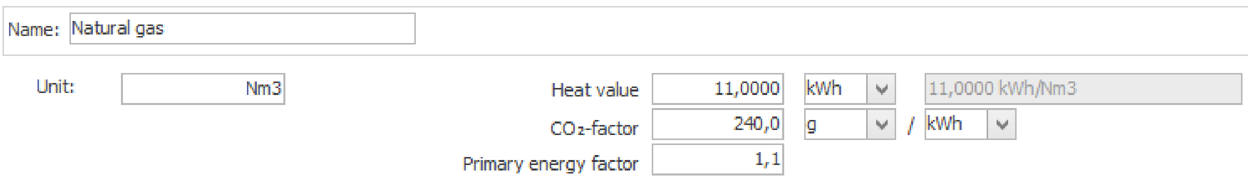

Figure 1: Fuel input data

The primary energy factor (PEF) is only visible if the user is adding a specific primary energy calculation to the project. For further information please check chapter 2.3.

Regarding the markets it is possible to define emission factors for imported and exported electricity of the market. There is no difference between fixed value markets and spot markets. In contrast to the fuels, it is also possible to define **dynamic time series** as emission factors for the electricity.

Figure 2: Market input data

These emission factors and the resulting carbon emissions are presented in different reports. See chapter 3 for more information.

The user can also define **payments relating to the emissions of fuels or electricity**. If "Imported fuel", "Exported electricity" or "Imported electricity" is chosen in "payment concerns" it is possible to choose between the energy amount and the defined CO_2 emissions. This is also possible if "fuel consumption" is chosen for a specific production unit.

With this option a payment could be directly defined on the emissions in €/tonne or the currency which is chosen on the economy form.

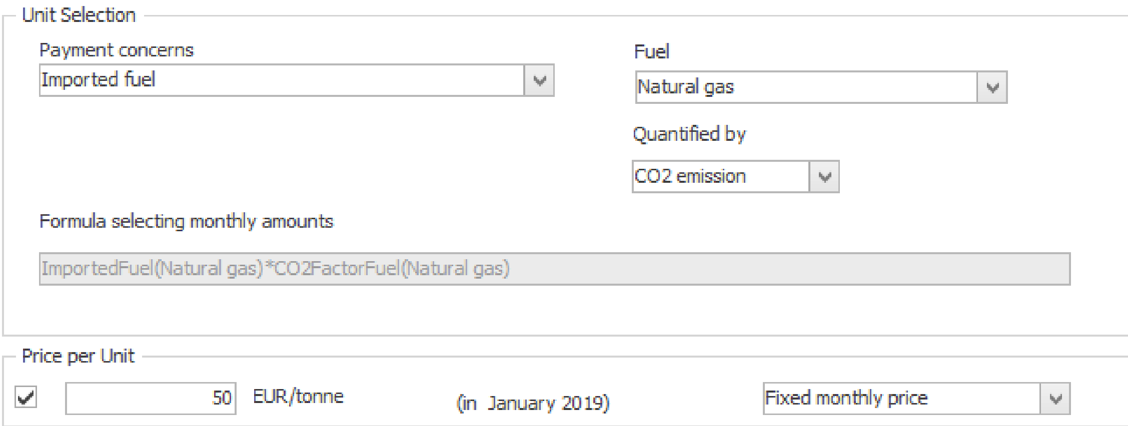

Figure 3: Payment input data

Please be aware of that the CO_2 emission formula does not include the heat value as a denominator. This may have an impact if the relationship is not 1 to 1 defined in the fuel (1 MWh/MWh for instance). The specific CO_2-factor in the fuel should be defined accordingly. Please check the examples below:

Example of the formula when choosing "amount":

ImportedFuel(Natural gas)/HeatValue(Natural gas)

Example of the formula when choosing "CO2 emission":

*ImportedFuel(Natural gas)*CO2FactorFuel(Natural gas)*

2.2 User-defined emissions

In the tree structure under "Environment" it is possible to define user-defined emissions and to set up specific CO_2 and PEF calculations to calculate the intensity of a system. For these calculations see the following chapter 2.3.

To add new user-defined emissions it is first necessary to add subfolders as emission types. For this please right-click on the environment folder and choose “Add emission type”. You can rename the emission types like CO_2, NO_X, SO_2 or any emissions you want to define.

By right-clicking on this new emission type it is possible to define user-defined emissions. The user-defined emissions can be defined in the same way as in the payment structure of energyPRO.

There is no limit in defining emissions and emission types. By double-clicking on the emission type, it is possible to define the unit of the input and the unit of the reports for this type.

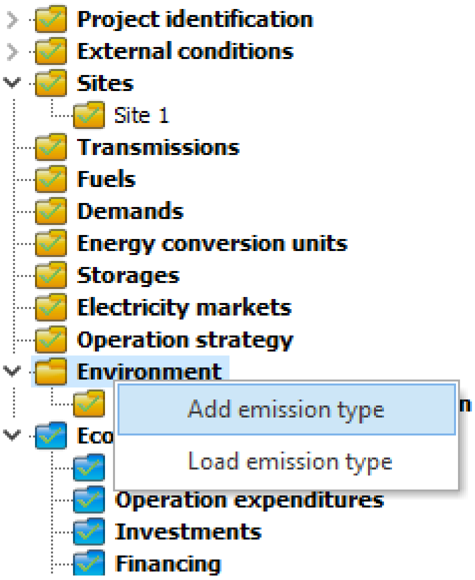

Figure 4: Adding an emission type

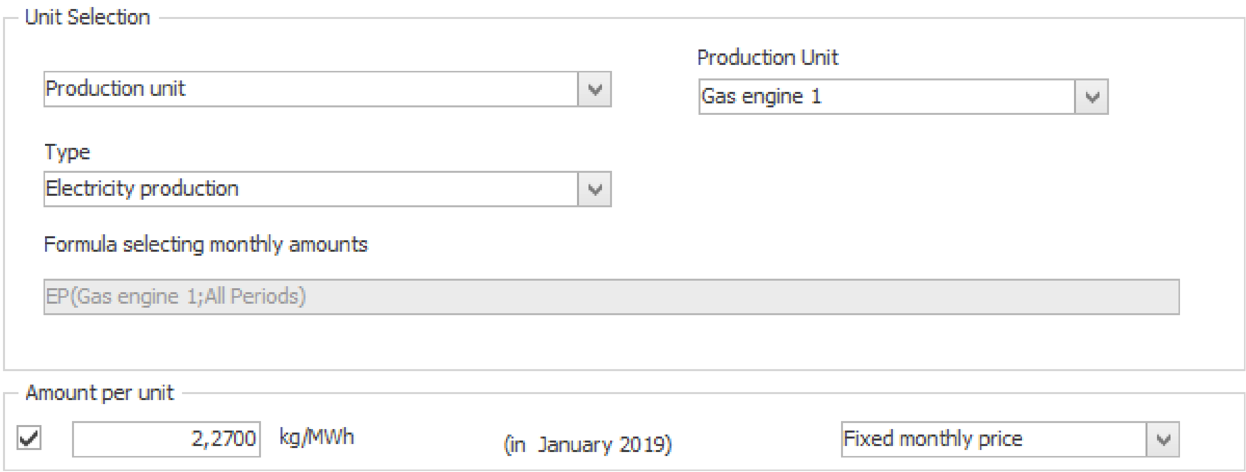

Figure 5: User-defined emission input data

2.3 CO_2 and PEF intensity calculation

In energy systems with several energy conversion units, it is often required that specific key figures be calculated out of the emission data. Beside the calculation of emission key figures, it is possible to calculate key figures based on primary energy factors (PEF) of fuels and of imported or exported electricity. These calculations can be done in the subfolder “CO_2 and PEF intensity calculation” in the “Environment” folder.

Basically, in those calculations all fuels and all electricity entering a system are multiplied with a specific CO_2 or PEF factor and divided by a heat or cooling demand to get a specific key figure for a system:

$$\frac{(fuel + electricity\ consumption) \cdot CO2/PEF\ factor}{heat\ /\ cold\ demand}$$

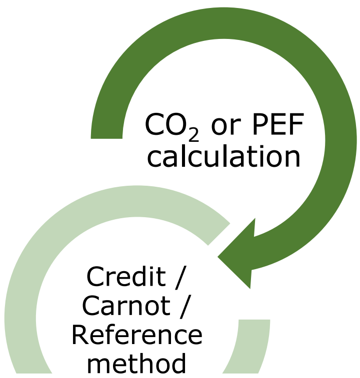

Figure 6: Type and method of CO_2 and PEF calculations resulting in six different possibilities

Right-clicking on the subfolder creates a new calculation wizard which can be opened by double-clicking on it. First the user needs to choose the type and the method of the calculation.

There are three different methods to choose from to calculate the allocation of CHP units. If there is no CHP unit in the project, there is no difference between the methods. The key figures to calculate are normalizing the emissions or the primary energy by a heat or cooling demand. Therefore, the electricity production of a CHP unit must be somehow considered.

Two types (CO_2 and primary energy) and three different methods result in six possible default calculations.

Detailed information about the allocation methods and their differences are given in chapter 4.

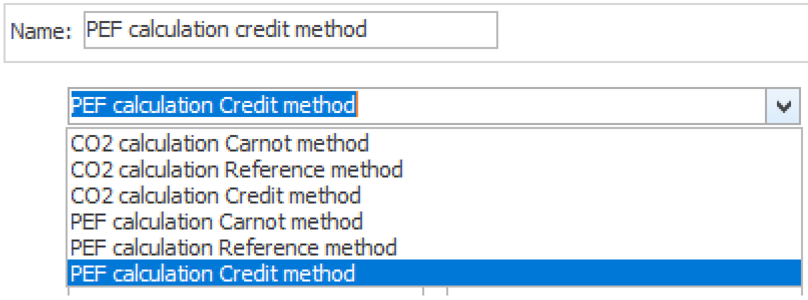

Figure 7: All methods listed in a dropdown menu in the wizard

Once the dropdown is chosen the user can select all units which should be considered. When selecting a unit, the formula in the bottom of the wizard is instantly updated. Further the user can select any heat, process heat or cold demand defined in the project. Every chosen demand is summed up in the end of the formula below the fraction line.

The specific factors of fuel consuming units are taken from the input in the fuel components, see chapter 2.1. When having an electricity consumption unit (e.g. a heat pump) in the project it is necessary to define the specific factor for importing electricity directly in the wizard. The emission factors defined in a market are not considered as they might contain dynamic time series.

When a CHP unit is chosen, more parameters must be defined. These parameters depend on the method which is chosen above and are described in detail in chapter 4.

The formula which is automatically created depending on the selection above is editable. Double-clicking in the field of the formula opens the function editor where it is possible to adapt the formula manually.

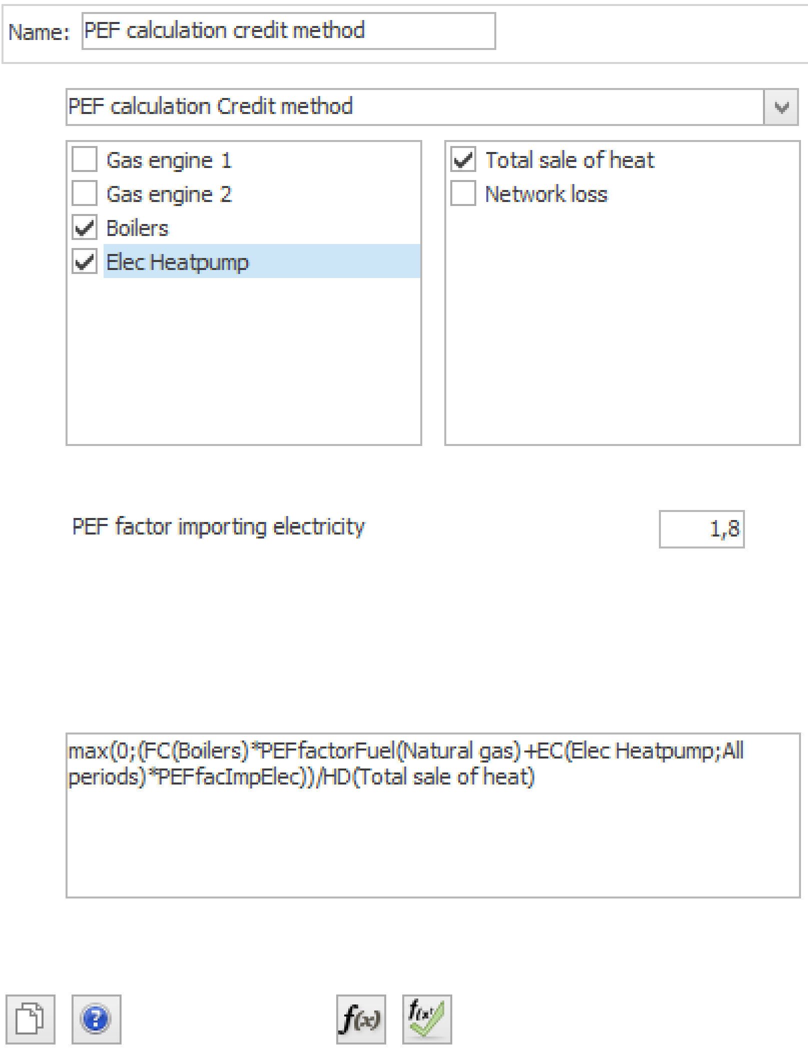

Figure 8: Wizard when PEF calculation method is chosen

3 Output data

The resulting emissions are shown in the energy conversion and the environmental reports. In the "**Energy conversion, annual**" report there is a section at the end of the report which shows all emissions grouped by the fuels, the units and the electricity markets.

CO2:

By fuel	
	CO2 emission
Natural gas	5.556,4 tonne
By energy unit	
Gas engine 1	1.697,7 tonne
Gas engine 2	1.642,6 tonne
Boilers	2.216,1 tonne
Total	5.556,4 tonne
By Electricity market	
Spot market	
Imported electricity	0,0 tonne
Exported electricity	-4.584,7 tonne
Total	-4.584,7 tonne

Figure 9: Energy conversion, annual report

In the "**Energy conversion, monthly**" report the emissions are also shown for all markets, units and fuels - always in the bottom line.

	Total	Jan	Feb	Mar
Heat demand [MWh]				
	15.032,9	2.093,2	1.642,2	1.617,9
Electricity produced by energy units [MWh]				
	5.730,9	638,4	79,8	88,2
Exported electricity, Spot market [MWh]				
	5.730,9	638,4	79,8	88,2
Peak [MW]	**4.200**	4.200	4.200	4.200
Avoided CO2 emission [tonne]	**4.584,7**	510,7	63,8	70,6
Energy unit: Gas engine 1				
Fuel consum. [Nm3]	**643.063,6**	70.472,7	8.809,1	9.736,4
Fuel consum. [MWh]	**7.073,7**	775,2	96,9	107,1
Heat prod. [MWh]	**3.190,1**	349,6	43,7	48,3
Elec. prod. [MWh]	**2.912,7**	319,2	39,9	44,1
Turn ons	**225**	23	6	7
Operating hours	**1.387**	152	19	21
Full load operating hours	**1.387**	152	19	21
Utilization factor [%]	**15,83**	20,43	2,83	2,82
Total efficiency [%]	**86,27**	86,27	86,27	86,27
CO2 emission [tonne]	**1.697,69**	186,05	23,26	25,70
Energy unit: Gas engine 2				
Fuel consum. [Nm3]	**622.200,0**	70.472,7	8.809,1	9.736,4
Fuel consum. [MWh]	**6.844,2**	775,2	96,9	107,1
Heat prod. [MWh]	**3.086,6**	349,6	43,7	48,3
Elec. prod. [MWh]	**2.818,2**	319,2	39,9	44,1
Turn ons	**217**	23	6	7
Operating hours	**1.342**	152	19	21
Full load operating hours	**1.342**	152	19	21
Utilization factor [%]	**15,32**	20,43	2,83	2,82
Total efficiency [%]	**86,27**	86,27	86,27	86,27
CO2 emission [tonne]	**1.642,61**	186,05	23,26	25,70

Figure 10: Energy conversion, monthly report

The “**Environment, summary**” report shows a short overview about the yearly sum of the emissions and all specific CO_2 or PEF factors defined. The “**Environment, monthly**” report is basically the same report with an additional monthly overview of the emissions and factors.

CalculatedPeriod: 01.2019 - 12.2019

	Total	Jan	Feb	Mar	Apr	May
CO2	**[tonne]**					
All production units	4.778	623	378	374	310	258
CO2 Total	**4.778**	**623**	**378**	**374**	**310**	**258**
NOx	**[kg]**					
Engines	9.350	1.025	128	142	0	135
Existing boilers	5.028	800	893	871	818	571
NOx Total	**14.378**	**1.824**	**1.021**	**1.013**	**818**	**706**
SO2	**[kg]**					
All production units	21	3	2	2	1	1
SO2 Total	**21**	**3**	**2**	**2**	**1**	**1**
CO2 and PEF factors						
PEF factor credit method	0,78	0,83	1,27	1,28	1,40	1,37
CO2 factor carnot method	228	223	284	288	306	312

Figure 11: Environment, monthly report

4 Calculation methodology

As mentioned in chapter 2.3 the user can choose between different methods of allocating CHP units. In the following all methods are mathematically described in detail.

First **systems without CHP units.** These are calculated in the same way, irrespective of the chosen method:

Specific CO_2 factor:

$$\frac{\sum_i (FC \cdot CO_2)_i + \sum_j (EC \cdot CO_2)_j}{\sum_x HD_x + \sum_y (PHD)_y + \sum_z (CD)_z}$$

or specific PE factor

$$\frac{\sum_i (FC \cdot PEF)_i + \sum_i (EC \cdot PEF)_i}{\sum_x HD_x + \sum_y (PHD)_y + \sum_z (CD)_z}$$

i for all chosen fuel consuming (FC) units

j for all chosen electricity consuming (EC) units

x for all chosen heat demands (HD)

y for all chosen process heat demands (PHD)

z for all chosen cold demands (CD)

For **balancing groups including CHP units** the calculation is different depending on the method which is chosen.

4.1 The electricity credit method:

This method subtracts the CO_2 related to the electricity produced in a CHP plant from the CO_2 related to the fuel consumption. The electricity generated is multiplied by a specific factor. This factor might be different from the factor for imported electricity as it might be assumed that the exported electricity is replacing a more carbon intensive energy mix than imported.

Normally this value is regulated by law. As this factor might be so high that the whole expression could become negative, in the default equation in energyPRO the minimum value is fixed to zero. If this is not the case, the user may edit the equation to the remove this limit. The default equation is shown below:

CO_2-factor:

$$\max\left(0\ ;\ \frac{\sum_{i;j}(FC\cdot CO_2)_{i;j}+\sum_j(EC\cdot CO_2)_j-\sum_k(EP\cdot CO_2)_k}{\sum_x HD_x+\sum_y(PHD)_y+\sum_z(CD)_z}\right)$$

i for all chosen fuel consuming units

j for all chosen electricity consuming units

k for all chosen CHP units

x for all chosen heat demands

y for all chosen process heat demands

z for all chosen cold demands

4.2 The carnot method:

First the Carnot factor (CF) must be calculated out of the three temperatures which are to be defined in the wizard:

$$CF = 1 - \frac{T_A}{T_m} \qquad with \qquad T_m = \frac{\left(T_{supply} - T_{return}\right)}{\ln\left(\frac{T_{supply}}{T_{return}}\right)}$$

With

- T_A: ambient temperature in Kelvin [K]
- T_m: average temperature of the system in Kelvin [K]
- T_{supply}: supply temperature of the system in Kelvin [K]
- T_{return}: return temperature of the system in Kelvin [K]

In energyPRO the user inputs the value above in Celsius (or Fahrenheit) and the values are adjusted accordingly.

With the Carnot factor the specific CO_2 factor can be calculated. The specific primary energy factor is calculated in the same way.

CO_2-factor:

$$\frac{\sum_i(FC\cdot CO_2)_i+\sum_j(EC\cdot CO_2)_j+\sum_k\left(FC\cdot\frac{(HP+PHP)\cdot CF}{EP+(HP+PHP)\cdot CF}\cdot CO_2\right)_k}{\sum_x HD_x+\sum_y(PHD)_y+\sum_z(CD)_z}$$

i for all chosen fuel consuming units without CHP

j for all chosen electricity consuming units

k for all chosen CHP units

x for all chosen heat demands

y for all chosen process heat demands

z for all chosen cold demands

4.3 The reference efficiency method:

The reference efficiency values can be found in EU 2015/2402 [2], the related values can be found directly in the annex. The thermal and electrical efficiency of the CHP unit is the ratio between the electricity/heat production and the fuel consumption of the CHP. The primary energy saving because of the combined production is calculated as follows:

Primary energy saving (PES): $$1 - \frac{1}{\frac{\eta_{th}}{\eta_{th,REF}} + \frac{\eta_{el}}{\eta_{el,REF}}}$$

Using this primary energy saving the specific CO_2-factor is calculated as follows:

Specific CO_2 factor:

$$\frac{\sum_i (FC \cdot CO_2)_i + \sum_j (EC \cdot CO_2)_j + \sum_k \left(FC \cdot \left((1 - PES) \cdot \frac{\eta_{th}}{\eta_{th,REF}} \right) \cdot CO_2 \right)_k}{\sum_x HD_x + \sum_y (PHD)_y + \sum_z (CD)_z}$$

i for all chosen fuel consuming units without CHP

j for all chosen electricity consuming units

k for all chosen CHP units

x for all chosen heat demands

y for all chosen process heat demands

z for all chosen cooling demands

5 Bibliography

[1] Directive 2012/27/EU, "EUR-Lex," [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1399375464230&uri=CELEX%3A32012L0027.

[2] Commission Delegated Regulation (EU) 2015/2402, "EUR-Lex," [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32015R2402.

[3] Wikipedia, "Carnot method," 01 03 2021. [Online]. Available: https://en.wikipedia.org/wiki/Carnot_method.

[4] AGFW, "FW 309 part 6," 01 03 2021. [Online]. Available: https://www.agfw.de/technik-sicherheit/erzeugung-sektorkopplung-speicher/energetische-bewertung/geg-und-fernwaerme/.

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[8] "BRE Garston," [Online]. Available: https://www.bregroup.com/wp-content/uploads/2019/10/SAP-10.1-01-10-2019.pdf.

[9] *Energiewirtschaftliche Tagesfragen 55.Jg. Heft 9 ,* 2010.

Annex

Tabelle A.1 — Primärenergiefaktoren und CO_2-Äquivalente[a]

Energieträger[a]		Primärenergiefaktoren f_p		CO_2-Äquivalent x_{CO_2} g/kWh
		insgesamt	nicht erneuerbarer Anteil	nicht erneuerbarer Anteil
		A	B	C
dem Bilanzraum zugeführte Endenergien (Index „f,in")				
Fossile Brennstoffe	Heizöl	1,1	1,1	310
	Erdgas	1,1	1,1	240
	Flüssiggas	1,1	1,1	270
	Steinkohle	1,1	1,1	400
	Braunkohle	1,2	1,2	430
Biogene Brennstoffe	Biogas	1,4	0,4	120
	Bioöl	1,4	0,4	190
	Holz	1,2	0,2	40
Nah-/ Fernwärme	aus KWK[b], fossiler Brennstoff bzw. Energieträger	0,7	0,7	c, e
	aus KWK[b], erneuerbarer Brennstoff bzw. Energieträger	0,7	0,0	c, e
	aus Heizwerken, fossiler Brennstoff bzw. Energieträger	1,3	1,3	c, e
	allgemeiner Fall	c	c	c
Fernkälte	allgemeiner Fall	c	c	c
Strom	allgemeiner Strommix	2,8	1,8	550
innerhalb der Bilanzgrenzen nutzbar gemachte Endenergien (Index „f,prod")				
Umwelt-energie	Wärme (Erdwärme, Geothermie, Solarthermie, Umgebungswärme)	1,0	0,0	0
	Kälte (Erdkälte, Umgebungskälte)	1,0	0,0	0
	Strom (aus Photovoltaik, Windkraft)	1,0	0,0	0
Abwärme	aus Prozessen, siehe 3.1.32	1,0	0,0	40
aus dem Bilanzraum abgeführte Endenergien (Index „f,out")				
Strom	Verdrängungsstrommix für KWK	2,8	2,8	860
	Verdrängungsstrommix für PV, WEA	2,8	1,8	550
thermische Energien	Wärme für andere Verbraucher	d	d	d
	Kälte für andere Verbraucher	d	d	d
Abwärme	aus Prozessen, siehe 3.1.32	1,0	0,0	40

[a] Bezugsgröße Endenergie: Heizwert H_i.
[b] Angaben sind typisch für durchschnittliche Nah-/Fernwärme mit einem Anteil der KWK von 70 %.
[c] Individuelle Berechnung für das Netz, aus dem der Bezug erfolgt, siehe A.4.
[d] Individuelle Berechnung für das Netz, in welches die Einspeisung erfolgt, siehe A.4.
[e] Eine Angabe von Standardwerten ist aufgrund der unterschiedlichen Energieträgermixe nicht möglich.

Figure 12: Primary energy and CO_2 emission factors according to DIN V 18599

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

Fuel	Standing charge, £ [(a)]	Unit price p/kWh	Emissions kg CO_{2e} per kWh [(b) (s)]	Primary energy factor [(t)]	Fuel code
Gas:					
mains gas	88	3.93	0.210	1.130	1
bulk LPG	58	6.59	0.241	1.141	2
bottled LPG (for main heating system)		7.85	0.241	1.141	3
bottled LPG (for secondary heating)		10.71	0.241	1.133	5
LPG subject to Special Condition 11F [(c)]	95	3.93	0.241	1.163	9
biogas (including anaerobic digestion)	70	6.59	0.024	1.286	7
Oil:					
heating oil		4.35	0.298	1.180	4
biodiesel from any biomass source [(d)]		6.11	0.038	1.437	71
biodiesel from vegetable oil only [(e)]		6.11	0.018	1.042	73
appliances able to use mineral oil or biodiesel		4.35	0.298	1.180	74
B30K [(f)]		4.88	0.220	1.257	75
bioethanol from any biomass source		47	0.105	1.472	76
Solid fuel: [(g)]					
house coal		4.18	0.395	1.064	11
anthracite		4.14	0.395	1.064	15
manufactured smokeless fuel		5.17	0.366	1.261	12
wood logs		4.65	0.028	1.046	20
wood pellets (in bags for secondary heating)		6.09	0.053	1.325	22
wood pellets (bulk supply for main heating)		5.51	0.053	1.325	23
wood chips		3.48	0.023	1.046	21
dual fuel appliance (mineral and wood)		4.53	0.087	1.049	10
Electricity: [(a)]					
standard tariff	72	17.56	0.136	1.501	30
7-hour tariff (high rate) [(h)]	8	20.72	0.136	1.501	32
7-hour tariff (low rate) [(h)]		8.13	0.136	1.501	31
10-hour tariff (high rate) [(h)]	7	18.71	0.136	1.501	34
10-hour tariff (low rate) [(h)]		10.68	0.136	1.501	33
18-hour tariff (high rate) [(h)]	11	15.73	0.136	1.501	38
18-hour tariff (low rate) [(h)]		10.66	0.136	1.501	40
24-hour heating tariff	31	10.38	0.136	1.501	35
electricity sold to grid, PV		5.3 [(i)]	0.136	0.501	36
electricity sold to grid, other		5.3 [(i)]	0.136	0.501	60
electricity displaced from grid		-	0.136	1.501	37
electricity, any tariff [(j)]		-	0.136	1.501	39
Heat networks: [(k)]	87 [(l)]				
heat from boilers – mains gas		4.79	0.210	1.130	51
heat from boilers – LPG		4.79	0.241	1.141	52
heat from boilers – oil		4.79	0.335	1.180	53
heat from boilers that can use mineral oil or biodiesel		4.79	0.335	1.18	
heat from boilers using biodiesel from any biomass source		4.79	0.038	1.437	
heat from boilers using biodiesel from vegetable oil only		4.79	0.018	1.042	
heat from boilers – B30D [(f)]		4.79	0.269	1.090	55
heat from boilers – coal		4.79	0.375	1.064	54
heat from electric heat pump		4.79	0.136	1.501	41
heat from boilers – waste combustion		4.79	0.074	1.169	42
heat from boilers – biomass		4.79	0.029	1.037	43
heat from boilers – biogas (landfill or sewage gas)		4.79	0.024	1.286	
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

Energy Cost Deflator [(r)] = 0.37

Figure 13: Primary energy and CO_2 emissions according to "The Government's Standard Assessment Procedure for Energy Rating of Dwellings" in the UK [7]

Emissionsfaktoren

Nummer	Kategorie	Energieträger	Emissionsfaktor [g CO_2-Äquivalent pro kWh]
1	Fossile Brennstoffe	Heizöl	310
2		Erdgas	240
3		Flüssiggas	270
4		Steinkohle	400
5		Braunkohle	430
6	Biogene Brennstoffe	Biogas	140
7		Biogas, gebäudenah erzeugt	75
8		Biogenes Flüssiggas	180
9		Bioöl	210
10		Bioöl, gebäudenah erzeugt	105
11		Holz	20
12	Strom	netzbezogen	560
13		gebäudenah erzeugt (aus Photovoltaik oder Windkraft)	0
14		Verdrängungsstrommix	860
15	Wärme, Kälte	Erdwärme, Geothermie, Solarthermie, Umgebungswärme	0
16		Erdkälte, Umgebungskälte	0
17		Abwärme aus Prozessen	40
18		Wärme aus KWK, gebäudeintegriert oder gebäudenah	nach DIN V 18599-9: 2018-09
19		Wärme aus Verbrennung von Siedlungsabfällen (unter pauschaler Berücksichtigung von Hilfsenergie und Stützfeuerung)	20
20	Nah-/Fernwärme aus KWK mit Deckungsanteil der KWK an der Wärmeerzeugung von mindestens 70 Prozent	Brennstoff: Stein-/Braunkohle	300
21		Gasförmige und flüssige Brennstoffe	180
22		Erneuerbarer Brennstoff	40
23	Nah-/Fernwärme aus Heizwerken	Brennstoff: Stein-/Braunkohle	400
24		Gasförmige und flüssige Brennstoffe	300
25		Erneuerbarer Brennstoff	60

Figure 14: CO_2 emission factors according to the German Building Law (GEG)

Harmonised efficiency reference values for separate production of electricity

(referred to in Article 1)

In the table below the harmonised efficiency reference values for separate production of electricity are based on net calorific value and standard atmospheric ISO conditions (15 °C ambient temperature, 1,013 bar, 60 % relative humidity).

Category		Type of fuel	Year of construction		
			Before 2012	2012-2015	From 2016
Solids	S1	Hard coal including anthracite, bituminous coal, sub-bituminous coal, coke, semi-coke, pet coke	44,2	44,2	44,2
	S2	Lignite, lignite briquettes, shale oil	41,8	41,8	41,8
	S3	Peat, peat briquettes	39,0	39,0	39,0
	S4	Dry biomass including wood and other solid biomass including wood pellets and briquettes, dried woodchips, clean and dry waste wood, nut shells and olive and other stones	33,0	33,0	37,0
	S5	Other solid biomass including all wood not included under S4 and black and brown liquor.	25,0	25,0	30,0
	S6	Municipal and industrial waste (non-renewable) and renewable/bio-degradable waste	25,0	25,0	25,0
Liquids	L7	Heavy fuel oil, gas/diesel oil, other oil products	44,2	44,2	44,2
	L8	Bio-liquids including bio-methanol, bioethanol, bio-butanol, biodiesel and other bio-liquids	44,2	44,2	44,2
	L9	Waste liquids including biodegradable and non-renewable waste (including tallow, fat and spent grain).	25,0	25,0	29,0
Gaseous	G10	Natural gas, LPG, LNG and biomethane	52,5	52,5	53,0
	G11	Refinery gases hydrogen and synthesis gas	44,2	44,2	44,2
	G12	Biogas produced from anaerobic digestion, landfill, and sewage treatment	42,0	42,0	42,0
	G13	Coke oven gas, blast furnace gas, mining gas, and other recovered gases (excluding refinery gas)	35,0	35,0	35,0
Other	O14	Waste heat (including high temperature process exhaust gases, product from exothermic chemical reactions)			30,0
	O15	Nuclear			33,0
	O16	Solar thermal			30,0
	O17	Geothermal			19,5
	O18	Other fuels not mentioned above			30,0

Figure 15: Harmonised efficiency reference values for separate production of electricity according to "Commission delegated regulation (EU) 2015/2402"

Harmonised efficiency reference values for separate production of heat

(referred to in Article 1)

In the table below the harmonised efficiency reference values for separate production of heat are based on net calorific value and standard atmospheric ISO conditions (15 °C ambient temperature, 1,013 bar, 60 % relative humidity).

Category		Type of fuel:	Year of construction					
			Before 2016			From 2016		
			Hot water	Steam (*)	Direct use of exhaust gases (**)	Hot water	Steam (*)	Direct use of exhaust gases (**)
Solids	S1	Hard coal including anthracite, bituminous coal, sub-bituminous coal, coke, semi-coke, pet coke	88	83	80	88	83	80
	S2	Lignite, lignite briquettes, shale oil	86	81	78	86	81	78
	S3	Peat, peat briquettes	86	81	78	86	81	78
	S4	Dry biomass including wood and other solid biomass including wood pellets and briquettes, dried woodchips, clean and dry waste wood, nut shells and olive and other stones	86	81	78	86	81	78
	S5	Other solid biomass including all wood not included under S4 and black and brown liquor.	80	75	72	80	75	72
	S6	Municipal and industrial waste (non-renewable) and renewable/bio-degradable waste	80	75	72	80	75	72
Liquids	L7	Heavy fuel oil, gas/diesel oil, other oil products	89	84	81	85	80	77
	L8	Bio-liquids including bio-methanol, bioethanol, bio-butanol, biodiesel and other bio-liquids	89	84	81	85	80	77
	L9	Waste liquids including biodegradable and non-renewable waste (including tallow, fat and spent grain).	80	75	72	75	70	67

Figure 16: Harmonised efficiency reference values for separate production of heat according to "Commission delegated regulation (EU) 2015/2402"

Category		Type of fuel:	Year of construction					
			Before 2016			From 2016		
			Hot water	Steam (*)	Direct use of exhaust gases (**)	Hot water	Steam (*)	Direct use of exhaust gases (**)
Gaseous	G10	Natural gas, LPG, LNG and biomethane	90	85	82	92	87	84
	G11	Refinery gases hydrogen and synthesis gas	89	84	81	90	85	82
	G12	Biogas produced from anaerobic digestion, landfill, and sewage treatment	70	65	62	80	75	72
	G13	Coke oven gas, blast furnace gas, mining gas, and other recovered gases (excluding refinery gas)	80	75	72	80	75	72
Other	O14	Waste heat (including high temperature process exhaust gases, product from exothermic chemical reactions)	—	—	—	92	87	—
	O15	Nuclear	—	—	—	92	87	—
	O16	Solar thermal	—	—	—	92	87	—
	O17	Geothermal	—	—	—	92	87	—
	O18	Other fuels not mentioned above	—	—	—	92	87	—

(*) If steam plants do not account for the condensate return in their calculation of CHP heat efficiencies, the steam efficiencies shown in the table above should be increased by 5 percentage points.
(**) Values for direct use of exhaust gases should be used if the temperature is 250 °C or higher.

Figure 17: Harmonised efficiency reference values for separate production of heat according to "Commission delegated regulation (EU) 2015/2402" page 2

Tab. 1: Übersicht der betrachteten Allokationsmethoden zur CO_2-Bewertung von KWK-Anlagen

Allokationsmethoden	Brennstoffanteil A_{Br}	absolute CO_2-Emissionen in g CO_2	spezifische CO_2-Emissionen in g CO_2/kWh
IEA-Methode*	$A_{Br,el} = \frac{\eta_{el}}{\eta_{el} + \eta_{th}}$	$CO_{2,el} = \text{spez. } CO_{2,Gas} \cdot A_{Br,el} \cdot W_{Gas}$	$\text{spez. } CO_{2,el} = \frac{CO_{2,el}}{W_{el}}$
	$A_{Br,th} = \frac{\eta_{th}}{\eta_{el} + \eta_{th}}$	$CO_{2,th} = \text{spez. } CO_{2,Gas} \cdot A_{Br,th} \cdot W_{Gas}$	$\text{spez. } CO_{2,th} = \frac{CO_{2,th}}{W_{th}}$
Wirkungsgradmethode	$A_{Br,el} = \frac{\eta_{th}}{\eta_{el} + \eta_{th}}$	$CO_{2,el} = \text{spez. } CO_{2,Gas} \cdot A_{Br,el} \cdot W_{Gas}$	$\text{spez. } CO_{2,el} = \frac{CO_{2,el}}{W_{el}}$
	$A_{Br,th} = \frac{\eta_{el}}{\eta_{el} + \eta_{th}}$	$CO_{2,th} = \text{spez. } CO_{2,Gas} \cdot A_{Br,th} \cdot W_{Gas}$	$\text{spez. } CO_{2,th} = \frac{CO_{2,th}}{W_{th}}$
Finnische Methode	$A_{Br,el} = (1 - PEE) \cdot \frac{\eta_{el}}{\eta_{el,REF}}$	$CO_{2,el} = \text{spez. } CO_{2,Gas} \cdot A_{Br,el} \cdot W_{Gas}$	$\text{spez. } CO_{2,el} = \frac{CO_{2,el}}{W_{el}}$
	$A_{Br,th} = (1 - PEE) \cdot \frac{\eta_{th}}{\eta_{th,REF}}$	$CO_{2,th} = \text{spez. } CO_{2,Gas} \cdot A_{Br,th} \cdot W_{Gas}$	$\text{spez. } CO_{2,th} = \frac{CO_{2,th}}{W_{th}}$
	mit: $PEE^{**} = 1 - \frac{1}{\frac{\eta_{th}}{\eta_{th,REF}} + \frac{\eta_{el}}{\eta_{el,REF}}}$		
Wärmegutschrift	$A_{Br,el} = 0$	$CO_{2,el} = \text{spez. } CO_{2,Gas} \cdot W_{Gas} - CO_{2,th}$	$\text{spez. } CO_{2,el} = \frac{CO_{2,el}}{W_{el}}$
	$A_{Br,th} = 1$	mit: $CO_{2,th} = \text{spez. } CO_{2,Wärme} \cdot W_{Gas} \cdot \eta_{th}$	$\text{spez. } CO_{2,th} = \frac{CO_{2,th}}{W_{th}}$
Stromgutschrift	$A_{Br,el} = 1$	$CO_{2,el} = \text{spez. } CO_{2,Strom} \cdot W_{Gas} \cdot \eta_{el}$	$\text{spez. } CO_{2,el} = \frac{CO_{2,el}}{W_{el}}$
	$A_{Br,th} = 0$	$CO_{2,th} = \text{spez. } CO_{2,Gas} \cdot W_{Gas} - CO_{2,el}$	$\text{spez. } CO_{2,th} = \frac{CO_{2,th}}{W_{th}}$

* IEA = Internationale Energieagentur (von engl. International Energy Agency)
** PEE = Primärenergieeinsparung

Figure 18: Overview of different allocation methods in German [8]