Calculation of energy indicators for district energy systems in the course of the Global District Energy Climate Awards

Preface

Applicants are asked to provide data focusing their efforts on reducing primary energy, i.e. Primary Energy Factor ($f_{P,dh}$), emission coefficient (K_{dh}) and renewable and recycled fraction (R_{dh}) mirroring the state before and after implementation of the scheme / project. The calculation of those factors shall be based on the results of the IEE-funded Ecoheat4Cities project (www.ecoheat4cities.eu) and in particular on the Guidelines for technical assessment of District Heating systems.

The following pages provide the applicants with the needed information, formulae and default values to execute the necessary calculations as defined in the above mentioned document. Applicants are asked to include their results and input data as part of their online submission.

1. Definitions

For the purposes of this document, terms and definitions given in EN 15603:2008 and in EN 15316-4-5:2007 and the following apply.

1.1
energy class
easy to understand metric for indicating the energy performance of a district heating system

1.2
reference value
standard calculated value against which an energy indicator is compared

1.3
energy performance indicator
energy input to or emissions from a district heating system divided by delivered energy

1.4
energy source indicator
energy output from a defined source divided by total energy output

1.5
measured energy indicator
energy performance indicator based on measured data of an existing system

1.6
design energy indicator
energy performance indicator based on design data for a future system

1.7
tailored energy indicator
energy performance indicator based on design, forecast and measured data

EXAMPLE applicable for existing systems that will be retrofitted (e.g. new heat generators, connection of existing networks)

1.8
delivered energy
energy, expressed per energy carrier, supplied to the technical building system through the system boundary

1.9
primary energy
energy that has not been subjected to any conversion or transformation process

NOTE Primary energy includes non-renewable energy and renewable energy. If both are taken into account it can be called total primary energy.

1.10
primary bio fuel
solid, fluid or gaseous fuel from renewable sources that is sole produced for energy purposes e.g. wood or energy crops

1.11
secondary bio fuel
solid, fluid or gaseous fuel from renewable sources that is a co-product or residue from another process with another main product e.g. biogas from sewage treatment or wood chips from timber production

1.12
refined bio fuel
solid, fluid or gaseous fuel from renewable sources that passes a refining step in the upstream fuel chain for energy purposes e.g. compression and drying of wood chips to obtain pellets or the production of biooil from energy crops

2. Symbols and Abbreviations

Table 1 — Symbols

E	energy
Q	heat
K	emission coefficient
R	renewable and recycled fraction
β	ratio of any specified energy to total heat
EP	energy performance indicator
ES	energy source indicator
f	factor
ref	reference
σ	power-to-heat ratio
η	efficiency

Table 2 — Subscripts

aux	auxiliary	hn	heating network
cond	in condensation mode	hp	heat producer
chp	combined heat and power	Hi	heating value Index i: inferior / Index s: superior
del	delivered	mar	marginal
dir	direct emissions at plant site	ng	natural gas
dh	district heating	nren	non-renewable
el	electricity	P	primary energy
ext	external	R	renewable and recycled
F	fuel	ref	reference
I	index for energy carrier	tot	total

3. Energy Indicators

A district heating system is defined by energy indicators:

The energy performance of a district heating system is represented by the indicators *EP*

primary energy factor $f_{P,dh}$

emission coefficient K_{dh}

The energy source of a district heating system is represented by the indicator *ES*

renewable and recycled fraction R_{dh}

determining the energy data

The indicators shall be based on one of the three types of ratings:

design energy rating;

tailored energy rating;

measured energy rating.

All indicators should be determined with the same energy data, system boundaries and time period. Indicators on the basis of measured energy rating reflect the energy performance of the past. The energy performance calculation must be based at least on 12 consecutive months (one year). The calculation of the energy performance before installation / commencement of the project must be based on the data of 12 consecutive months (one year) before installation / commencement of the project. The calculation of the energy performance after installation / commencement of the project must be based on the latest available data of 12 consecutive months (one year) after installation / commencement of the project. Only for projects/schemes installed less than 12 consecutive months ago a shorter period can be considered.

The energy data shall be validated by plausibility check. Depending on the available data the following indicators can provide plausibility:

efficiency of the heating network

efficiency of heat generators

power-to-heat ratio of chp units

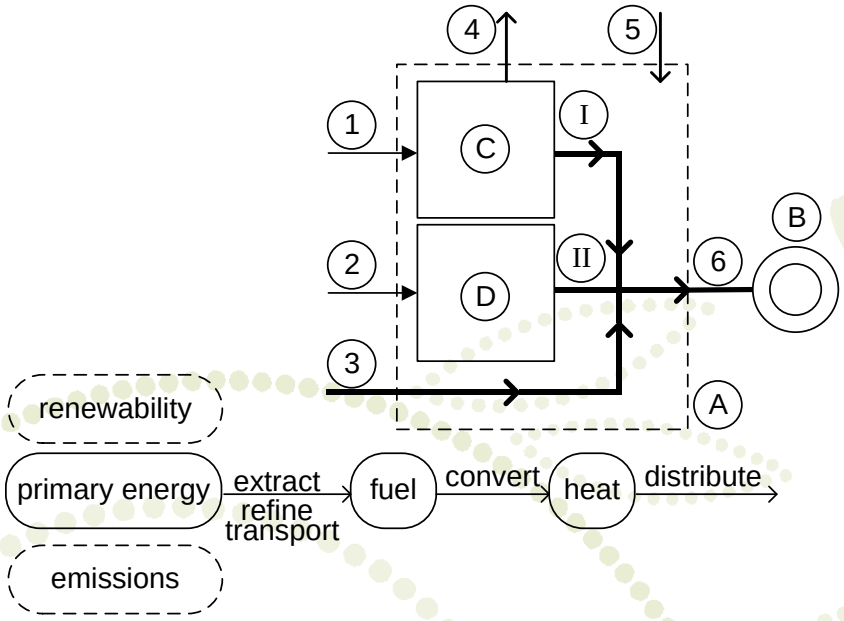
ratio of auxiliary electricity to produced heat

Electricity from cogeneration $E_{el,chp}$ and the related amount of fuel is determined according to 2008/952/EC. Additional calculation methods can be found in the CEN workshop agreement CWA 45547:2004.

determining the system boundaries

EP shall be determined within the thermodynamic system borders of the specific district heating system. This is usually the area supplied by one heating network bordered by the primary side of building substations. Within this area, all energy inputs and all energy outputs are considered. Energy as input to the system is weighted by its specific conversion factor. Thus, the heat losses of the heating network are taken into account as well as all other energy used for extraction, preparation, refining, processing and transportation of the fuels to produce the heat.

Figure 1 — system boundaries for district heating energy rating



A	system boundary		1	energy input to cogeneration unit	E_{chp}
B	heat consumers		2	energy input to heat producer	E_{hp}
C	cogeneration unit		3	heat from external source	Q_{ext}
D	heat producer		4	chp electricity	$E_{el,chp}$
			5	auxiliary electricity	$E_{el,aux}$
			6	delivered heat	Q_{del}
			I	heat from cogeneration unit	Q_{chp}
			II	heat from heat producer	Q_{hp}

If it is not possible or useful to calculate connected plants and networks together, they may be broken down into subsystems. This results in some subsystems which consume heat and others that supply heat. The heat from a supplier subsystem shall be assessed with its own energy indicators. For the consumer subsystem this is an external heat supply which is taken into account as an energy input Q_{ext} with its specific energy indicators.

Note: It may be useful or necessary to divide a system when parts of the district heating network are operated by different utility companies or with different system parameters.

calculation

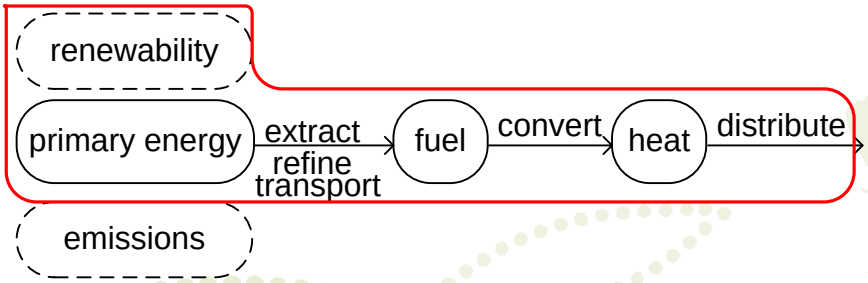
In some cases negative calculation results may occur. They shall be set to zero.

i. primary energy

According to clause 8 of EN 15603 there are two conventions of primary energy factor: Total primary energy factor and non-renewable primary energy factor. In this guideline the non-renewable primary energy factor is

used and is calculated according to EN 15316-4-5 (2007) if no national calculation rules are given. National variations shall be defined in a national annex.

Figure 2 — non-renewable primary energy factor of district heating $f_{P,dh,nren}$



NOTE Renewability, recyclability and emissions are attributes of primary energy. Renewability and recyclability are conventions that may be taken into account by setting renewable and recycled primary energy to zero.

$$f_{P,dh,nren} = \frac{\sum_i E_i \cdot f_{P,nren,i} + Q_{ext} \cdot f_{P,nren,ext} + \left(E_{el,aux} - E_{el,chp}\right) \cdot f_{P,el}}{\sum_j Q_{del,j}}$$

E_i energy content of input to the system of energy carrier *i* in MWh_{Hi}

$f_{P,nren,i}$ non-renewable primary energy factor of energy carrier *i* from table 3

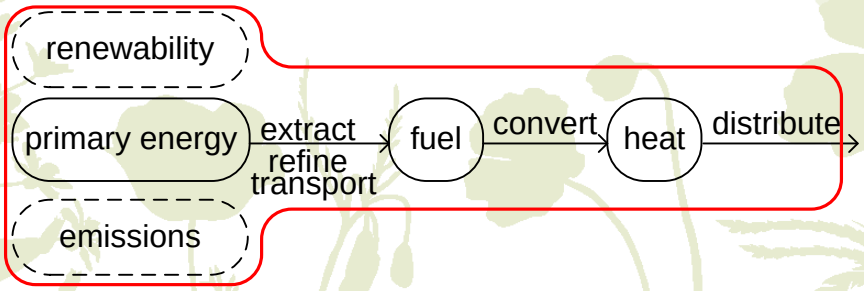
$f_{P,nren,ext}$ non-renewable primary energy factor of the external heat supply

$f_{P,el}$ primary energy factor of electricity from table 3

ii. emissions

For the purpose of certification according to this guideline the non-renewable primary CO_2-emission coefficient represents the emissions of a district heating system if no national calculation rules are given.

Figure 3 — non-renewable primary emission coefficient of district heating $K_{P,dh,nren}$



$$K_{P,dh,nren} = \frac{\sum_i E_i \cdot K_{P,nren,i} + Q_{ext} \cdot K_{ext} + E_{el,aux} \cdot K_{el} - \left(\sum_i \frac{E_{el,chp,i} \cdot K_{P,nren,chp,i}}{\eta_{el,i}}\right)}{\sum_j Q_{del,j}}$$

$K_{P,dh,nren}$ non-renewable primary CO_2-emission coefficient of district heating in kg/MWh

E_i energy content of energy carrier *i* input to heat producer and cogeneration unit in MWh_{Hi}

$K_{P,nren,i}$ non-renewable primary CO_2-emission coefficient of energy carrier *i* in kg/MWh_{Hi} from table 3

Q_{ext} energy content of heat from external source in MWh

K_{ext} non-renewable CO_2-emission coefficient of external heat in kg/MWh

K_{el} non-renewable CO_2-emission coefficient of electricity in kg/MWh from table 3

$E_{el,chp,i}$ cogenerated electricity produced with fuel *i* in MWh

$K_{P,nren,chp,i}$ non-renewable primary CO_2-emission coefficient of energy carrier *i* that was used in chp-unit in kg/MWh_{Hi} from table 3

$\eta_{el,i}$ electric efficiency of fuel *i* from 2011/877/EU, Annex I

NOTE Correction factors according to Annex III and Annex IV shall not be applied. The year of construction may be taken into consideration.

$Q_{del,j}$ delivered heat to customer *j* in MWh

iii. renewable and recycled fraction

R is the ratio of heat from renewable and/or recycled energy carriers to total heat in %. If electricity is used as fuel (e.g. for heat pumps or electric boilers) 20% of this electricity is regarded as renewable/recycled.

iv. heat from nuclear power plants

If heat is extracted from a condensation turbine of a nuclear power plant it shall be calculated by

$$f_{P,ext} \cdot Q_{ext} = f_{P,el} \cdot \Delta E_{el,ext}$$

$f_{P,ext}$ primary energy factor of the external heat

Q_{ext} amount of heat supplied by external system

$f_{P,el}$ primary energy factor of electricity

$\Delta E_{el,ext}$ annual power loss of the external power plant due to heat extraction and transport with $\Delta E_{el,ext}=(s+\beta_{aux})\cdot Q_{ext}$ where *s* is the power loss index.

If $\Delta E_{el,ext}$ is not available default values for *s* and β_{aux} may be determined on national level. The values for *s* usually range between 0,1 and 0,3. If no national default values are set, external heat from nuclear power plants is assessed with the $f_P = 0{,}25 \cdot f_{P,el}$, $K_P = 0{,}25 \cdot K_{el}$, R=0.

conversion factors and coefficients

According to EN 15603 clause 8.2 average, marginal and end-use factors and coefficients may be applied. Values for factors and coefficients needed to calculate the energy performance indicators should be defined in a national annex.

i. primary energy factors for fuels

The primary energy factors for fuels are calculated by taking into account losses that occur during extraction, processing/refining, storage and transport of the fuels. For a given fuel the primary energy use is divided by the net energy content of the fuel (lower heating value) at the gate where it is finally transformed into heat. The gate could be represented by either an energy plant or a building with its own boiler. The energy taken into account is all energy required from cradle to the final use of one unit of fuel at the gate and is calculated accordingly:

$$f_{P,F} = \frac{E_{P,extract} + E_{P,refine} + E_{P,transport} + E_{P,F}}{E_{F,del}}$$

$E_{P,extract}$ primary energy demand for fuel extraction

$E_{P,refine}$ primary energy demand for fuel processing/refining

$E_{P,transport}$ primary energy demand for transport of the fuel

$E_{P,F}$ primary energy content of the fuel

$E_{F,del}$ net energy content of the fuel delivered to the gate (using lower heating value)

Note A primary energy factor for one fuel may consist of different energy sources such as natural gas, oil and coal.

Lower heating values are used to convert primary energy and fuels into energy units. The factor is applicable for fuels used for district heating generation, electricity generation as well for fuels delivered into buildings where they are finally transformed into heat.

ii. CO_2-emission coefficients for fuels

The primary carbon dioxide emission coefficients are calculated by taking into account emissions that occur during extraction, processing/refining, storage, and transport of the fuels. The carbon dioxide emission coefficients of fuels are calculated according to:

$$K_P = K_{F,extract} + K_{F,refine} + K_{F,transport} + K_F$$

K_P primary carbon dioxide emission coefficient of the fuel (kg CO_2/MWh_{Hi})

$K_{F,extract}$ carbon dioxide emissions (kg CO_2) during extraction of 1 MWh_{Hi} of fuel

$K_{F,refine}$ carbon dioxide emissions (kg CO_2) during processing/refining of 1 MWh_{Hi} of fuel

$K_{F,transport}$ carbon dioxide emissions (kg CO_2) during transport of 1 MWh_{Hi} of fuel

K_F carbon dioxide emissions (kg CO_2) during combustion of 1 MWh_{Hi} of fuel

If no national values are given the following default values shall be used:

Table 3 — conversion factors

		f_P		K_P (kg/MWh$_{Hi}$)
		total	nren	CO_2, nren
fossil fuels	natural gas	1,1	1,1	230
	liquid gas	1,1	1,1	260
	light oil	1,1	1,1	290
	heavy oil	1,1	1,1	300
	coal	1,1	1,1	370
renewable	primary bio fuel	1,1	0,1	20
	refined primary bio fuel	1,2	0,2	40
recycled	secondary bio fuel	0,1	0,1	20
	refined secondary bio fuel	0,2	0,2	40
	residual fuel from another process	0,2	0,2	40
	municipal waste as fuel	0	0	0
	industrial waste heat	0	0	0
electricity		3	2,6	420

simplifications for external heat supply

If Q_{ext} is supplied to a district heating system and *EP/ES* of Q_{ext} are unknown default values are required. For this purpose default values may be determined on national level.

i. industrial waste heat

Industrial waste heat comes from processes whose primary purpose is the manufacturing of goods. It usually consists of a process-related component and a district heating component. The process-related component is the minimum amount of waste heat which is generated in the production process and must be released to the environment via cooling systems if not used for district heating. The energy input for this portion of the industrial waste heat is entirely allocated to the product and is evaluated using the primary energy factor and emission coefficient 0 (see table 3). The district heating component is the amount of additional heat that is required to supplement the process component in order to meet the requirements of the district heating system (e.g. boosting pressure, temperature and flow rate). The energy input for generating the district heating component shall be integrated into the numerator of the formulas above. If the district heating component cannot be identified a default value may be determined on national level. If no national default values are set, external heat from industrial sites is assessed with the f_P = 0,4, K_P = 90 kg/MWh, R = 0,6.

ii. heat from waste-to-energy plant

Municipal waste comes from processes whose primary purpose is not energy production. So its energy content is not allocated to the energy products (heat and electricity) and is evaluated using the primary energy factor and emission coefficient 0 (see table 3). The energy input for processes such as ignition, auxiliary firing and flue gas cleaning shall be integrated into the numerator of the formulas above. If this energy input cannot be identified a default value may be determined on national level. If no national default values are set, external heat from waste-to-energy plants is assessed with the f_P = 0,1, K_P = 25 kg/MWh, R = 0,9.

4. Default Values

Fuel class	Fuel/energy carrier	$f_{P,F,nren}$	$K_{F(i)}$ (kg CO_2/MWh)	$R_{F(i)}$
Fossil	Natural gas	1,1	230	0
Fossil	Liquid gas	1,1	260	0
Fossil	Light oil	1,1	290	0
Fossil	Heavy oil	1,1	300	0
Fossil	Coal	1,1	370	0
Fossil	Lignite	1,1	370	0
Renewable	Primary bio fuel, liquid	0,1	20	1
Renewable	Primary bio fuel, gas	0,1	20	1
Renewable	Primary bio fuel, wood	0,1	20	1
Renewable	Primary bio fuel, agricultural	0,1	20	1
Renewable	Refined primary bio fuel, liquid	0,2	40	1
Renewable	Refined primary bio fuel, gas	0,2	40	1
Renewable	Refined primary bio fuel, wood	0,2	40	1
Renewable	Refined primary bio fuel, agricultural	0,2	40	1
Recycled	Secondary bio fuel, liquid	0,1	20	1
Recycled	Secondary bio fuel, gas	0,1	20	1
Recycled	Secondary bio fuel, wood	0,1	20	1
Recycled	Secondary bio fuel, agricultural	0,1	20	1
Recycled	Refined Secondary bio fuel, liquid	0,2	40	1
Recycled	Refined Secondary bio fuel, gas	0,2	40	1
Recycled	Refined Secondary bio fuel, wood	0,2	40	1
Recycled	Refined Secondary bio fuel, agricultural	0,2	40	1
Recycled	Residual fuel from other process, gas	0,2	40	1
Recycled	Residual fuel from other process, liquid	0,2	40	1
Recycled	Residual fuel from other process, solid	0,2	40	1
Recycled	Waste as fuel, gas	0	0	1
Recycled	Waste as fuel, liquid	0	0	1
Recycled	Waste as fuel, solid	0	0	1
Recycled	Waste as heat	0	0	1
Renewable	Geothermal heat	0	0	1
Renewable	Solar heat	0	0	1
Electricity	Electricity	2,6	420	0,2

Notes