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Technical report on labeling criteria for DHC

Report prepared by:

IVL Swedish Environmental Research Institute

This report was elaborated in the framework of the Ecoheat4cities project supported by the Intelligent Energy Europe Programme.

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Project Summary

Project Partners

Supported by the Intelligent Energy Europe Programme (IEE), the Ecoheat4cities project promotes awareness and knowledge-based acceptance of District Heating and Cooling (DHC) systems through the establishment of a voluntary green heating and cooling label. The label will provide useful information on key energy related parameters of DHC systems to interested stakeholders throughout Europe and participating countries, including local policy makers, other DHC companies, citizens and related industries.

The three labeling criteria: **Renewability, Resource efficiency (Primary Energy Factor) and CO2 efficiency/emissions** reflect the aims of the EU 2020-targets and will thus enable stakeholders from all over Europe to see and show how District Heating and District Cooling can contribute to reaching the EU's energy targets and assess DHC as a competitive and viable option in Europe's heating and cooling market.

Project outcomes include:

- a label design tool, labeling governance and guidelines, including all details concerning the calculation methods as well as related technical and scientific background research on DH performance and best available and not available technologies;

- a tool enabling cities and municipal planners to compare different heating and cooling options;

- a guide for city planners and DHC companies to better understand the labeling process, also offering insight into how the label can provide added value and a green image.

The Ecoheat4cities label provides a way to measure sustainability and performance of DHC systems based on available and verified, local knowledge and resources.

If your organization would like to know more about the Ecoheat4cities green label, governance structure of the labeling scheme, or participate in any of its activities, please contact Euroheat & Power or its national partners. DHC companies and cities are actively invited to provide additional guidance and feedback about the on-going work by contacting us.

All information is available on the Ecoheat4cities website at
www.ecoheat4cities.eu

Preface

This is the technical report of the European Ecoheat4cities (E4C) project on labelling criteria. The overall goal of the Ecoheat4cities project is to support the implementation of the Renewable Energy Directive (2009/28/EC). The expected output from the project is to design and establish a voluntary European green energy labelling scheme striving to make renewable energy and energy efficiency in DHC applications a good choice and to accelerate the Renewable Energy Directive implementation. District heating and cooling (DHC) systems have the potential to substantially contribute to achieving the goals of the Renewable Energy Directive. The scheme shall be comparable between individual DHC systems, but also with alternative heating and cooling (individual heat pumps, boilers etc.).

The methodological work started with an overview of existing schemes and labelling systems assessing district heating. A long list of relevant environmental criteria was lifted out and grouped together to categories each one linked to the environmental performance of a district heating system. Next, three labelling criteria were chosen after a thorough evaluation. Finally, a methodology was elaborated for three identified labelling criteria.

This report defines three labelling criteria (primary energy, carbon dioxide emissions and share of renewable and recycled energy) and a methodology for the calculation of the criteria. The labelling system shall encourage the use of district heating of high environmental performance for European consumers, contributing to the goals of the Renewable Energy Directive (2009/28/EC).

Based on the three criteria, a number of DH systems will be test-labelled. The test-labelling phase will provide the project group with additional information on the practicability of the three criteria.

The report was prepared by Fredrik Martinsson, Jenny Gode and Jonas Höglund at IVL Swedish Environmental Research Institute. Expert comments were received from the steering group of the E4C project.

Report prepared by:

IVL Swedish Environmental Research Institute

Executive summary

The goal of this technical report is to evaluate *"energy and related environmental performance of DHC systems and their contribution to the 20-20-20 targets"*.

District heating and cooling (DHC) plays an important role in the transition from fossil to renewable energy in Europe. By using surplus heat from industrial processes, electricity production and waste (which otherwise would be wasted) as well as renewables, district heating reduces the need for fossil fuels to meet heating and cooling demands, in particular in urban areas. The potential for using more district heating in Europe is high. DHC has a large potential to contribute to achieving the EU goals of 20 % reduction in primary energy use, 20 % energy from renewable resources and 20 % reduction of greenhouse gas emissions by 2020 (the 20-20-20 targets).

The development and current status of the district heating market differ across Europe. The differences are explained e.g. by region specific policies addressing district heating, access and abundance of fossil fuel substitutes such as biomass resources, infrastructure and demography. There are a number of obstacles altering the development of district heating in Europe including difficulties to compare district heating with other options, the local character of the district heating infrastructure and the low public awareness of the environmental benefits of district heating.

Several policies and measures are in place regulating the environmental performance of district heating and cooling systems, but a comprehensive European system to account for energy as well as environmental performance of district heating is lacking. Nevertheless, a common European system could contribute to achieving the objectives of the Renewable Energy Sources Directive (2009/28/EC)[1] as well as the Energy Performance of Buildings Directive (2010/31/EC)[2]

Aim and purpose

The strategic scope of the Ecoheat4cities project is to stimulate the development of environmentally friendly district heating and cooling by establishing a green labelling scheme. The key challenges in this respect are to address the technical and performance aspects related to DHC. It is expected that the project should result in an ambitious and useful method to account for environmental performance of DHC systems.

The purpose with this report is to define criteria for evaluating energy and environmental performance of district heating and a method for the calculation of these. The methodology will encourage the use of district heating of high environmental performance for European consumers and to achieve the combined effects from the use of renewable and resource efficient energy sources, in the long run contributing to the goals of the Renewable Energy Directive. With the voluntary labelling system in place it should be possible for customers to compare the environmental benignity of heat from a given district heating network with alternative heating options such as heat pumps, boilers etc.

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[1] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources

[2] Directive 2010/31/EC of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)

Overview

The major output from this technical report is a short list of three labelling criteria and a methodology for the calculation of these. The first step was to collect a long list of environmental criteria addressing district heating. This was done by as a first step examining existing standards, regulations, policy documents, directives and other relevant sources where information regarding suitable criteria may be found. As a second step in the project, this list of relevant existing criteria was reviewed in order to select the most important ones best fulfilling the purpose of the study. Important aspects when compiling the short list have been that the criteria must allow for comparability with individual technologies, avoid incoherencies and conflicts with legislation in practice and allow for comparability between the countries. A methodology has also been developed for the calculation of criteria.

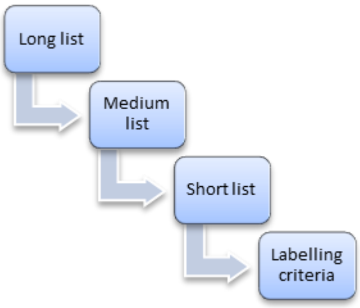
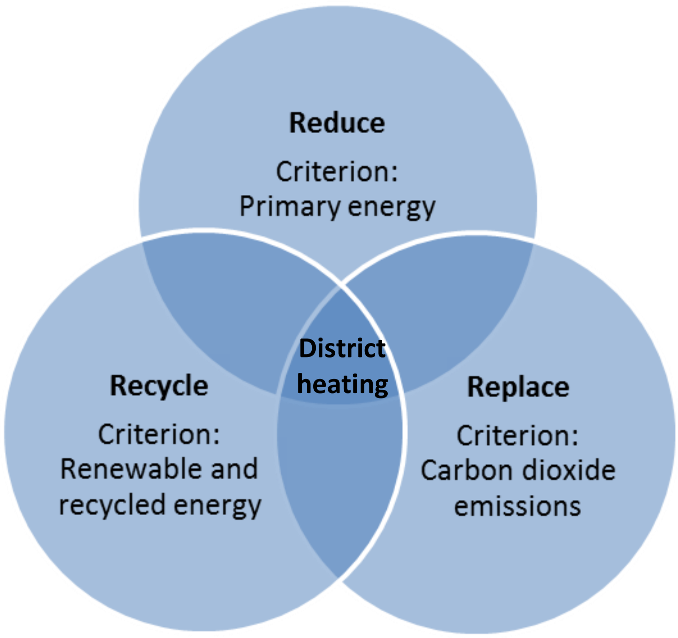


Figure 1 Overview of the selection process.

Three labelling criteria

The labelling criteria and methodology have been developed based on a thorough assessment of existing and future policies, standards, directives, certifications and other documents with criteria addressing environmental performance of district heating. All criteria found during the assessment were comprehensively analysed in order to find the best performing criteria to be included in the labelling scheme. The three criteria that were found to best meet the objectives of the labelling scheme are primary energy, carbon dioxide emissions and share of renewable and recycled energy. The reason for using these criteria is that they correspond well with the EU targets for renewable energy and allow for comparison between different heating technologies and their competitors. The E4C project has a strong European dimension in contributing to the 20-20-20 targets.

One way to illustrate the three criteria in the method and the interconnected relationship between them is to assign three “RE’s”; Reduce, Recycle and Replace. This means reducing primary energy use, recycle energy that would otherwise be wasted and replace fossil fuels. In the context of district heating and the E4C labelling criteria this corresponds to primary energy, share of renewable and surplus energy as well as carbon dioxide emissions. The three “RE’s” thus summarise the opportunities of district heating to contribute to the 20-20-20 targets.



Methodology

The methodology is developed mainly based on existing standards to ensure the best possible harmonization with the policy framework in Europe and allowing for comparison between district heating networks in Europe as well as with different heating alternatives. Strongly coupled to the EU 20-20-20 targets it is expected that the foreseen labelling scheme should contribute significantly to the achievement of the EU targets for reduction of primary energy use, greenhouse gas emission reduction and increased use of renewable energy.

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Terms and definitions

BAT benchmark	A potential criterion accounting for the performance of a DH boiler or specific DH technology in relation to a BAT system (best available technology). During the analytical work of this work package BAT benchmark was proposed as a potential criterion.
CHP directive	Directive 2004/8/EEC on the promotion of cogeneration based on useful heat demand in the internal energy market and amending Directive 92/42/EEC.
Criteria	In this report the term criteria refers to criteria assessing district heating, i.e. criteria that in some way can be linked to the environmental performance of a DHC system and that is lifted out from existing schemes, regulations, labelling etc.
DH	District Heating
DHC	District Heating and Cooling. The system presented in this report (the results from WP2) is solely taking district heating into consideration and not district cooling.
E4C	Ecoheat4cities
Evaluation principles	In this report evaluation principles refer to the basic conditions that must be fulfilled for each criterion to qualify to be included in the medium list.
Industrial surplus heat	Hot stream from industry that is a by-product, impossible to avoid at the production of the industrial product and could not be used inside for industrial production.
Long list	The first brief compilation of criteria in WP2 containing criteria assessing district heating.
Medium list	An intermediate list where the criteria are defined which will provide the basis for the labelling system.
Non-renewable energy	Non-renewable energy is energy taken from a source which is depleted on extraction (e.g. fossil fuels or nuclear energy)
Non-renewable primary energy factor	Non-renewable primary energy factor for a given energy carrier. Defined as non-renewable primary energy divided by delivered energy, where the non-renewable energy is that required to supply one unit of delivered energy, taking account of the non-renewable energy required for extraction, processing, storage, transport, generation, transformation, transmission, distribution and any other operation necessary for delivery to the building in which the delivered energy will be used. A low factor means lower use of non-renewable energy sources and/or high resource efficiency. Non-renewable energy factor can be less than unity if renewable energy is used.

Primary energy	Energy which has not been subjected to any transformation or conversion process (executed by mankind)
Short list	The expected outcomes from WP2 are presented in a short list containing the most highly performing criteria.
Total primary energy	Non-renewable and renewable primary energy.
Total primary energy factor	Non-renewable and renewable primary energy divided by delivered energy, where the primary energy is that required to supply one unit of delivered energy, taking account of the energy required for extraction, processing, storage, transport, generation, transformation, transmission, distribution, and any other operation necessary for delivery to the building
Residues	Residues from a process used as a fuel in energy conversion. Residues are considered not to any primary energy apart from primary energy used for collection, refining and transport of the residue.
Renewable and recycled energy fraction	Share of renewable and recycled energy of input fuels to district heating production.
RESD or RES directive	Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

Symbols, units and subscripts

The symbols, units and subscripts below are the same as in the European standards EN 15603 and prEN 15316-4-5.

Table 1. Symbols

Symbol		Unit
E	Energy in general	MWh
Q	Thermal work	MWh
W	Electrical or mechanical work	MWh
F	factor	-
Σ	Power to heat ratio	-
B	Relation between heat produced in chp and total produced heat	-
η	efficiency	-
Κ	CO_2 emission coefficient	g/kWh
R	Renewability and recycled energy coefficient	-

Table 2. Subscripts

P, p	Primary energy
Aux	Auxiliary
Del	Delivered
Dh	district heating (DH)
El	Electrical
Nren	non-renewable energy
F	Fuel
RES	renewable energy sources
Extr	Extraction
Ref	Refinery
Tpt	Transportation
Net	gross production minus auxiliary energy
Lhv	lower heating value
E	External
Hn	heating network
Tot	Total
Out	Output
In	Input
gen	Generation
T	Thermal

The overall goal of the Ecoheat4cities (EHC) project is to support the implementation of the Renewable Energy Directive (2009/28/EC). The expected output from the project is to design and establish a voluntary European green energy labelling scheme striving to make renewable energy and energy efficiency in DHC applications a good choice and to accelerate the Renewable Energy Directive implementation. The Renewable Energy Directive sets ambitious goals for the EU member states, such as decreasing the emissions of greenhouse gases and to increase the use of renewable energy sources. District heating and cooling (DHC) systems have the potential to become an even more important tool in achieving these goals. The scheme shall be comparable between individual DHC systems, but also with alternative heating and cooling (individual heat pumps, boilers etc.).

Overview of task 2.1 of work package 2

The major output from task 2.1 is a short list of three labelling criteria and a methodology for the calculation of these. The first step was to collect a long list of environmental criteria addressing district heating. This was done by as a first step examining existing standards, regulations, policy documents, directives and other relevant sources where information regarding suitable criteria may be found. As a second step in the project, this list of relevant existing criteria was reviewed in order to select the most important ones best fulfilling the purpose of the study. Important aspects when compiling the short list have been that the criteria must allow for comparability with individual technologies, avoid incoherencies and conflicts with legislation in practice and allow for comparability between the countries. A methodology has also been developed for the calculation of criteria.

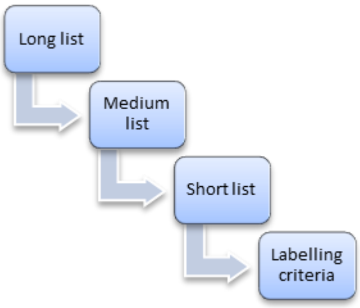

Figure 2 Overview of the selection process.

Part 1. Criteria calculation methodology

1. Summary of criteria and methodology

The following section summarises the E4C labelling criteria and methodology. For details and motivations of methodology choices as well as description of methodology choices, see PART 2 of the report.

1.1. Labelling criteria

The evaluation process of task 2.1 resulted in the recommendation to use the following labelling criteria:

Labelling criteria (all countries)	***Comment***	***Symbol***
Primary energy	Non-renewable primary energy factor ($MWh_{p,nren}/MWh_{dh}$)	$f_{P,dh,nren}$
Carbon dioxide emissions	CO_2 (kg CO_2/MWh_{dh})	$K_{,dh}$
Renewable and recycled energy fraction	Share of renewable and recycled (surplus) energy in fuel mix (%)	R_{dh}

Apart from the above-mentioned labelling criteria, optional information about the DH may also be added. The informative labels will be further discussed and decided upon in task 3 of the E4C project where the E4C labelling scheme will be implemented. Below are some examples of information that potentially could be provided in the labelling information:

Informative DH indicators (optional)	***Comment***
Fuel mix	
Renewable energy share	Included in R_{dh} labelling criteria together with recycled energy
Surplus energy share	Included in R_{dh} labelling criteria together with renewable energy
Environmental Impact (air and water pollutants)	
Nuclear waste	
System efficiency (ETA)	This indicator will be further investigated in a later stage of the E4C project.

1.2. Methodology

Below is a summary of important methodology parameters. The methodology is further explained in the following chapters.

Methodology parameter	***E4C***
CHP allocation method – primary energy	Power bonus method
CHP allocation method – CO_2	Power bonus method as described in Renewable Energy Sources Directive (2009/28/EC)
Electricity value	Two tiers; 1) EU default value ($f_{P,el}$ = 2.6, K_{el}= 420 kg/MWh, R_{el}= 0.19) 2) National values if other electricity value is stated by national law
$f_{P,F,nren}$	Non-renewable primary energy factors of fuels used for DH. Three tiers; 1) EU default values (see list in chapter 0) 2) National default values 3) Case-specific values
$f_{P,dh,nren}$	Non-renewable primary energy factors of DH (MWh/MWh$_{dh}$); $f_{P,dh,nren(i)} = \frac{\sum_{i=1}^{n} E_{F(i)} * f_{P,F,nren(i)} - (E_{el,chp} - E_{el,hn}) * f_{P,el,nren}}{\sum_{j=1}^{n} Q_{del,j}}$
K_{dh}	Carbon dioxide emissions of DH (kg/MWh$_{dh}$); $K_{dh} = \frac{\sum_{i=1}^{n} E_{F(i)} * K_{F,tot(i)} - \left(\sum_{i=1}^{n} \frac{E_{el,chp(i)} * K_{F,chp(i)}}{\eta_{el(i)}}\right)}{\sum_{j=1}^{n} Q_{del(j)}}$
R_{dh}	Share of renewable and recycled energy in DH fuel mix (%); $R_{dh} = 100 * \frac{\sum_{i=1}^{n} E_{F(i)} * R_{F(i)}}{E_F}$
System boundaries	Cradle to gate for fuels, cradle to delivered heat in buildings. System boundaries are further explained in Annex B.

2. Non-renewable primary energy factors

Non-renewable primary energy includes all fossil and nuclear energy resources as well as peat. These resources are depleted upon extraction. Examples of non-renewable primary energy sources are crude oil, coal and natural gas. Sometimes the terms *"primary energy resource"* or *"primary resource"* are used. However, the European standards EN 15603 and 15316 use "*non-renewable primary energy"*, and thus this term is used in the Ecoheat4cities project.

2.1. Non-renewable primary energy factors for fuels, $f_{P,F,nren}$

The non-renewable primary energy factors for fuels are calculated by taking into account losses that occur during extraction, processing/refining, storage and transport of the fuels (system boundaries 5-3 in Figure 7 of Annex B). For a given fuel the non-renewable 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 non-renewable primary energy required from cradle to the final use of one unit of fuel at the gate and is calculated accordingly:

Equation 1. Non-renewable energy factors for fuels

$$f_{P,F,nren} = \frac{E_{P,extr,nren} + E_{P,ref,nren} + E_{P,tpt,nren} + E_{P,F,nren}}{E_{F,del}}$$

where

$E_{P,extr,nren}$ = non-renewable primary energy demand for fuel extraction

$E_{P,ref,nren}$ = non-renewable primary energy demand for fuel processing/refining

$E_{P,tpt,nren}$ = non-renewable primary energy demand for transport of the fuel

$E_{P,F,nren}$ = non-renewable primary energy content of the fuel

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

Note that a non-renewable 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 non-renewable 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.

The E4C methodology allows for using three different tiers of non-renewable primary energy factors:

1. EU default values, $f_{P,F,nren}$
2. National default values, $f_{P,F,nren}$
3. Case-specific values, $f_{P,F,nren}$

Tier 1 non-renewable primary energy factors are listed in section 5. Note that these factors have been chosen since they are more conservative than non-renewable primary energy factors in other sources. Calculation of non-renewable primary energy factors in tier 2 or tier 3 should be made according to the formulas above. It is also to be noted that there is an ISO standard currently (2011) under development which aims to standardize the methodology for calculating primary energy factors. The ISO development is based on existing methodology in European standards. The outcome of this work should be implemented in the E4C methodology when completed.

2.2. Non-renewable primary energy factor for heat delivered to the building, $f_{P,dh,nren}$

For a given unit of delivered heat to a building (e.g. district heating or heat from individual natural gas boiler) the energy in the fuels is divided by the energy in the delivered heat. The non-renewable primary energy taken into account is all non-renewable primary energy required for extraction, processing, storage, transport, generation, transmission and distribution from cradle to beneficial heat (system boundaries 5-1 in Figure 7 of Annex B). Non-renewable primary energy factors for fuels used to deliver the heat are multiplied with lower heating value of the fuel in order to get the required non-renewable primary energy factor for DH.

Equation 2. Non-renewable primary energy factor for delivered heat (dh or Q_{del})

$$f_{P,dh,nren(i)} = \frac{\sum_{i=1}^{n} E_{F(i)} * f_{P,F,nren(i)} - (E_{el,chp} - E_{el,hn}) * f_{P,el,nren}}{\sum_{j=1}^{n} Q_{del,j}}$$

where

$f_{P,dh,nren(i)}$	=	non-renewable primary energy factor for delivered heat delivered to the building from a DH grid and/or individual heating system within a considered period (one year)
$f_{P,F,nren(i)}$	=	non-renewable primary energy factor for the fuel *i*
$E_{F(i)}$	=	net energy content of fuel *i* delivered to the gate where it is finally converted to heat (using lower heating value).
$f_{P,el,nren}$	=	non-renewable primary energy factor for electricity (according to Tier 1 or 2, see section 5 and 10).
$E_{el,chp}$	=	*net* produced electricity in co-generation plants measured at the output of the plant. Only applicable for electricity produced in combined heat and power mode.
$E_{el,nh}$	=	*all* use of electrical energy for operating the heating network
$Q_{del,j,}$	=	delivered heat to the building, j, at system boundary 1 (see Annex B). For DH this is the same as measured heat at system boundary 2[3] which is the primary side of the substation.

[3] As described in Annex B, for district heating there is a DH heat exchanger between system boundary 2 and 1. However, the efficiency is normally very high (close to 100%) and potential heat losses could often be recycled to the building. Therefore, it may be assumed that system boundary 2 equals system boundary 1 for district heating. If the efficiency of the district heating heat exchanger would be substantially below 100%, the environmental performance of all criteria would be overestimated (i.e. the values for e.g. $f_{P,dh,nren}$ would in reality be higher).

2.3. Non-renewable primary energy factor for delivered heat from a future heating system based on design data

To estimate the non-renewable primary energy factor for a planned future heating system where the delivered heat and produced electricity are lacking some design data must be known and used instead. Explanation and equations are presented in Annex C.

3. Carbon dioxide emission factors

Carbon dioxide emission factors describe the life cycle emission of carbon dioxide released when one energy unit, lower heating value, of a fuel is extracted, refined, stored and transported and finally converted to useful heat. The criterion is described in the unit kg CO_2 per MWh_{fuel} for fuels and kg CO_2 per MWh_{dh} for district heating.

3.1. Carbon dioxide emission factors for fuels, $K_{F,tot}$

The carbon dioxide emission factors are calculated by taking into account emissions that occur during extraction, processing/refining, storage, and transport of the fuels (system boundaries 5-3 in Figure 7 of Annex B). The carbon dioxide emission factors of fuels are calculated according to Equation 3:

Equation 3. Carbon dioxide factors for fuels

$$K_{F,tot} = K_{F,extr} + K_{F,ref} + K_{F,tpt} + K_{F,fuel}$$

where

$K_{F,tot}$ = total carbon dioxide emission factor of the fuel (kg CO_2/MWh_{fuel}, lower heating value)

$K_{F,extr}$ = carbon dioxide emissions (kg CO_2) during extraction of 1 MWh of fuel

$K_{F,ref}$ = carbon dioxide emissions (kg CO_2) during processing/refining of 1 MWh of fuel

$K_{F,tpt}$ = carbon dioxide emissions (kg CO_2) during transport of 1 MWh of fuel

$K_{F,fuel}$ = carbon dioxide emissions (kg CO_2) during combustion of 1 MWh of fuel

Default carbon dioxide emission factors for fuels in a life cycle perspective, Tier 1, are presented in section 5. Thus, the values represent both upstream (emissions during extraction, refining, transport etc.) and downstream (emissions from combustion of the fuels) emissions. Most of the downstream values are based on the guidelines of the United Nations Framework Convention on Climate Change (UNFCCC)[4] for national inventory reports of greenhouse gas emissions. The upstream emissions are mostly based on data compiled by IVL (Gode et al, 2011).

3.2. Carbon dioxide emission factors for delivered heat provided to the building, K_{dh}

To calculate the carbon dioxide emission factors for a district heating system, the emission factors of all fuels are multiplied with the lower heating value of the fuel and then divided by the delivered heat (see Equation 4). Carbon dioxide emissions from CHP plants are allocated between heat and electricity according to the power bonus method as described in the Renewable Energy Directive. A simplified version of this method can be used in exceptional cases when applying this method on a vast number

[4] IPCC 2006, Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Tables 1.4 and 2.2

of networks where detailed input information is scarce (see explanation and motivation in section 9).

Equation 4. Carbon dioxide emission factor for delivered heat

$$K_{dh} = \frac{\sum_{i=1}^{n} E_{F(i)} * K_{F,tot(i)} - \left(\sum_{i=1}^{n} \frac{E_{el,chp(i)} * K_{F,chp(i)}}{\eta_{el(i)}}\right)}{\sum_{j=1}^{n} Q_{del(j)}}$$

where

K_{dh} = carbon dioxide emission factor for delivered heat provided to the building, in kg CO_2/MWh

$K_{F,tot(i)}$ = carbon dioxide emission factor for fuel *i*, in kg CO_2/MWh_{fuel}

$E_{F(i)}$ = net energy content of fuel *i* delivered to the gate where it is finally converted to heat (using lower heating value).

$E_{el,chp(i)}$ = *net* produced electricity in co-generation plant from fuel *i* (Produced electricity minus auxiliary electricity use). Only applicable for CHP. If more than one fuel is used in CHP mode the electricity produced from fuel *i* can be approximated the energy input fraction from fuel i to the CHP ($E_{F(i)}/ E_{F,chp}$)

$K_{F,tot(i)}$ = carbon dioxide emission factor for fuel *i* used in CHP plant, in kg CO_2/MWh_{fuel}

$\eta_{el(i)}$ = net electrical efficiency in condensing mode for fuel *i*. Default values for each fuel are presented in Table 15 in chapter 10

$E_{el,nh}$ = *all* use of electrical energy for operating the heating network

$Q_{del,(j)l}$ = delivered heat to the building, j, at system boundary For DH this is the same as heat at system boundary 2[5].

3.3. Carbon dioxide emission factors for a future heating system based on design data

K_{dh} for a planned future DH system can be solved in a corresponding manner as non-renewable primary energy factor, see Annex C.

[5] As described in Annex B, for district heating there is a DH heat exchanger between system boundary 2 and 1. However, the efficiency is normally very high (close to 100%) and potential heat losses could often be recycled to the building. Therefore, it may be assumed that system boundary 2 equals system boundary 1 for district heating. If the efficiency of the district heating heat exchanger would be substantially below 100%, the environmental performance of all criteria would be overestimated (i.e. the values for e.g. $f_{P,dh,nren}$ would in reality be higher).

4. Renewable and recycled energy fraction

A major advantage of district heating is the possibility to use renewable fuels and surplus energy that would otherwise be wasted. The criterion renewable and recycled energy fraction (R_{dh}) is introduced to specifically support the use of renewable and surplus energy in district heating systems. The criterion is also needed to visualise the use of non-fossil fuels. It could be considered additional information to non-renewable primary energy factor. However, with the E4C methodology natural gas fired CHP plants will receive very low values for both non-renewable primary energy and carbon dioxide emissions, although natural gas is a fossil fuel. Therefore, the renewability and recycled energy fraction criterion adds important information for the labelling.

The criterion is calculated as the percentage of renewable and recycled energy content of the fuels delivered to the gate where they are finally converted. The primary energy input prior to the final energy conversion is thus not included. The renewable energy sources are all non-fossil and non-nuclear and are by definition not depleted upon extraction. This includes energy from sun, wind, water, biomass and geothermal sources. By definition renewable fuels should be produced in a sustainable way as stated in the RES directive. Recycled fuels are defined as secondary fuels such as municipal waste, industrial surplus heat and industrial residual fuels.

The calculation formula for the criterion renewable and recycled energy fraction is shown by Equation 5.

Equation 5. Renewable and recycled energy fraction

$$R_{dh} = 100 * \frac{\sum_{i=1}^{n} E_{F(i)} * R_{F(i)}}{E_F}$$

where

R_{dh} = Share of renewable and recycled energy of the district heating system, in %.

$R_{F(i)}$ = Renewable and recycled energy factor for fuel *i*, between 0-1. See list in section 1.1.

$E_{F(i)}$ = Energy content of fuel *i* delivered to the gate where it is finally converted to heat (using lower heating value).

E_F = Energy content of all fuels delivered to the gate where they are finally converted to heat (using lower heating value).

$R_{F(i)}$ values for all fuels are presented in chapter 5.2 (Table 4). The RF(i) values are defined so as to promote both renewable and recycled fuels. The $R_{F(i)}$ value for municipal waste is set to 1 as a default value. The value for electricity (R_{el}) varies between different years. The default value for EU27 electricity mix has been calculated using latest available statistics from 2008 with the result 0.19[6] (at Tier 1), see section 10.

[6] The percentage of the gross production from hydro power, wind power, geothermal power, municipal waste, wood, biogas, industrial waste and derived gas are added to get the total of 19 % renewables and recycled energy (17 % renewables).

5. E4C default values

5.1. EU default values for fuels – $f_{P,F,nren}$, K_{dh}, R_{dh}

Table 3 Default values (Tier 1) for $f_{P,F,nren}$ and $K_{F,tot}$

Fuel/energy carrier	$f_{P,F,nren}$		$K_{F(i)}$ (kg CO_2 /MWh)		$R_{F(i)}$	
		Source		**Source (upstream/combustion)**		**Motive (see also section 5.2 below)**
Lignite	1.02	ELCD DATBASE 2.0	369	ELCD DATBASE 2.0/IPCC 2006	0	Non-renewable, non-recycled
Hard Coal	1.19	CEN 15603:2008	369	IVL 2010/IPCC 2006	0	Non-renewable, non-recycled
Heavy fuel oil	1.35	CEN 15603:2008	296	IVL 2010/IPCC 2006	0	Non-renewable, non-recycled
Light fuel oil	1.35	CEN 15603:2008	283	IVL 2010/IPCC 2006	0	Non-renewable, non-recycled
Natural Gas	1.36	CEN 15603:2008	222	IVL 2010/IPCC 2006	0	Non-renewable, non-recycled
Peat	1.02	IVL 2010	417	IVL 2010/Swedish NIR	0	Non-renewable, non-recycled
Bioenergy (primary)	0.1	CEN 15603:2008	7	IVL 2010	1	Renewable, non-recycled
Bioenergy (refined)[7]	0.2	AGFW FW 309	12	IVL 2010	1	Renewable, (sometimes recycled)
Bioenergy (secondary)	0.06	CEN 15603:2008	3	IVL 2010	1	Renewable, recycled
Residual fuel[8]	0.05	IVL 2010	88	IVL 2010[8]	1	Recycled, (sometimes renewable)
Waste as fuel	0	PCR	94	IVL 2010/IPCC 2006	1	Recycled energy (partly renewable)
Electricity (input and output)	2.6	Calculation based on Eurostat statistics[9]	420	Calculation based on Eurostat statistics[9]	0.19	Partly renewable, partly recycled
Industrial waste heat	0	By definition (see chapter 8.3)	0	By definition (see section 8.3)	1	Recycled, (sometimes renewable)
Geothermal heat[10]	0	AGFW FW 309	0	AGFW FW 309	1	Renewable
Solar heat	0	Does not include the plant construction etc.	0	Does not include the plant construction etc.	1	Renewable

[7] Assumed to be biomass briquettes (upstream)
[8] Assumed to be a mix of paper, wood and plastics (upstream)
[9] Statistics can be found at: http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database. Simplified calculations are presented in section 10.
[10] In this report both deep geothermal heat and geothermal heat are included although there are physical differences in the origins between the two energy sources

5.2. Default values – R_F as well as renewable and recycled energy factors

Table 4. Default values for R_F for fuels and the derivation of these

Fuel	Renewable energy factor	Recycled energy factor	$R_{F(i)}$
Lignite	0	0	0
Hard Coal	0	0	0
Heavy fuel oil	0	0	0
Light fuel oil	0	0	0
Natural Gas	0	0	0
Peat	0	0	0
Bioenergy (primary)	1	0	1
Bioenergy (refined)	1	0-1	1
Bioenergy (secondary)	1	1	1
Residual fuel	0-1	1	1
Waste as fuel	0.5	1	1
Electricity (consumed)	0.17	0.02	0.19
Industrial surplus heat	0-1	1	1
Geothermal heat	1	0	1
Solar heat	1	0	1

5.3. Default values – design data

Table 5. Example of design input data for calculations of the default DH networks

District heating	*efficiency generation, η_3=$\eta_{T,gen}$*	*efficiency heating network, η_2=η_{nh}*	*El/heat, σ*	*Net generated el/ tot fuel input*	[11]*Auxiliary electricity, β_{aux}*
DH Natural Gas (NGCC12)	0.95	0.88	0.95	0.41	0.04
DH Natural Gas (DH)	0.95	0.88	-	-0.05	0.04
DH Coal (CHP)	0.95	0.88	0.45	0.24	0.04
DH Heat pump (COP = 3.5)	3.50	0.88	-	-0.05	0.04
DH Biomass (CHP)	1.00	0.88	0.4	0.27	0.04
DH Biomass (DH)	0.95	0.88	-	0	0.04
DH Waste to heat (CHP)	1.00	0.88	0.3	0.18	0.04
DH Waste to heat	0.90	0.88	-	0	0.04
DH Industrial surplus heat		0.88	-	0	0.04

Table 6. Example of design input data for calculations of the default individual heating system

Individual heating	*efficiency, generation, η_1*	*Auxiliary electricity, % of delivered heat*
Natural gas (individual boiler)	0.90	0.04
Heat Pump (COP =3)	3.00	0.04
Electricity (electrical radiators)	1.00	0
Biomass (pellet boiler)	0.85	0.04

[11] Average auxiliary electricity for Swedish DH networks
[12] NGCC (natural gas combined cycle) gas turbine combined with a steam cycle.

5.4. Example values – DH from CHP

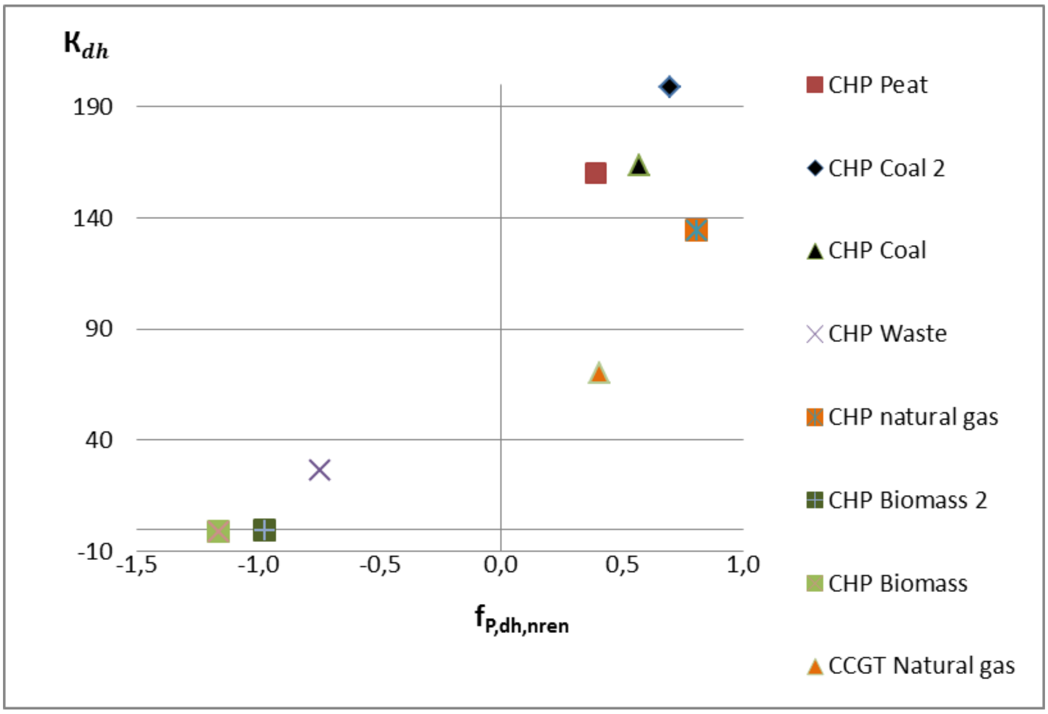

Figure 3. Example calculations (values below zero are not put to zero for informative reasons).

Table 7. Calculated default values for $f_{P,dh,nren}$ and K_{dh}

District heating	$f_{P,dh,nren}$	K_{dh} ***[kg/MWh$_{lhv}$]***
CHP Peat	0.39	174
CHP Coal 2	0.70	137
CHP Coal	0.57	113
CHP Waste	-0.75	67
CHP natural gas	0.81	50
CHP Biomass 2	-0.97	1
CHP Biomass	-1.16	1
CCGT Natural gas	0.41	-62
Building specific heating	$f_{P,Q,nren}$	$K_{Q,del}$ ***[kg/MWh$_{lhv}$]***
Natural gas (individual boiler)	1.67	224
Heat Pump (COP =3)	1.00	141
Electricity (electrical radiators)	2.6	425
Biomass (Pellet boiler)	0.2	14

6. Validation and variation of data

The result of the calculation can vary a lot between different years due to the annual climate and unpredicted events. For an existing network an average value for the last three years can be used. If substantial changes are made in the network (for example change in fuel mix) the $f_{P,dh,nren}$ and K_{dh} should be updated. The average value should then be taken from that year and further on.

Part 2. Selection, description and motivation of labelling criteria and methodology

7. Selection of labelling criteria – long list to short list

7.1. Long list

The Long list is the first compilation of sources and references with different criteria assessing district heating. A number of relevant EU documents, national standards and regulations as well as country specific environmental certifications schemes (hereinafter referred to as sources) were collected from the EU27 countries. This overview included European rules and recommendations such as Eco-design implementations of boilers and heaters, Euroheat & Power Guidelines for the certification of pipes, policy documents, assessment schemes etc. The long list was based on information from the partners of the E4C project to ensure a comprehensive screening of relevant documents. Information was provided from project partners in Denmark, Germany, Netherlands, UK, Lithuania and Sweden (see Table 8). The long list was general and broad and included all the criteria that might indicate environmental performance.

Table 8. Examples of sources in the long list

EU directives	EC Decision Heat Pump Ecolabel of heat pumps Background Report EU ECO label for heating systems Ecodesign Directive 2009/125/EC, Annex I 1.3 Heating systems in buildings - Doc. CEN/TC 228 N544 Energy performance of buildings - CEN/BT WG173 CHP - Green Public Procurement Product Sheet and Technical Background Report IPPC Directive
UK	Energy Performance Certificates (DECs) / Display Energy Certificates (DECs)
Netherlands	NEN-EN 15316-4-5 (standard for determining the primary energy factor of DHC)
Denmark	Research on Primary Resource Factors
Germany	Din V, AGFW Technical Regulations
Sweden	Reko fjärrvärme (Swedish DH Association, market label) Bra Miljöval Värme Svanen (wood pellets, heating pumps, residential stoves) Fjärrvärden R&D project District heating code (Fjärrvärmelagen) Ecolabel Swedish DHC Company Norrenergi
Lithuania	DH systems efficiency, NCCPE
Nordic	Nordic Ecolabelling of Heat Pumps

A summary of criteria categories from the long list is shown in Table 9 and the resulting complete long list can be found in Annex A.

Table 9 Examples of criteria found in each category.

Criteria category	*Examples of criteria found in sources*
Energy efficiency	COP, efficiency rates, losses etc.
Primary energy or primary resource	Primary energy/resource use in LCA perspective
Climate impact (GHG)	CO_2, GHG, methane leakage, leakage of refrigerants etc.
Environmental impact	Air quality, land use, acidification, eutrophication, biodiversity etc.
Renewable share, non-fossil share	
Fuel/energy source origin	Biogenic or fossil, prohibition of GMO:s, FSC requirements etc.
Security of supply	Reliability, age of system/lifetime, interruptions etc.
Customer relations, quality, public acceptance	Noise, smell, prices, information, eco management system
Market aspects/Financial report	investments, price information, third party access etc.
Other	fuel storage, waste plan, boiler type etc.

7.2. Medium list

Many of the criteria of the long list were similar, or served the same purpose. Therefore they were grouped into criteria categories. These were presented and discussed at a project meeting in Brussels in October 2010. The meeting decided upon a medium list that should be evaluated and assessed further before the final establishment of the short list. The criteria included in the medium list are summarised in Table 10.

Table 10 Medium list criteria.

Criteria	*Explanation/comment*
Criteria decided by E4C project group to evaluate:	
Greenhouse gas emissions	Different greenhouse gases have different relative climate impact. CO_2 accounts for the total largest climate impact from the energy sector, and must be included. N_2O and CH_4 emissions are dependent on the technical performance of individual boilers and fuels and are more difficult to define. There are also indirect climate gases (e.g. NO_x), but they are excluded due to large uncertainty about the effects.
Primary Energy in some way (f_P or $f_{P,nren}$)	Primary energy is directly linked to the purpose of the study. However, decision has to be made whether to use primary energy factor, f_P , or non-renewable primary energy factor, $f_{P,nren}$. The use of $f_{P,nren}$ reveals the share of non-renewables in a system, whereas f_P covers all primary energy (non-renewable as well as renewable energy). In a later stage of E4C WP2, it was decided to use $f_{P,nren}$ (see part 2).
Renewability	Show the share (0-100 %) of renewable energy compared to total fuel input. The criterion visualises the use of fossil fuels. It gives extra information to $f_{P,nren}$ since very low $f_{P,nren}$ may be achieved for high-efficient natural gas CHP.
Emissions of air and water pollutants	The environmental impact of e.g. NH_3, NO_x, SO_2 and particles should ideally be included in a labelling scheme. However, emissions such as particles are hard to measure correctly and the impacts depend on local conditions. Available data might be scarce. Furthermore, these emissions are already regulated.
Nuclear waste	DH production may cause a share of nuclear waste (from use of electricity). A criterion for nuclear waste would stimulate reduction of GHG emissions but on the other hand contradict the objective of renewable fuels (a large fraction of nuclear waste per kWh of heat would, in most cases, mean heat with low GHG emissions).
Surplus Energy	Surplus energy refers to surplus heat from industrial processes, heat from waste (CHP) and heat from combustion of surplus fuels (e.g. gasworks gas). Surplus energy is an unintended products resulting from other processes.
In addition to the criteria above IVL Swedish Environmental Research Institute decided to evaluate the following criteria:	
BAT benchmark[13]	A criteria visualizing the plant efficiency in relation to best available technology, BAT. The heating system would be benchmarked to a comparable system with the same fuel. The disadvantage is the need to find and define BAT systems and at the same time consider the diversity of DH technologies and sizes all over Europe.
Electricity Surplus	By electricity surplus we mean produced electricity minus used electricity for DH production. It is a criterion for visualization of electricity production in CHP.

[13] BAT Benchmark was proposed as a potential criterion during the analytical work of this work package. The criterion accounts for the performance of a DH boiler or specific DH technology in relation to a BAT system (best available technology).

7.2.1. Assessment of the medium list

The criteria identified in the medium list are not equally important; some may overlap others or may not be possible to include in a DHC scheme for practical reasons. To overcome this issue it was decided that the criteria must fulfil the following basic evaluation principles:

Evaluation principle	*Description*
Measurable?	Some criteria may not be possible to measure making them unsuitable as part of the scheme. For instance, particle matter is problematic to measure.
Unregulated on DH-level?	If the criterion in question is already regulated at district heating-level it might be unnecessary to include it in the scheme. Emissions to air may be regulated at DH-level, but not on national level.
Statistics available?	If statistics are available or not is of major importance for the practical implementation of a scheme. In the case of GHG emissions there are emission factors available for most fuels in the National Inventory Reports and default factors accessible from the RES directive. In the case of PEF´s only some default values may be available.
Possible for comparison to alternatives?	It is important that all performance criteria are possible to compare to alternatives to district heating (individual systems such as heat pumps). Surplus energy for example may only be relevant for some alternatives.
Understandable for target groups?	The components of at DH-scheme must be understandable for the target groups (DH-companies/labelling bodies, municipalities).

All criteria were rated according to how well they fulfilled the evaluation principles above. A summary of the evaluation is shown below and in Table 11.

Table 11. Criteria evaluated in the medium list.

Greenhouse gas emissions, GHG	*Primary energy, f_P*	*Renewability*	*Surplus energy*
Serves the goals of the scheme. Proposed as threshold. Can easily be compared to alternatives.	***Serves the goals of the scheme.*** Proposed as threshold. Can be compared with alternatives.	***Serves the goals of the scheme.*** Proposed as threshold. Supplementary criteria to GHG and $f_{P,nren}$.	***Serves the goals of the scheme.*** Proposed as threshold criterion together with renewability in a later stage of the evaluation.
Emissions to air and water	***Nuclear waste***	***Electricity surplus***	***BAT benchmark***
Impact dependent on local conditions. Covered by national legislation, difficult to measure.	Involves difficulties about choosing electricity mix. May contradict the labelling purpose.	Promotes efficient CHP but so does f_P and GHG. Industrial surplus will get a low value.	Overlaps with $f_{p,nren}$, but could be used as supplementary information to $f_{P,nren}$.

Criteria qualifying for the short list

As shown from Table 11 three criteria turned out to comply best with the evaluation principles; greenhouse gas emissions, primary energy in some way and renewability. All these criteria are explained in more detail in the methodology chapter.

Motivation of criteria not qualifying for the short list

Emissions to air and water do not qualify for the short list because its impact on the surrounding area is heavily dependent on where the actual district heating system is situated. Moreover, a criterion based on other emissions such as particles is hard to measure making it unsuitable as a criterion for the DHC scheme.

Nuclear waste is discarded because such a criterion involves difficulties about choosing a proper electricity mix. A criterion measuring the amount of nuclear waste generated for district heating may also be contra-productive in the way that low nuclear waste is not equal to low greenhouse gas emissions, which is one of the objectives of the labelling scheme.

BAT benchmark could be used as additional information to primary energy/primary resource, but does not qualify as labelling criterion because it may be difficult to calculate for complicated CHP systems (e.g. co-combustion plants). It also overlaps with non-renewable primary energy.

Surplus energy is tricky to use as a criterion since it overlaps with primary energy. It is also of a very local character since the availability of surplus energy may depend on industries in the surrounding area and it might be difficult to understand for the target group as the definition of surplus energy is unclear.

Electricity surplus (electricity produced minus electricity use) promotes efficient CHP but is partly overlapping with both primary energy and greenhouse gas emissions. Electricity surplus is also dependent on plant scale (larger plants usually mean higher electricity surplus) and gives a low value for industrial surplus heat, something that the scheme should promote.

7.2.2. Informative or threshold?

When including the selected criteria in a labelling scheme it is not possible to assign a value to all. Some criteria are more relevant as information and others as thresholds.

Criteria with local characters for example may not be suitable as threshold criteria. The same is valid for emissions to air and water. The impact of the emissions is dependent on e.g. how sensitive the surrounding environment is to emissions, how densely populated the area is, the resistance for acidification etc.

Other criteria that are more relevant as information are criteria which are hard to measure such as nuclear waste.

Greenhouse gases, primary energy and renewability are examples of criteria that could function as thresholds.

7.3. Short list

The short list includes the criteria that best meet the objective of the labelling scheme. The actual label can only be based on a limited number of environmental criteria to avoid getting too complex and hard to implement.

7.3.1. Recommended short list

Based on the previous assessment the following three criteria were chosen for the short list:

- Greenhouse gas emissions in some way, either CO_2 only or CO_{2eq}[14]
- Primary energy in some way
- Renewable and recycled energy fraction. Note that recycled energy was added to this criterion to support use of energy sources that would otherwise be wasted. Using renewability only would disfavour some surplus energy, such as municipal waste.

These criteria are best fulfilling the goals for the scheme and the methodology in chapter 5 is based on these criteria. The selected criteria correspond well with the aim of the labelling system as well as with the EU 20-20-20 targets. The definition of the criteria and the methodology for calculating them are presented in chapter 1 and onwards.

Criteria that may be used for additional information or as supplementary indicators are e.g. electricity surplus, surplus energy, nuclear waste and environmental impact.

Strengths and weaknesses of the criteria

The strength of the criteria carbon dioxide emissions, primary energy and renewable and recycled energy is the consistency in their purpose of fulfilling the goals set up for the labelling-system. Carbon dioxide emissions do already have a common methodology (the methodology pointed out in RES directive, IPCC etc.) and will easily be understood for all parts of interests. Both carbon dioxide emissions and primary energy also rate high regarding how straightforwardly the criteria can be compared to the alternatives. A further strength is that none of the criteria are regulated on DH grid level which will avoid possible legislation conflicts.

The weaknesses of both carbon dioxide emissions and primary energy are the difficulties to the determine factors for by-products used as fuels and surplus energy. The results are highly dependent on how allocations are made in the earlier lifecycle and the method can vary from case to case. For carbon dioxide emissions the methodology is more defined in the RESD but still not completely clear for surplus energy (e.g. industrial surplus energy and use of waste and by-products for heat).

The reason why renewability doesn't fulfil the evaluation criteria as well as the others is partly because it has not been considered to promote the use of surplus energy as well as the others. Renewability in any kind of surplus energy is hard to define since the primary energy use is allocated to the main processes from where the surplus energy originate.

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[14] CO_{2eq} = CO_2 equivalents taking into account the climate effect of other greenhouse gases than carbon dioxide, e.g. methane and nitrous oxide.

8. Assessment of waste, surplus heat, geothermal heat and electricity

8.1. Waste to heat

The system boundaries for waste as fuel are different from other fuels. Waste has in its prior life been a product in which non-renewable primary energy for extracting and refining already are included in a life cycle assessment for the product. In E4C the included non-renewable primary energy are only those needed to use the generated heat after the incineration. This is according to the polluter pays principle stated in the PCR[15]. In practice only auxiliary electricity for distribution is included. A default value of 5 % auxiliary electricity compared to the distributed district heating can be used.

Note that the definition of waste does not include co-products with an alternative use, e.g. the use of cake from biodiesel production for energy purposes. In this case the share of used non-renewable primary energy should be allocated by physical allocation methods according to RESD.

The $R_{F(i)}$ value for municipal waste is set to 1 as a default value.

8.2. Residues to heat

The RESD states that for agricultural crop residues and residues from processing, no emissions occurring prior to collection should be included. In the directive the zero emission exception for residues from processing is restricted to agricultural crops, but it is reasonable to anticipate that this is also valid for saw-mill by products and clear-cutting residues.

In E4C (according to definition above) the non-renewable primary energy factor for residual fuel will be defined as all non-renewable primary energy used after the collection of the fuel according to the RESD, for instance transport of residues from industrial processes to the district heating plant.

Fossil carbon dioxide emissions from the incineration will be included in this case.

8.3. Industrial surplus heat

Industrial surplus heat comes from processes where the main purpose is to manufacture goods. According to CEN 15316:4:5 industrial waste heat is *"Hot streams from industry that is a by-product, impossible to avoid at the production of the industrial product and could not be used inside for industrial production. High quality heat from industry that can be used to produce electricity are not considered as surplus heat*". This is also the definition chosen in E4C methodology.

Auxiliary non-renewable primary energy for distribution of the industrial waste heat shall be included as well as carbon dioxide emissions resulting from use of auxiliary energy. However these emissions are included when the auxiliary electricity for the whole district heating network is included in the total emissions. Therefore zero emissions can be assumed for the industrial surplus heat delivered to the DH network

[15] Product category rules for preparing an environmental product declaration for Electricity, steam, hot and cold water generation and distribution. Version 1.1

For industrial surplus heat with a lower temperature than district heating that needs to be upgraded the non-renewable primary energy and carbon dioxide emissions for auxiliary energy needed for upgrading the heat to district heating shall be included (this normally means higher use of electricity in the DH fuel mix).

8.4. (Deep) geothermal energy

The non-renewable primary energy factor for (deep) geothermal energy is set to 0. As for all other upgrading of the heat, the non-renewable primary energy and carbon dioxide emissions from the auxiliary energy must be added.

8.5. Electricity values – non-renewable primary energy factor and carbon dioxide emission factor

The default value (Tier 1) for $f_{\mathrm{P,el,nren}}$ is 2.6. This number is valid for EU27 electricity mix in 2008. It has been calculated using the power bonus method and statistics from Eurostat[16]. In many European countries this also reflects what electricity would meet an extra demand of electricity (marginal electricity).

The default value for carbon dioxide emission, $K_{el,}$ is valid for the same electricity mix and is calculated to 420 kg CO_2 per MWh of electricity. This reflects the life cycle emissions, see simplified calculations presented in chapter 10.

[16] Statistics can be found at http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database

9. Allocation methods

Allocation is in general needed to share the environmental burdens for a process where more than one product is produced. Regarding district heating, allocation is most of all needed to share environmental burdens between heat and electricity produced in combined heat and power plants. There is no physical law that will determine how much the heat and electricity should get of the burden. Since there is no exact truth, the allocation method can be decided upon other decisions. An allocation method can be chosen for many reasons. For example because it;

- best reflects the real consequences of using heat and electricity,
- reflects a political direction (make the "best" choice[17] the most favourable)
- is hard to question because of the methods robustness, giving the same result all the time.
- Etc. etc.

9.1. Description of analysed primary energy allocations

The choice of allocation method for non-renewable primary energy was <u>not</u> made upon an analysis of different methodologies. There is already an existing solid methodology, the Power Bonus method, in use which described in the CEN-standard 15316-4-5[18] as well as in the Renewable Energy Directive. This method is also used in the Ecoheatcool methodology.

The decision to use this method was made upon a consensus decision at a E4C steering group meeting in Stockholm 8-9th of December 2010.

9.2. Description of analysed CO_2 allocations

9.2.1. Power Bonus method

Background, philosophy and principles behind the Power bonus method

The power bonus method is well described in the CEN-standard 15316-4-5[19]. This method describes allocation of **primary energy** in a combined heat and power plant. The exact use of the power bonus method for allocation of carbon dioxide emissions is however not described in detail in the standard.

Normally the Power Bonus method is used to describe what happens in the energy system when there is a change in the use of district heating[20]. The consequence of increasing the use of heat from an existing CHP plant is that more CHP electricity will be produced and replace "other" electricity. Consequently, in the power bonus method, the heat is given a "CO_2 credit" for that replaced electricity. The CO_2 value for the heat is calculated by subtracting the emissions of the replaced electricity from the total CHP emissions (see formulas in Annex D). Depending on the purpose of the method different assumptions may be made regarding the replaced electricity.

[17] For example from a socioeconomically aspect

[18] prEN 15316-4-5 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-5: Space heating generation systems, the performance and quality of district heating and large volume systems.

[19] prEN 15316-4-5 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-5: Space heating generation systems, the performance and quality of district heating and large volume systems.

[20] This purpose of the method is most of all valid when marginal electricity is used as credit

Consequently, there are various interpretations of the Power bonus method. Three different interpretations of the Power Bonus method were investigated:

I. **Power Bonus Simple**[21]

Principle:

- The credit the heat gets for the replaced electricity is assumed to be the same as emissions from European average electricity.
- In this case the carbon dioxide emissions are assumed to be 558 gram per kWh electricity[22].

Evaluation:

- This is not a pure "allocation method" where the separate emissions from the heat and electricity will sum up to the total emissions from the CHP. It is a system expansion method because emissions outside the studies system is taken into account.
- It gives zero emissions for heat from most DH networks with large CHP share in Sweden. This might be considered as unfair since there obviously are CO_2 emissions from e.g. a NGCC.
- The method might be more difficult to communicate / less credible and is therefore not recommended.

II. **Power Bonus RES**[21]

Principle:

- In the RESD[23] the following definition can be found. *"The greenhouse gas emission saving associated with that excess electricity shall be taken to be equal to the amount of greenhouse gas that would be emitted when an equal amount of electricity was generated in a power plant using the same fuel as the cogeneration unit".*
- The interpretation is that the replaced electricity is produced in condensing mode with the same fuel and with electricity efficiency specific for that particular fuel. The used reference efficiencies can be found in a EU commission decision of 21 December 2006[24]

Evaluation:

- This method will not give negative values since the produced electricity in a CHP unit is always lower than with the same amount of fuel in a condensing power plant (electricity efficiency usual decrease with 15-20 %).
- It can be seen as a pure allocation method without system expansion (no emissions outside the CHP plant will be included and the total emissions from the plant are equal to the emissions from heat and electricity).
- The heat will get the benefit from the increased overall efficiency in CHP plant compared to a heat-only boiler

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21 Formulas are presented in Annex D

22 CO_2 in an LCA perspective. Value from 2002. Source: PE INTERNATIONAL published in the ELCD database. **This value was used as an assumption since the calculation of CO_2 value wasn't finished** yet.

23 Described in Annex V article 16 in Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

24 COMMISSION DECISION of 21 December 2006 establishing harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2004/8/EC of the European Parliament and of the Council

- The method requires more input data than the other methods and uses a somewhat more complicated calculation procedure. However this method serves the objectives of the E4C-method to promote both efficient DH and the use of renewables (reflected in a balanced way also in the CO_2 emissions) and is therefore recommended.

III. Power Bonus RES SIMPLE[21]

Principle:

- The only difference from **Power Bonus RES** is that the fuels specific electrical efficiency is replaced by a general electrical efficiency of 40 %. This will make the calculations procedure easier.

Evaluation:

- The method gives about the same result as the Power bonus RES method.
- In extreme cases where the CHP plants electrical efficiency is higher than 40 % it would be possible to get zero emissions.
- The method is recommended for exceptional cases when preforming calculations on a vast number of networks with poor input data since the method is very similar to the Power bonus RES method, but easier to use.

9.2.2. The Dresden Method or Decreased electricity production method

This method is described in a German power point presentation[25] and in a report from IVL[26]. The method reflects the consequences of extracting heat from CHP plants compared to a pure condencing power plant, i.e. decreased electricity efficiency. The consequence of using the heat is calculated by using the “decreased electricity production method” (DEPM). The DEPM calculate the emissions for heat in CHP plants by examining the decrease in electricity production when the power plant is used as CHP plant instead of only producing electricity. The produced heat in CHP plant gets the “CO_2-burden” for this decrease in electricity. This is done by calculating the possible electrical generation from the exergy content in the heat. For calculation procedure[27], see Annex D. In the report from IVL the power loss is regarded as marginal electricity from the grid and in the Dresden method the lost power is produced with the same fuel as used in the CHP plant. As for the power bonus method the purpose of the method will determine which electricity to use. Unfortunately this method was regarded in the discussions too late to be thoroughly investigated.

9.2.3. Other allocation methods

The following allocation methods have been discussed and analysed but are not recommended mainly due to inconsistency with the E4C methodology for calculating non-renewable primary energy factors:

- Alternative production method
- Energy allocation
- Economic allocation
- Exergy allocation

[25] Dresdner Methode Aufteilung von Koppelprodukten in der Kraft-Wärme-Kopplung, 27.01.2011

[26] Särnholm et al 2009, sustainable cities’ energy demand and supply for heating and cooling. Svenk Fjärrvärme 2009. Stockholm

[27] Note that the calculation procedure is **not** taken from any defined formula in standard. It is an interpretation of a formula that fits the definition. There may be other ways of interpretation.

The sources for different allocation methods can be seen in Table 12.

Table 12 Description of sources for different allocation methods

	RESD	CHPD	prEN 15316	PCR	Ecoheat-cool	AGFW
Alternative production method		X		X		
Energy method	X					
Power bonus(credit for el mix)	X		X		X	X
Power bonus, (credit marginal el.)			X			
Exergy method[28]	-	-	-	-	-	-
Economic[28] allocation	-	-	-	-	-	-

9.2.4. Conclusions

- Power Bonus method has been decided for calculation of non-renewable primary energy factors in E4C.
- Power Bonus method is suitable for markets which already use CHP.
- Power Bonus method reflects the objectives of the E4C project to promote effective DH and the use of renewables in a balanced way.
- Power Bonus RES[29] method comes from an existing well-known document.
- Power Bonus RES SIMPLE is an easier version which gives almost the same result as Power Bonus RES
- The Dresden method (DEPM by IVL) is most of all suitable for investigating consequences of introducing CHP on heat markets where CHP doesn't exist. The majority of the countries which will be labelled in E4C already have CHP and the method will then not reflect the reality.

Figure 4 shows that the results are relatively independent on choice of allocation method. On the other hand, the Power Bonus RES and Power bonus RES SIMPLE methods originate from an existing, official and well known source and are therefore recommended before the Dresden method. Furthermore, the Power Bonus RES method is recommended before the Power Bonus RES SIMPLE method due to the fact that it is more trustworthy to use (it is a method defined in widely accepted official documents). In exceptional cases when applying this method on a vast number of networks where the details in the input information are poor the Power Bonus RES SIMPLE may be used in order to analyse the data. The differences in the results are, as mentioned before, often very small (shown in Figure 4).

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[28] Not found in any of the relevant sources however they are used in various cases

[29] using credit for the from electricity as it was produced in condensing mode with the same fuel used with this fuels specific electricity generation efficiency.

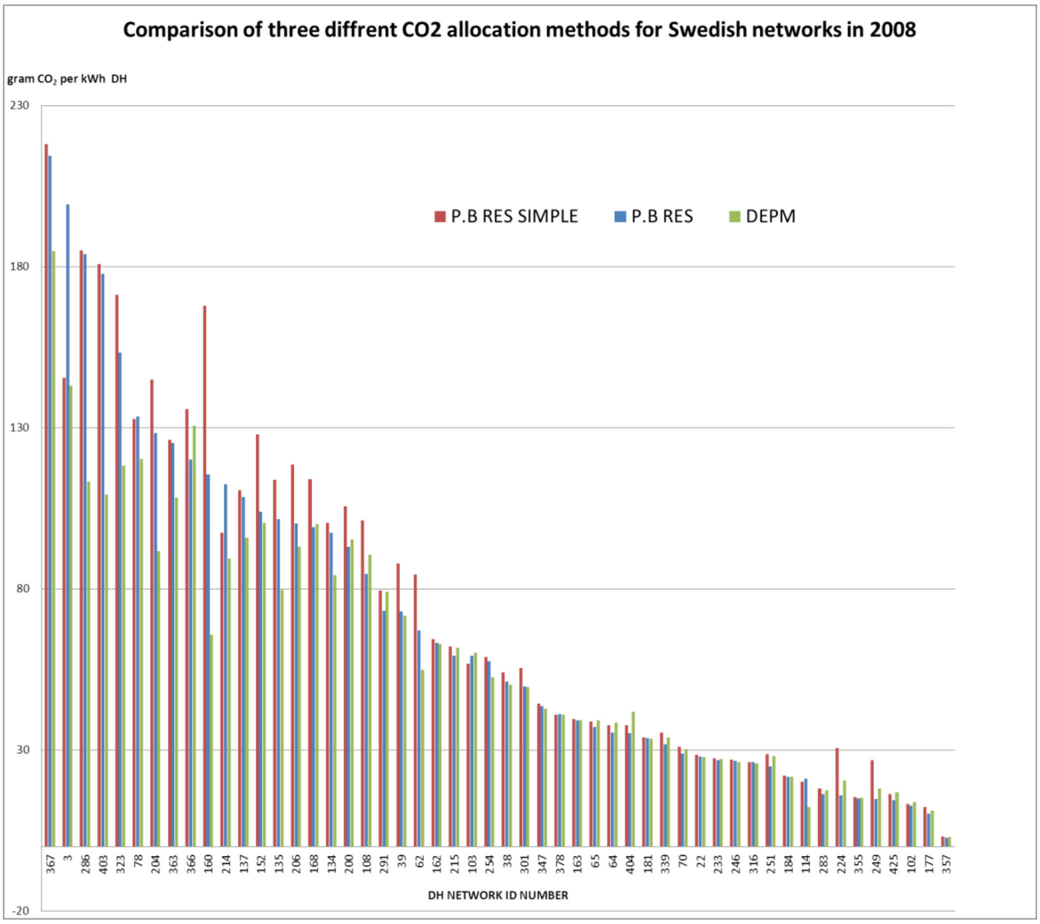

Figure 4. Swedish DH networks with CHP using three different allocation methods (statistics from 2008). Power Bonus RES SIMPLE (P.B RES SIMPLE) in red, Power Bonus RES (P.B RES) in blue and Dresden method (DEPM) in green.

10. Electricity value

10.1. EU electricity mix 2008

The electricity production mix in 2008 for EU27 is shown in Figure 5. The figure shows that renewable or recycled energy sources accounted for 19 % of the gross electricity production.

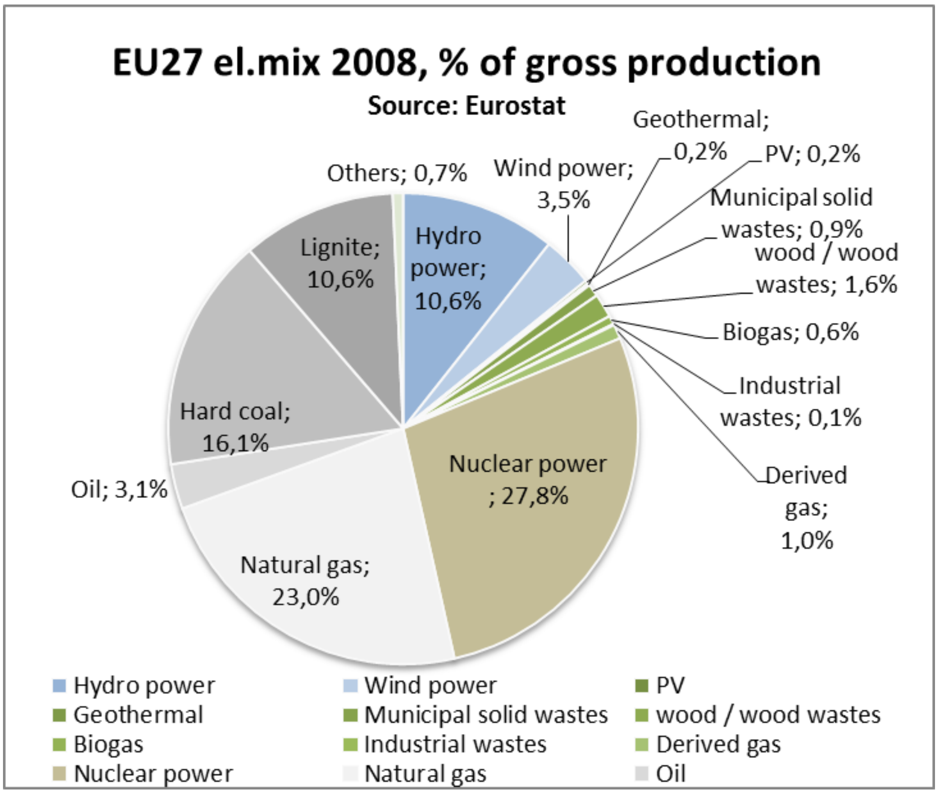

Figure 5. EU27 electricity production mix in 2008, in % of gross production. SOURCE: Eurostat[30]

10.2. Default value EU27 electricity mix

CO_2 emission factor for EU average electricity is needed to calculate emission from electricity use in district heating and to compare individual heating with electrical heating.

To be as consistent as possible, the calculation of emissions from EU electricity production mix should follow the methodology for district heating, as explained in this report. Correspondingly, this involves using

- the latest available statistics of electricity production
- Power Bonus RES method for calculating emissions and primary energy for electricity produced in CHP plants in the EU27 electricity mix
- the same emission factors and primary energy factors for input fuels to EU electricity production as for input to district heating.

[30] http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database.

The best available source for electricity production statistics found is the Eurostat database[31]. The latest annual statistics are from 2008.

Table 13. Calculation of CO_2 emission of EU27 electricity 2008.

	Gross production, %	TWh el	TWh fuel input[32]	CO_2 combustion emissions fuel [kton][33]	CO_2 LCA emission for total [kton]
Hydro power	*10.6%*	*359.2*	n.a	n.a	1 629
Wind power	*3.5%*	*118.7*	n.a	n.a	1 569
Photovoltaic power	*0.2%*	*7.4*	n.a	n.a	
Geothermal	*0.2%*	*5.7*	0	0.0	0.0
Municipal solid waste	*0.9%*	*29.1*	116	10 459	10 869
Wood / wood wastes	*1.6%*	*55.4*	222	0	589
Biogas	*0.6%*	*20.1*	38	0	102
Industrial wastes	*0.1%*	*2.6*	10	0	916
Derived gas	*1.0%*	*33.5*	64	12 890	14 154
Nuclear power	*27.8%*	*937.2*	n.a	n.a	3 273
Natural gas	*23.0%*	*774.8*	1 476	298 044	327 264
Oil	*3.1%*	*104.5*	236	62 387	66 813
Hard coal	*16.1%*	*543.0*	1 229	434 772	453 127
Lignite	*10.6%*	*358.2*	857	311 611	316 148
Others	*0.7%*	*24.0*	96	238	8 417
Total	*100%*	*3 373.4*	4 344	1 130 402	1 204 870
Final electricity consumption	*84.7%*	*2 855.6*			
Net imports		*16.5*			
per kWh el used				398.2	**424.4**

[31] Statistics can be found at: http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database

[32] The fuel input is estimated using the default electricity efficiency for each fuel seen in Table 15. There is no allocation of CO_2 emissions to the any produced heat in CHP in accordance to the power bonus method.

[33] Each fuel is multiplied with the corresponding emission factor in Table 3.

Calculation example

- 774.8 TWh electricity was generated from natural gas.

The energy content (net heating value) is calculated using the reference efficiency for electricity generation in Table 15Natural gas input, $E_{ng} = E_{el}/\eta_{el.}$= 774.8/0.525 = 1474.8 TWh fuel input (net heating value)

- The emission factor per kWh of natural gas used is 221.8 g CO_2, see section 5.1. Note that this emission factor includes upstream emissions from extraction and transport of natural gas.
- The total emissions from the use of natural gas is 1474.8 TWh* 221.8 kton/TWh = 327 264 kton CO_2.

  When calculating the total emissions per kWh electricity used the total emissions are divided with the final electricity used. The net import are subtracted from the final use of electricity. This means that only the final used electricity where the production of electricity is within EU27 is accounted for. The imports assumed to have the same environmental performance as the average EU-electricity.
  K_{el}=1205 Mton CO_2/(2855.6-16.5 TWh el) = **424.4 g CO_2/kWh used electricity**.

Table14. Calculation of primary energy factor of EU27 electricity mix 2008.

	Gross production, %	Produced electricity, TWh	TWh fuel input[34]	TWh primary resource input[35]
Hydro power	10.6%	*359.2*	*n.a*	*1.7*
Wind power	3.5%	*118.7*	*n.a*	*5.9*
Photovoltaic power	0.2%	*7.4*	*n.a*	-
Geothermal	0.2%	*5.7*	*0.0*	*0.0*
Municipal solid wastes	0.9%	*29.1*	*116.2*	*0.0*
wood / wood wastes	1.6%	*55.4*	*221.5*	*0.0*
Biogas	0.6%	*20.1*	*38.2*	*7.6*
Industrial wastes	0.1%	*2.6*	*10.4*	*0.5*
Derived gas	1.0%	*33.5*	*63.8*	*3.2*
Nuclear power	27.8%	*937.2*	*n.a*	*2 736.7*
Natural gas	23.0%	*774.8*	*1 475.8*	*2 007.0*
Oil	3.1%	*104.5*	*236.4*	*319.2*
Hard coal	16.1%	*543.0*	*1 228.6*	*1 462.0*
Lignite	10.6%	*358.2*	*857.0*	*872.9*
Others	0.7%	*24.0*	*95.9*	*4.8*
Total	**100%**	***3 373.4***	***4 343.9***	***7 421.7***
Final energy consumption		*2 855.6*		
Net imports		*16.5*		
kWh primary resources per kWh electricity used, $f_{p,nren,el}$				***2.61***

[34] The fuel input is estimated using the default electricity efficiency for each fuel seen in Table 15

[35] Each fuel is multiplied with the corresponding non-renewable primary energy factor in Table 3

Calculation example

- 774.8 TWh electricity was generated from natural gas.

The energy content (net heating value) is calculated using the reference efficiency for electricity generation in Table 15

Natural gas input, $E_{ng} = E_{el}/\eta_{el.} = 774.8/0.525 = 1475.8$ TWh fuel input (lower heating value)

- The non-renewable primary energy factor for natural gas used is 1.36, see section 5.1.
- The total use of non-renewable primary energy from the use of natural gas is 1474.8 TWh fuel input* 1.36 = 2007 TWh non-renewable primary energy.

According to the calculation procedure of the primary energy savings of co-generation in the CHP Directive (2004/8/EC), reference values for alternative electricity and heat production are regarded. These reference values can be found in a commission decision of 21 December 2006[36].

The efficiencies are based on standard ISO conditions[37] using the lower heating value. The efficiencies shown in Table 15 are valid for appliances built after 2006. The alternative electrical efficiencies are net-efficiencies valid for electricity production in condensing mode. The alternative heat efficiencies are net-efficiencies for heat-only boilers.

Table 15. Default electricity efficiency used in calculations

Fuel	Alternative electricity efficiencies	Alternative heat efficiencies
Lignite	0.418	0.88
Hard Coal	0.442	0.88
Heavy fuel oil	0.442	0.89
Light fuel oil	0.442	0.89
Natural Gas	0.525	0.9
Peat	0.390	0.86
Bioenergy (primary)	0.330	0.86
Bioenergy (refined) [38]	0.390	0.86
Bioenergy (secondary)[39]	0.250	0.86
Residual fuel	0.250	0.8
Waste as fuel	0.250	0.8

[36] COMMISSION DECISION of 21 December 2006 establishing harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2004/8/EC of the European Parliament and of the Council

[37] 15°C ambient temperature, 1,013 bar, 60 % relative humidity. Note that a correction factor due to the regional climate should be used for the electrical efficiencies. 0,1 %-point efficiency loss for every degree above 15 °C, 0,1 %-point efficiency gain for every degree under 15 °C.

[38] Assumed to have the same efficiency as peat.

[39] Assumed to have the same efficiency as agricultural fuels

11. References

11.1. General

Gode J, Martinsson F, Hagberg, L, Öman A, Höglund J, Palm D. Miljöfaktaboken 2011 - Emissionsfaktorer för bränslen, el, värme och transporter. Värmeforsk report in preparation. Stockholm, March 2011.

Särnholm E et al 2009, sustainable cities' energy demand and supply for heating and cooling. Fjärrsyn report 2009:18. Svensk Fjärrvärme 2009. Stockholm

11.2. EU directives

CHPD, Directive 2004/8/EEC on the promotion of cogeneration based on useful heat demand in the internal energy market and amending Directive 92/42/EEC.

COMMISSION DECISION of 21 December 2006 establishing harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2004/8/EC of the European Parliament and of the Council

Ecodesign Directive, DIRECTIVE 2009/125/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products recast)

Energy Service Directive, DIRECTIVE 2006/32/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC

EPBD, DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (recast)

IPPC-directive, DIRECTIVE 2008/1/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 January 2008 concerning integrated pollution prevention and control

RESD , Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

11.3. European standards

prEN 15316-4-5 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-5: Space heating generation systems, the performance and quality of district heating and large volume systems.

EN 15603:2008 Energy performance of buildings – Overall energy use and definition of energy ratings.

11.4. Eurostat

European statistical database
http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database visited 2011-02

11.5. German standards

AGFW worksheet FW 309 Part 1, May 2010

11.6. IPCC

2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Energy

11.7. Swedish standards

Bra Miljöval kriterier Naturskyddsföreningen 2008, uppdaterad version okt 2009. ISBN 91 558 8101 7

Nordic Eco-labelling(Svanen) of Heat Pumps (Version 2.1 • 14 March 2007 – 31 March 2012)

Nordic Ecolabelling of Closed fireplaces (version 2.3 March 2006 – 31 October 2011)

Annexes

Annex A. Long list

Annex B. System boundaries

Annex C. Design data for calculation of labelling criteria for planned future systems

Annex D. Allocation methods – equations

Annex A. Long list

The table shows the long list before criteria evaluation (sources are coloured red in the table). Criteria lifted out are listed under each source.

Criterion	*Source with comments for each criterion*
	Kick-Off Meeting Ecoheat4Cities - Minutes
Losses	Low density in a network leads to x% losses of efficiency
Fuel	The type of used fuel might have a great influence on the rating. This information should then be provided very visibly.
	EC Decision Heat Pump
Coefficient of performance [COP]	Ratio of heat output to electricity or gas input; measures efficiency in heating mode
Energy efficiency ratio [EER]	Ratio of cold output to electricity or gas input; measures efficiency in cooling mode
Primary energy ratio [PER] - heating mode	COP x 0.4 (electrically driven); COP x 0.91 (gas driven)
Primary energy ratio [PER] - cooling mode	COP x 0.4 (electrically driven); COP x 0.91 (gas driven)
Refrigerant	Global Warming Potential (GWP) of refrigerant
Secondary Refrigerant	Must not be substances classified as environmental hazardous. Names must be submitted with application
Noise	dB(A), test report
Heavy metals and flame retardants	Substances not allowed to be used in the system; Certificate required
Installer Training	Suitable training in member states is available
Documentation	Providing of a comprehensive manual for installation, maintenance and operating manual
Spare Parts Availability	Declaration that spare parts will be made available for 10 years submitted with application
Information Fiche	Information fiche must be submitted; Applicant must describe how he intends to make it available
	Background Report EU ECO label for heating systems
Energy efficiency	-

Criterion	*Source with comments for each criterion*
Global warming impact	-
SOx, NOx	-
HC	(hydrocarbon)
Particulate matters	-
-	5 climate zones are distinguished: heat pumps optimised towards different temperatures --> not accepted by EC
	Ecodesign Directive 2009/125/EC, Annex I 1.3
-	Weight and volume of the product
-	Use of materials issued from recycling activities
-	Consumption of energy, water and other resources throughout the life cycle
-	Use of substances classified as hazardous to health and/or the environment according to 67/548/EEC [...]
-	Quantity and nature of consumables needed for proper use and maintenance
-	Ease for reuse and recycling [...]
-	Incorporation of used components
-	Avoidance of technical solutions detrimental to reuse and recycling of components of whole appliances
-	Extension of lifetime: min. guaranteed lifetime, min. time availability spare parts, modularity, upgradeability, reparability
-	Amounts of waste generated and amounts of hazardous waste generated
-	Emissions to air (greenhouse gases, acidifying agents, volatile organic compounds,...) [...]
-	Emissions to water (heavy metals, substances with an adverse effect on the oxygen balance, persistent organic pollutants)
-	Emissions to soil (leakage and spills of dangerous substances, potential for leaching upon its disposal as waste)
	Heating systems in buildings - Doc. CEN/TC 228 N544
-	Considered system according to figure 1 page 8, i.e. 1. Fuel input, 2. heat (& power) generation, 3. heating network
	Energy performance of buildings - CEN/BT WG173
Auxiliary energy	E_{aux} - in the building (!)
System thermal losses	$Q_{s,ls}$- in the building (!)

Criterion	*Source with comments for each criterion*
Recoverable system thermal losses	$Q_{s,rb}$- in the building (!)
	Ecolabel Swedish DHC Company Norrenergi - requirements in general
The company must be certified according to ISO 14001.	
Maximum 10% non-renewable energy in the whole system.	
Electricity used in heat pumps must origin from renewable sources.	
Specific requirements for the procurements of bio fuels.	
	Annex 1 to the Ecoheat4Cities contract
Land use	-
Public health	-
CO2 emissions	-
Pollution control	-
Cost-effectiveness	-
Customer benefits	-
Longer-term possibilities for climate strategies	-
Age of the system	-
Temperature Levels	-
Reliability	Activities related to maintenance of the network
	CHP - Green Public Procurement Product Sheet and Technical Background Report
Dust	-
Overall Efficiency	= Output divided by Input. Threshold depending on plant capacity and calculation method (cf. Annex to CHP Directive)
Primary Energy Savings	-
High Efficiency acc.to 2004/8/EC	Threshold compared to separate production of heat and power; PES=Primary Energy Savings

Criterion	Source with comments for each criterion
Award Criteria I (comprehensive GPP criteria)	Additional points in proportion to the extent that the CHP plant exceeds the above mentioned PES criteria
Award Criteria II (comprehensive GPP criteria)	Additional points in proportion to the extent that the CHP plant exceeds min. requirements in relation to air emissions
Award Criteria III (comprehensive GPP criteria)	Additional points in proportion to the extent that the CHP plant exceeds the above mentioned Overall Efficiency criteria
"Environmental award criteria share"	Environmental award criteria should at least count for 10% to 15% of the total points available
-	Is the CHP plant designed according to the heat demand of the application it is used for; cf. paragraph Key Environmental Impacts
-	Mercury from coal combustion; cf. paragraph Key Environmental Impacts
-	Blue Angel: General requirement to have the CE label
Energy Performance Certificates (DECs) / Display Energy Certificates (DECs)	
Energy used in buildings	Since October 2008 occupiers of public buildings with floor areas of more than 1000m^2, have been required to have a Display Energy Certificate (DEC). DECs contain information about the actual energy used in buildings based on records of gas, electricity and other fuel consumption
Energy rating A-G	DECs include an A-G energy rating for the building where A has the lowest emissions (best)
CRC Energy Efficiency Scheme	
Price on carbon emissions	The scheme provides a financial incentive to reduce the energy use by putting a price on carbon emissions.
Energy efficiency	The CRC is a mandatory energy efficiency scheme aimed at improving energy efficiency in large public and private sector organisations.
National Indicator 185	
CO_2 emissions	NI185 requires each local authority to calculate its CO2 emissions from National Indicators analysis of the energy and fuel
Enhanced Capital Allowances	
Tax relief	This scheme sets out qualifying criteria for tax relief on investments in equipment that meets published energy-saving criteria.
CHPQA (Quality Assurance for Combined Heat and Power)	
Boiler type	The method assumes that the boiler is installed in typical UK conditions
Fuel used	The method assumes that the boiler is installed in typical UK conditions
Burner control	The method assumes that the boiler is installed in typical UK conditions

Criterion	*Source with comments for each criterion*
Ignition method	The method assumes that the boiler is installed in typical UK conditions
Quality assurance	provides the principal evidence required to determine whether or not CHP schemes are eligible for various benefits designed to encourage the development of good quality CHP.
	SEDBUK (Seasonal Efficiency of Domestic Boilers in the UK)
Efficiency (boilers)	assigns efficiency bands to domestic boilers on an "A" to "G" scale.
	Ecolabel of heat pumps
Energy efficiency during heating and cooling modes	The ecolabel can be awarded to electrically driven, gas driven or gas absorption heat pumps with the purpose of space heating or the opposite process space cooling
Use of hazardous substances	The ecolabel can be awarded to electrically driven, gas driven or gas absorption heat pumps with the purpose of space heating or the opposite process space cooling
Global warming impact (GWP)	The ecolabel can be awarded to electrically driven, gas driven or gas absorption heat pumps with the purpose of space heating or the opposite process space cooling
Instructions for correct environmental use and installation	The ecolabel can be awarded to electrically driven, gas driven or gas absorption heat pumps with the purpose of space heating or the opposite process space cooling
	Ecodesign of boilers, combi-boilers and water heaters
Energy efficiency	Test procedures and mathematical models have been developed to describe the energy efficiency of a range of heating systems
	Daan van Beekum (Development of District Heating Networks in Urban Areas, Research Institute OTB, Delft University of Technology, master thesis)
Primary energy use	a method is proposed to label the DHC according to primary energy use, CO2 emissions, investments, operational costs and user fees.
CO2	a method is proposed to label the DHC according to primary energy use, CO2 emissions, investments, operational costs and user fees.
Investments	a method is proposed to label the DHC according to primary energy use, CO2 emissions, investments, operational costs and user fees.
Operational costs	a method is proposed to label the DHC according to primary energy use, CO2 emissions, investments, operational costs and user fees.
User fees	a method is proposed to label the DHC according to primary energy use, CO2 emissions, investments, operational costs and user fees.
	EPD´s general criteria (exempelvis Vattenfall Uppsalas EPD)
GHG	
Particle matters to air	

Criterion	Source with comments for each criterion
Toxicity	
Eutrophication potential	
Abiotic depletion	
Global Warming	
Ozone layer depletion	
Acidification	
Eutrophication	
Human toxicity	
Ecosystem toxicity	
Photochemical oxidation	
SI 2005/1726 (Household Air Conditioners)	
Energy efficiency ratio	The rating is determined by a set of tables within SI 2005/1726
"Brainstorming"	
Exergy	Exergy may be used instead of energy to estimate the efficiency of the energy conversion and distribution.
NEN-EN 15316-4-5 (new standard for determing the primary energy factor of DHC)	
Distribution system - energy efficiency	
Delivered heat	Applicable for planned buildings
Svanen-label of biofuel pellets (Version 2.0 • 13 December 2007 – 31 December 2012)	
Fuel properties	Proportion of certified wood, raw material
Fuel properties	Additives. The use of additives is prohibited. Exceptions: Nordic Ecolabelling may approve the use of additives if the following items are fulfilled: Chemically untreated biomass is used (as per CEN/TS 14961),l The quantity of additives does not exceed 2% w/w The levels of heavy metals- and the halogen content in the pellets with additives are equivalent to those in pure wood. The manufacturer shall also demonstrate that neither emissions nor ash content are influenced from a health or environmental perspective.
Primary Energy	Primary energy use in the production of wood pellets

Criterion	*Source with comments for each criterion*
GWP	CO2 from the production of pellets (NOTE: ONLY fossil CO2)
	Nordic Eco-labelling of Heat Pumps (Svanen) (Version 2.1 • 14 March 2007 – 31 March 2012)
Noise	The noise level must be tested and reported to Nordic Ecolabelling. Noise is tested as per ENV-12 102.
Energy efficiency	The annual average efficiency for heat production (Annual average efficiency = EPROD / ELCON , where ELCON annual electricity consumption in kWh, EPROD annual produced useful heat in kWh. Tested in accordance with EN 14 511
Refrigerant	Refrigerant and global warming potential
Refrigerant	Refrigerant and assessment of environmental and health hazards
Supplementary heating system components?	Supplementary heating system components
Flame retardants	The use of DecaBDE and highly chlorinated short-chain chloroparaffins is prohibited, In exceptional cases, halogenated flame retardants may be acceptable if they are necessary for electrical or fire safety, in accordance with the low voltage directive 72/23/EEC and EN 603 35-1
Plastics	7diffrent phthalates prohibited, Plastic components weighing more than 50 g must be marked according to ISO 11469,
Organic solvents	Solvent for surface treatment may not contain more than 5 % (vol/vol) organic solvent
Materials and chemicals	The materials in the heat pump must fulfil the requirements of the RoHS Directive (2002/95/EC RoHS).
Documentation	The following documentation must be kept by the licensee: Copy of the entire application and copy of submitted documents, Facts/supporting data for the documents submitted during the application procedure. Results from inspections of the production of the ecolabelled product, Returns and complaints.
	Nordic Ecolabelling of Closed fireplaces (version 2.3 March 2006 – 31 October 2011)
Energy efficiency	The efficiency of slow heat release fireplaces, ŋk, must be at least 78%.The efficiency of sauna stoves, ŋk, must be at least 60%, The efficiency of wood stoves and inset appliances, ŋk, must be at least 73 %, The efficiency of pellet stoves, ŋk, must be at least 75 %.
Noise	The noise level from automatic feed fireplaces must not exceed 45 d(B)A during normal use.
Air emissions	OGC (organic), CO and Particles
Supplementary heating system components?	Supplementary heating system components
Phthalates	The following phthalates must not be added to plastic materials: Dicyclohexyl phthalate, Diisobutyl phthalate, Dibutyl phthalate (DBP), Benzylbutyl phthalate (BBP), Diethylhexyl phthalate (DEHP), Diisooctyl phthalate, Diisononyl phthalate (DINP), Diisodecyl phthalate (DIDP)

Criterion	*Source with comments for each criterion*
Flame retardants	IN accordance with the low voltage directive 72/23/EEC and EN 60335-1. Must however not be used:Polybrominated biphenyls (PBB), Polybrominated diphenyl ethers (PBDE), Highly-chlorinated, short-chain chloroparaffins
Heavy metals	Cadmium (Cd), lead (Pb) mercury (Hg) or their compounds must not be added to plastic components.
Plastics	10 different phthalates prohibited, Plastic components weighing more than 50 g must be marked according to ISO 11469,
Documentation	The following documentation must be kept by the licensee: Copy of the entire application and copy of submitted documents, Facts/supporting data for the documents submitted during the application procedure, Results from inspections of the production of the ecolabelled product, Returns and complaints.
Health	Information about how the fuel shall be stored.
	Reko fjärrvärme (SDHA market label, Customer relations)
Price list information	DH-Price (Pricelist shall be simple and comparable with other heat alternatives), Different price components shall be displayed, information about extra cost for utility services, information about ownership of the heat exchanger, possible to estimate annual cost for DH, Price list shall be displayed on the web,
Price changes	Price changes shall be announced at least 60 days in fore hand, Price changes should be avoided more than 1 time per year
Contract setup	Possible to buy less district heating than the customers total consumption
Customer relations (information meetings)	Invite customers at least once a year for information about future plans (price, development etc.), Make a anonymous customer service
Security of supply	Inform customers about all interruptions longer than 2 hours. Find information about maintenance work and grid development plans
	District Heating Act (Sweden)
Price information	Rules for how the price shall be presented
Contract setup	Rules for how an agreement between customer and DH-company shall be preformed
Delivery interruptions	Rules for when interruptions are acceptable etc.
Third party access negotiations	Rules for how to handle negations in case of third party access
Financial report	Rules for what the company shall present and how.
	Energy Markets Inspectorate (Energimarknadsinspektionens särskilda rapport, SWE)
Energy delivery	Amount of district heating delivered to different types of customers
Information about investments	Expansion rate of the DH-system

Criterion	*Source with comments for each criterion*
	NFS 2006:9, Thresholds, Swedish environmental protections agency (implementation of the Environmental Code ch. 26 paragraph 20)
Air and water emissions	Thresholds for total emissions for plants > 50 MW. CO2 (bio and fossil), CH4, CO, N20, Nox, SO2, NH3, Heavy metals, totP, tot N etc-
	Klimatneutral Fjärrvärme- Fortum Värme (Climate compensated DH)
GWP	Compensation for GHG emissions from DH. Calculations according to GHG Protocol. Third party verification according to ISO 14021.
Information	Information about CO2-eq/kWh heat and report about the compensations that are made
	PCR (For preparing an Environmental Product Declaration (EPD) for Electricity, Steam, and Hot and Cold Water Generation and Distribution) version 1.1 2007-10-31
GHG	Rules for method and system boundaries
Particles	Rules for method and system boundaries
Toxicity	Rules for method and system boundaries
Eutrophication potential	Rules for method and system boundaries
...and additional criteria to be included in EPD´s.	Rules for method and system boundaries
	Ecoheatcool
Primary resource factors	the ratio between the non-generative resources (fossil fuels) and the energy supplied to the building
CO_2	CO_2 per kWh heat delivered
	IPPC (Directive 2008/1/EG) 2008-01-29
Air emissions	Sulphur dioxide and other sulphur compounds Oxides of nitrogen and other nitrogen compounds, Carbon monoxide, Volatile organic compounds, Metals and their compounds, Dust, Asbestos (suspended particulates, fibres), Chlorine and its compounds, Fluorine and its compounds, Arsenic and its compounds, Cyanides, Substances and preparations which have been proved to possess carcinogenic or mutagenic properties or properties which may affect reproduction via the air, Polychlorinated dibenzodioxins and polychlorinated dibenzofurans

Criterion	*Source with comments for each criterion*
Water emission	Organohalogen compounds and substances which may form such compounds in the aquatic environment, Organophosphorus compounds, Organotin compounds, Substances and preparations which have been proved to possess carcinogenic or mutageni properties or properties which may affect reproduction in or via the aquatic environment, Persistent hydrocarbons and persistent and bioaccumulable organic toxic substances, Cyanides, Metals and their compounds, Arsenic and its compounds, Biocides and plant health products, Materials in suspension, Substances which contribute to eutrophication (in particular, nitrates and phosphates), Substances which have an unfavourable influence on the oxygen balance (and can be measured using parameters such as BOD, COD, etc.)
	Bra Miljöval Värme (Swedish Ecolabelling of district heating)
Fuel requirements	Extraction and production of fuels and heat shall be made in a way that does not reduce the possibilities for an environmentally and socially sustainable society.
Share of non-fossil energy	A maximum of 10% of the delivered heat may be non-renewable in a life-cycle perspective (includes energy for extraction, transport, refining of fuel, process energy at the plant as well as energy for transport of residuals. Energy allocation according to ISO 14001. Allocation method shall be stated and described.
Environmental management system	The heating plant must have an environmental management system according to ISO 14000, EMAS or equal.
Market aspects / Quality	Balance of supply and sale of heating labelled Bra Miljöval Värme.
Energy efficiency	Plants built after 2007 must have an efficiency rate exceeding 70%.
Fuel requirements	Fuels from GMO:s are prohibited
Fuel requirements	Tracking of biofuel origin is required.
Ash treatment	Ash from biomass combustion must not be mixed with other ashes.
Fuel requirements	Co-combustion of biomass and other fuels is only allowed is the resulting ash fulfils the requirements from the guidelines from the Swedish Forest Agency.
Fuel requirements	Imported biofuels from outside EU must fulfil FSC requirements or equal.
Fuel requirements	Forest fuels: Wood fuels must originate from FSC forestry or other sustainable forestry. Needles, leaves and roots shall be left in the forest and thus may not be combusted. forest fuels must not originate from illegal forestry or from areas with specific protection values (e.g. high biodiversity, species under threat of extermination...).
Fuel requirements	Agricultural biofuels: requirement of crop rotation, fuels from pastureland and meadows are prohibited, use of straw must be consistent with maintained soil nutrient status, methane from manure digestion is allowed.

Criterion	*Source with comments for each criterion*
Fuel requirements	Palm oil is prohibited
Fuel requirements	Biomass residuals from forest industry is allowed, e.g. sawdust, chip, bark. However, recycled wood must not be painted, chemically treated or contain plastics or metal.
Fuel requirements	Landfill gas is prohibited
Fuel requirements	Biogas from anaerobic digestion of waste is allowed only if the methane leakage is not exceeding 10% of the delivered heat.
Fuel requirements	Heat pumps are allowed if the heat originates from geothermal, solar heat, solar energy, sewage treatment plants of process water from food-processing industry or drinking industry.
Fuel requirements	Waste heat from industries is allowed only if the industrial processes are energy efficient and the waste heat does not originate from industries counteracting the purpose of the ecolabelling (e.g. fossil fuel treatment...)
Fuel requirements	Electricity for heat pumps must be renewable.
	Bra Miljöval El (Swedish Ecolabelling of electricity)
Fuel requirements	Only renewable energy sources are allowed. I.e. hydropower, wind power, solar energy, wave energy, tidal energy, bioenergy or biogas.
Additionality requirements	A certain additionality system is presented. To fulfil the requirements of additionality, a certain point system i introduced and the electricity supply must achieve at least 30 points + 5 point specifically regarding energy efficiency improvement. One point equals 100 SEK/GWh.
Share of non-fossil energy	A maximum of 10% of the delivered electricity may be non-renewable in a life-cycle perspective (includes energy for extraction, transport, refining of fuel, process energy at the plant as well as energy for transport of residuals. If both electricity and heat is produced (CHP), the energy shall be allocated using primarily physical allocation and secondly economic allocation.
Other, not yet categorised	Balance of supply and sale of electricity labelled Bra Miljöval El.
Energy efficiency	500 SEK/GWh electricity labelled with Bra Miljöval El shall be set aside for certain energy efficiency improvement measures.
Environmental management system	The heating plant must have an environmental management system according to ISO 14000, EMAS or equal.
Fuel requirements	Hydropwer: Only plants constructed before 1996 are eligible. Energy efficiency improvements may be allowed if not environmentally harmful. Improvements in plants newer than 1996 may also be eligible, but must be proved by SNF. Requirement of minimum low-water-level.
Fuel requirements	Fuels from GMO:s are prohibited
Fuel requirements	Tracking of biofuel origin is required.
Ash treatment	Ash from biomass combustion must not be mixed with other ashes.

Criterion	*Source with comments for each criterion*
Fuel requirements	Co-combustion of biomass and other fuels is only allowed if the resulting ash fulfils the requirements from the guidelines from the Swedish Forest Agency.
Fuel requirements	Imported biofuels from outside EU must fulfil FSC requirements or equal.
Fuel requirements	Forest fuels: Wood fuels must originate from FSC forestry or other sustainable forestry. Needles, leaves and roots should preferably be left in the forest. forest fuels must not originate from illegal forestry or from areas with specific protection values (e.g. high biodiversity, species under threat of extermination...).
Fuel requirements	Agricultural biofuels: requirement of crop rotation, fuels from pastureland and meadows are prohibited, use of straw must be consistent with maintained soil nutrient status, methane from manure digestion is allowed.
Fuel requirements	Palm oil is prohibited
Fuel requirements	Biomass residuals from forest industry are allowed, e.g. sawdust, chip, bark. However, recycled wood must not be painted, chemically treated or contain plastics or metal.
Fuel requirements	Landfill gas is prohibited
Fuel requirements	Biogas from anaerobic digestion of waste is allowed only if the methane leakage is not exceeding 10% of the delivered heat.
Fuel requirements	Unsorted (mixed) waste is not allowed.
Fuel requirements	Sorted waste may be eligible if the organic content exceeds 90%.
Fuel requirements	Wind power: shall not be built in protected areas (by law, international conventions, specific areas stated by SNF), requirement of self-monitoring.
Fuel requirements	Solar energy: waste plan is required
Fjärrvärden (R&D project on environmental values for DHC)	
Primary energy	Primary energy is one suggested KPI, calculated by taken into account primary energy performance of fuels and all losses from cradle to grave.
Climate impact	Climate impact is one of the suggested KPI, taking all emissions of greenhouse gases into account.
Net electricity	Supplementary indicator aiming at describing and allowing for comparisons between DH production and other heating options. Net electricity is one of the proposed supplementary indicators. It is a new concept developed in the project and takes into account both production and utilisation of electricity for DH production. Net electricity is calculated as (electricity production - electricity utilisation)/delivered DH. A high value thus means net electricity production (CHP). A negative value (below zero) means net electricity utilisation (e.g. heat pumps).
Share of renewable energy	Supplementary indicator aiming at describing and allowing for comparisons between DH production and other heating options. Share of renewable energy is one of the proposed supplementary indicators.

Criterion	*Source with comments for each criterion*
Origin of biofuels	Supplementary indicator aiming at describing and allowing for comparisons between DH production and other heating options. Origin of biofuels is one of the proposed supplementary indicators.
Emissions of regulated pollutants	Supplementary indicator aiming at describing and allowing for comparisons between DH production and other heating options. Emissions of regulated pollutants (NOx, SO_2, particulate matter...), could also be supplementary indicators.
	Design temperatures of building heating and cooling systems
Design conditions for DH	
	Danish Building Regulations 2010
Limits for the energy performance of buildings	Limits on gross heat energy input (kWh/m2). In the former building code (BR08), district heating had an energy factor of 1 (for boilers fired with oil, gas or biomass it is also 1). In the new BR10 it is 0.8 for low energy buildings, but still 1 for standard buildings. The energy factor of 0.8 is the same for all Denmark even though large differences between different utilities. Further information in Bekendtgørelse om offentliggørelse af bygningsreglement 2010 (BR10), Erhvervs- og Byggestyrelsen, den 28. juni 2010,Danish Enterprise and Construction Authority, www.ebst.dk.
	Research on Primary Resource Factors
Primary resource factor	A Danish research project has compared different ways to estimate primary resource factors including the EuroheatCool method. The objective was to give documentation and examples on how district heating resource factors can be incorporated in the Building Code. Also the economical consequences of using/denying primary resource factors were assessed. More information in EUDP-projekt: Lavressource fjernvarme, Foreløbig delrapport om Primære ressourcefaktorer, Anvendelse af primære ressourcefaktorer i bygningsreglementet - metode og eksempler, Rambøll, April 2009.
	Guideline for socio-economic analysis in the field of energy
Socio-economic analysis	The Danish Energy Agency has published guidelines for analysing the socio-economic when two or more heat sources are to be compared (e.g. natural gas boilers compared with district heating). As part of this CO_2, NOx and SO_2 emissions socio-economic impact is also analysed. More information: Vejledning i samfundsøkonomiske analyser på energiområdet, Energistyrelsen, april 2005 (Beregningseksempler revideret juli 2007), Danish Energy Agency, www.ens.dk
	AGFW (Abteilung Technik bei der Arbeitsgemeinschaft Fernwärme) - several regulations
Specific primary energy factors	FW309 "Energy Performance of District Heating - Determination of the specific primary energy factors in district heating supply
CHP electricity	FW308:2009, Certification of CHP-plants – Determining the CHP Electricity
Pipes	FW601:2007, Qualification criteria for pipeline construction companies
Pipes	FW602:2007, Joint casing application on preinsulated bonded pipes and flexible pipes; examination of fitters

Criterion	*Source with comments for each criterion*
Pipes	FW604:2007, Joint casing on preinsulated bonded pipes and flexible pipes; acknowledgement from inspection stations to the examination from sleeve fitters of work sheet FW603
Pipes	FW 605:2003, Sleeve mounting on preinsualted bounded pipes on flexible pipes; requirements for companies which carry out sleeve mounting
	DIN V (German Institute for Standardization)
	DIN V 4701-10: 2003-08, Energetische Bewertung heiz- und raumlufttechnischer Anlagen - Teil 10: Heizung, Trinkwassererwärmung und Lüftung
	DIN V 18599-1:2007-02, Energetische Bewertung von Gebäuden - Berechnung des Nutz-, End- und Primär-energiebedarfs für Heizung, Kühlung, Lüf-tung, Trinkwarmwasser und Beleuchtung - Teil 1: Allgemeine Bilanzierungsverfahren, Begriffe, Zonierung und Bewertung der Energieträger
	EnEV, German Energy Saving Ordinance/Directive
	EnWärmeG, The Renewable Energies Heat Act
	DH systems efficiency, NCCPE (National Control Commission on Prices and Energy)
Heat loss	Heat losses in networks (%)
Fuel use	Comparative fuel use (kgoe /MWh)
Fuel price	Average price of fuel (fuel mix) (LTL/toe)
Electricity use	Electricity use (kWhe/MWhth)
Network	Length of network maintained by 1 employee, (km)
Capacity	Usage of heat production capacity (Max. heat demand/ installed capacity)
Maintenance	Repair costs in heat production and transportation (LTL/MW, LTL/kmc)
Economic	Average monthly salary (LTL)
Costs	Average heat supply cost and tariff (LTL/kWh)
Cost structure	Cost structure: (Fuel, Other variable, Consumables, Depreciation, Labour and social security, Other fixed costs, Management)

Annex B. System boundaries

It is necessary to define the system boundaries when calculating primary resource factors for fuels and different heating systems. If different system boundaries are chosen, the comparisons will not be reliable. Figure 6 illustrate alternative system boundaries. A more detailed overview of system boundaries is presented in Figure 7.

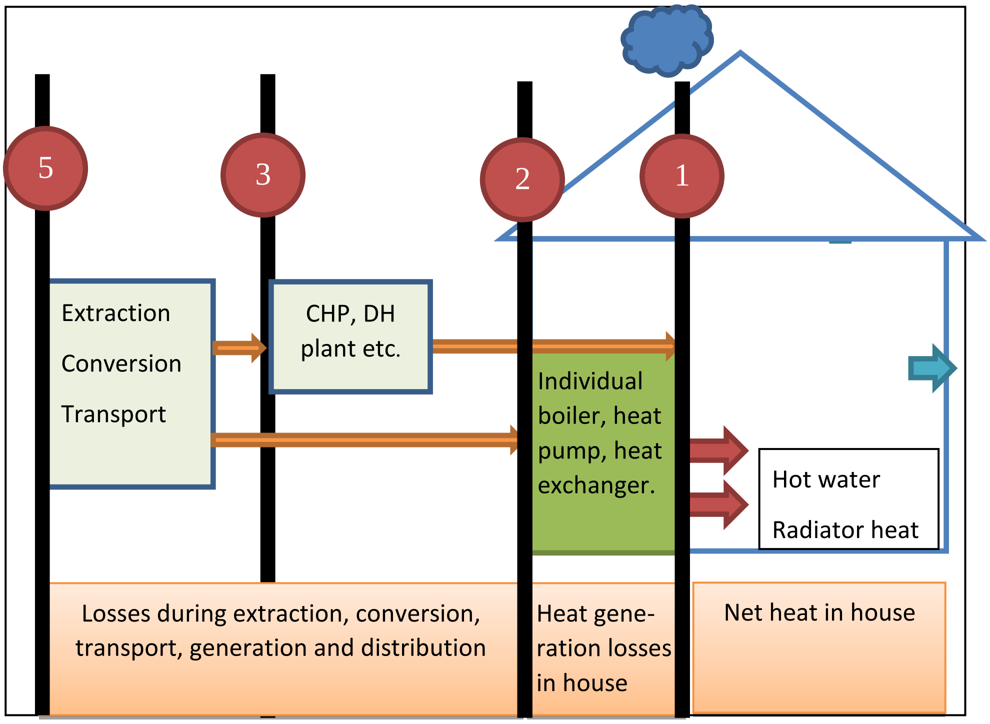

Figure 6. System boundaries along the chain from fuel extraction through refining, distribution and conversion to delivered heat to the building.

The E4C project aims at defining labelling criteria and methodology for calculation of these criteria. One important prerequisite is also to make possible comparisons of performance between district heating systems and alternative heating. In the EU the alternatives to district heating vary between different countries, but common competitors are individual natural gas boilers, electric boilers and heat pumps. This means that the methodology needs to define primary resource factors for the most commonly used fuels for district heating and individual heating as well as some primary resource factors illustrating the primary resource need for providing heat to a building. As shown in Figure 7, primary resource factors for fuels are illustrated by system boundaries 5-3, whereas primary resource factors for heating is illustrated by system boundaries 5-1. The energy in the primary resource is transformed to energy either at system boundary 3 or 1, depending on whether the transformation is taking place in a DH plant or in an individual boiler.

This means that for a strict comparison between e.g. district heating and individual natural gas boiler the efficiency of the district heating heat exchanger within the building as well as the efficiency of the natural gas boiler have to be taken into account. However, the efficiency of district heating heat exchangers can often be regarded as 100 %, firstly because they are normally very efficient and secondly because the potential heat loss is often recovered. This means that in practice the primary resource factors for system boundary 5-1 can be regarded as equal to system boundary 5-2 (see Figure 7). A primary resource factor that can easily be calculated by the DH company by applying the E4C methodology explained in annex. On the other hand, the efficiency of the natural gas boiler must be taken into account since some heat will always be lost through the chimney.

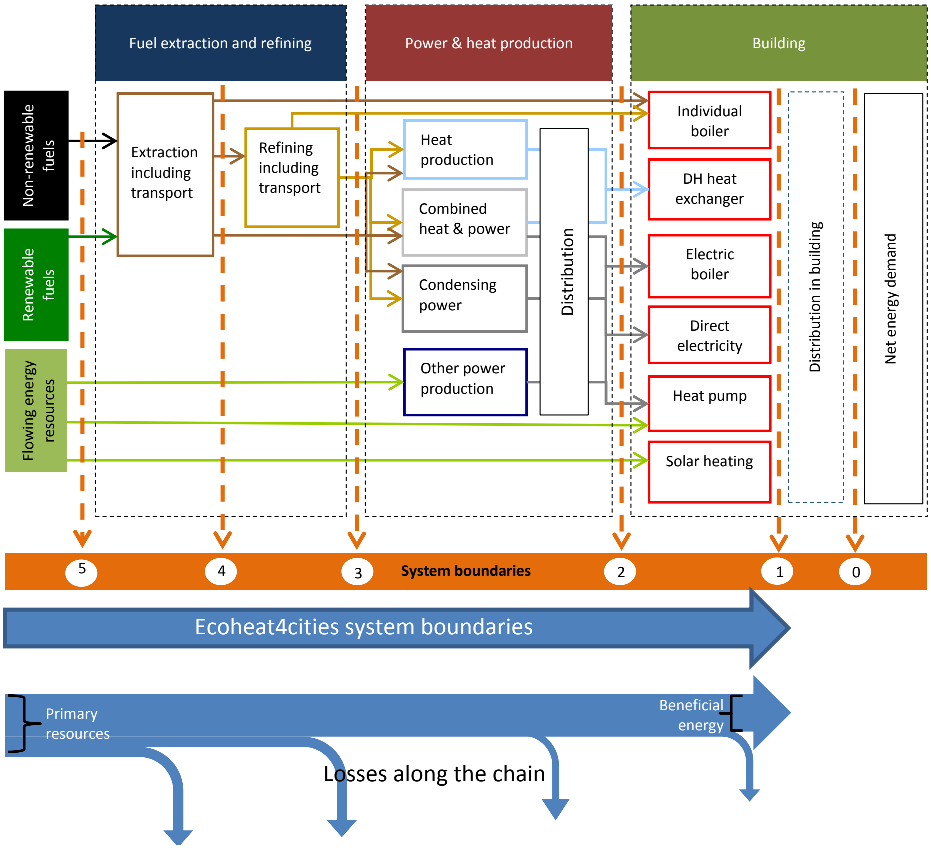

Figure 7 Illustration of alternative system boundaries and of losses along the energy chain from primary resource to heating of a building.

Annex C. Design data for calculation of labelling criteria for planned future systems

To estimate labelling criteria for any planned future DH system, e.g. a future DH system, design data has to be used instead. This annex describes the calculation procedures for all labelling criteria based on design data.

Non-renewable primary energy factors for delivered heat from a planned future system

To estimate the non-renewable primary energy factor ($f_{P,dh,nren}$) of a planned future DH

Equation 6 is used by inserting design data (see Equation 8 - Equation 11). The corresponding procedure for calculating the non-renewable primary energy factor of an individual boiler ($f_{P,b,nren}$) is shown in Equation 7.

Equation 6.The non-renewable primary energy factor for future heating system

$$f_{P,dh,nren} = \frac{1-\beta}{\eta_{hn} * \eta_{T,gen}} * f_{P,F,nren} + \frac{(1+\sigma)*\beta}{\eta_{hn} * \eta_{chp}} * f_{P,F,chp,nren} - \frac{(\sigma*\beta-\beta_{aux})}{\eta_{hn}} * f_{P,el,nren}$$

where

η_{hn} = heating network efficiency

$f_{P,F,nren}$ = non-renewable primary energy factor for fuels used for heat generation only (note: all fuels for co-generation are excluded)

$f_{P,F,chp,nren}$ = non-renewable primary energy factor for fuels used in CHP plants

$f_{el,chp,nren}$ = non-renewable primary energy factor for the replaced electrical energy (default electricity value is shown in Table 7)

β_{aux} = share of auxiliary electricity in relation to the total heat production, $\beta_{aux} = \frac{E_{el,hn}}{Q_{chp}+Q_{T,gen}}$. The fraction can, if unknown, be set to 0.04[40]

For an individual heating system without co-generation, $\beta = \sigma = 0$, the formula can be reduced to Equation 7.

Equation 7.The non-renewable primary energy factor for future individual heating system

$$f_{P,b,nren} = \frac{1-\beta}{\eta_{hn} * \eta_{T,gen}} * f_{P,F,nren} + \cancel{\frac{(1+\sigma)*\beta}{\eta_{hn} * \eta_{chp}}} * f_{P,F,chp,nren} - \frac{(\sigma*\beta-\beta_{aux})}{\eta_{hn}} * f_{P,el,nren} = \frac{1}{\eta_{T,gen}} * f_{P,F,nren} + \beta_{aux} * f_{P,el,nren} = f_{P,Qdel,nren}$$

[40] Average for Swedish district heating network during 2008. .

Since no heating network prior to system boundary 1 exists the efficiency, η_{hn} can be excluded from the equation.

Equation 8. The thermal generation efficiency

$$\eta_{T,gen} = \frac{Q_{T,gen}}{E_{F,T,gen}}$$

where

$\eta_{T,gen}$ = heat generation efficiency (in average during a certain time period)

$Q_{T,gen}$ = heat production from the combustion heat generator during a certain time period

$E_{F,T,gen}$ = fuel input to the combustion heat generator during the same time period

Equation 9. The combined heat and power efficiency

$$\eta_{chp} = \frac{E_{el,chp} + Q_{chp}}{E_{F,chp}}$$

where

η_{chp} = co-generation efficiency

Q_{chp} = net heat production from co-generation plants during a certain time period measured at the output of the appliance

$E_{el,chp}$ = *net* produced electricity in co-generation plants (produced electricity minus auxiliary electricity use). Only applicable for produced electricity in combined heat and power mode.

$E_{F,chp}$ = fuel input to the co-generation plants during the same time period

The power to the heat ratio, σ, is the relationship between the electricity production, $E_{el,chp}$, and heat production, Q_{chp}, in combined heat and power mode for the future system, see below. The σ can range from approximately 0.25 for a waste to heat co-generation plant to 0.95 for a natural gas combined cycle[41].

Equation 10. The power to heat ratio in combined heat and power mode

$$\sigma = \frac{E_{el,chp}}{Q_{chp}}$$

[41] Used in CHP directive

Equation 11. The heat produced in CHP in relation to the total heat generation in the heating system.

$$\beta = \frac{Q_{chp}}{Q_{chp} + Q_{T,gen}}$$

Carbon dioxide emission factors for delivered heat from a planned future system

K_{dh} for a planned future DH system can be solved in a corresponding manner as non-renewable primary energy factor. The same is valid for an individual heating system. See Equation 12 below. Design data according to Equation 8 - Equation 11.

Equation 12. Carbon dioxide emission factor for a delivered heat from a future heating system

$$K_{dh} = \frac{1-\beta}{\eta_{hn} * \eta_{T,gen}} * K_F + \frac{(1+\sigma) * \beta}{\eta_{hn} * \eta_{chp}} * K_{F,chp} - \frac{(\sigma * \beta - \beta_{aux})}{\eta_{hn}} * K_{el}$$

Annex D. Allocation methods – equations

The formulas below describe CO_2 allocation. Non-renewable primary energy can be calculated the same way by using the f_{pFnren} instead of K_F

Power Bonus SIMPLE

Carbon dioxide emission factor for delivered heat

$$K_{dh} = \frac{\sum_{i=1}^{n} E_{F(i)} * K_{F,tot(i)} - (E_{el,chp} - E_{el,hn}) * K_{el}}{\sum_{j=1}^{n} Q_{del(j)}}$$

where

K_{dh}	=	carbon dioxide emission factor for delivered heat provided to the building, in kg CO_2/MWh
$K_{F,tot(i)}$	=	carbon dioxide emission factor for fuel *i*, in kg CO_2/MWh_{fuel}
$E_{F(i)}$	=	net energy content of fuel *i* delivered to the gate where it is finally converted to heat (using lower heating value).
K_{el}	=	carbon dioxide emission factors for electricity **(EU AVERAGE)** in kg CO_2/MWh. The same value should be used for input and output electricity if not other methodology is defined by national law.
$E_{el,chp}$	=	*net* produced electricity in co-generation plant (Produced electricity minus auxiliary electricity use). Only applicable for CHP.
$E_{el,nh}$	=	*all* use of electrical energy for operating the heating network
$Q_{del,(j)l}$	=	delivered heat to the building, j, at system boundary 1. For DH this is the same as heat at system boundary 2

Power Bonus RES

$$K_{dh} = \frac{\sum_{i=1}^{n} E_{F(i)} * K_{F,tot(i)} - \left(\sum_{i=1}^{n} \frac{E_{el,chp(i)} * K_{F,tot(i)}}{\eta_{el(i)}}\right)}{\sum_{j=1}^{n} Q_{del(j)}}$$

where

K_{dh}	=	carbon dioxide emission factor for delivered heat provided to the building, in kg CO_2/MWh
$K_{F,tot(i)}$	=	carbon dioxide emission factor for fuel *i*, in kg CO_2/MWh_{fuel}
$E_{F(i)}$	=	net energy content of fuel *i* delivered to the gate where it is finally converted to heat
$E_{el,chp(i)}$	=	*net* produced electricity in co-generation plant from fuel i (produced electricity minus auxiliary electricity use). Only applicable for CHP. The share of electricity produced from CHP fuel *i* can be estimated by taking the share of the fuel input compared to the total fuel input to the CHP, $E_{el,chp(i)} = E_{el,chp,tot} * (E_{F,chp(i)} / E_{F,chp,tot})$
$\eta_{el(i)}$	=	net electrical efficiency in condensing mode for fuel *i*. Default values for each fuel are presented in Table 15 in chapter 10
$E_{el,nh}$	=	*all* use of electrical energy for operating the heating network

$Q_{del,(j)l}$ = delivered heat to the building, j, at system boundary 1. For DH this is the same as heat at system boundary 2

Power Bonus RES SIMPLE

$$K_{dh} = \frac{\sum_{i=1}^{n}\left(E_{F(i)} * K_{F,tot(i)}\right) - \frac{\sum_{i=1}^{n}(E_{el,chp(i)} * K_{F,tot(i)})}{\eta_{el}}}{\sum_{j=1}^{n} Q_{del(j)}}$$

where

K_{dh} = carbon dioxide emission factor for delivered heat provided to the building, in kg CO_2/MWh

$K_{F,tot(i)}$ = carbon dioxide emission factor for fuel *i*, in kg CO_2/MWh_{fuel}

$E_{F(i)}$ = net energy content of fuel *i* delivered to the gate where it is finally converted to heat (using lower heating value).

$E_{el,chp(i)}$ = *net* produced electricity in co-generation plant from fuel i(Produced electricity minus auxiliary electricity use). Only applicable for CHP. The share of electricity produced from CHP fuel *i* can be estimated by taking the share of the fuel input compared to the total fuel input to the CHP, $E_{el,chp(i)} = E_{el,chp,tot} * (E_{F,chp(i)} / E_{F,chp,tot})$

η_{el} = default electrical efficiency condensing for a conventional thermal power plant set to **40 %.**

$E_{el,nh}$ = *all* use of electrical energy for operating the heating network

$Q_{del,(j)l}$ = delivered heat to the building, j, at system boundary For DH this is the same as heat at system boundary 2

Dresden method or DEPM[42]

$$K_{dh} = \frac{\sum_{i=1}^{n} E_{F\ heatonly(i)} * K_{F,tot(i)} + \left(\frac{\sum_{i=1}^{n} Q_{CHP(i)} * \epsilon_{90-20} * \eta_{is} * K_{F,tot(i)}}{\eta_{el(i)}}\right)}{\sum_{j=1}^{n} Q_{del(j)}}$$

where

K_{dh} = carbon dioxide emission factor for delivered heat provided to the building, in kg CO_2/MWh

$K_{F,tot(i)}$ = carbon dioxide emission factor for fuel *i*, in kg CO_2/MWh_{fuel}

ϵ = Carnot efficiency (theoretical possible exergy fraction to extract from 100 Celsius degrees hot water) , T_1-T_0 / T_1 = (373-293)/373 =0,21

$Q_{,chp(i)}$ = *net* produced heat in co-generation plant from fuel i Only applicable for CHP.

η_{is} = isentropic efficiency to correct the theoretical efficiency to real life conditions normally put to approximately 0.8

$E_{el,nh}$ = *all* use of electrical energy for operating the heating network

$Q_{del,(j)l}$ = delivered heat to the building, j, at system boundary For DH this is the same as heat at system boundary 2

[42] This is an interpretation of how the Dresden method formula can be displayed.

Results for different allocation methods

The table below shows results of applying three different allocation methods to all Swedish district heating networks (based on statistics from 2008).

Table 16 Resulting CO_2 emissions by applying three different allocation methods to Swedish DH networks (2008).

	P.B RES, kg CO_2/MWh	***P.B RES SIMPLE, kg CO_2/MWh***	***DEPM CO_2/MWh***
Weighted Average (delivered heat)	96	98	87
Average (number average)	57	58	55
Median	38	38	38