Reporting on the sustainability of district heating networks

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Abstract

The Netherlands is aiming at a climate neutral build environment in 2050, in line with the goals of the EU. This implies that district heating networks will have to be nearly climate neutral as well. A number of Dutch heat suppliers annually reports on their contributions to a climate neutral energy supply. It is, however, often unclear how these reductions are calculated, i.e. which information is being used and what the underlying assumptions are.

The Dutch government therefore has introduced a reporting obligation for district heating suppliers. Under this obligation, it will be mandatory for suppliers to report annually on the sustainability of the heat supplied to their customers by providing at least information on: (1) CO_2 emissions per unit of delivered heat, (2) Primary fossil energy use per unit of delivered heat and (3) the share of renewable energy sources.

To ensure that reported data are transparent and comparable, a mandatory uniform reporting format and method to calculate the three indicators was developed. It is based on existing definitions and methods that are already accepted and recognised by the stakeholders and in line with the buildings regulations. The methodology should provide insight on the actual sustainability of supplied heat by using annual measured data from the heat suppliers as well as annual monitoring data on e.g. the efficiency and CO_2 emissions of the Dutch electricity production systems. This paper outlines the methodology. The full method is available in a report in Dutch[1].

Table of contents

[1] Harmelink (2017) Duurzaamheid van warmtelevering. Voorstel voor inhoud van de rapportageverplichting onder de Warmtewet. (Sustainability of heat delivery. Proposal for reporting under the Dutch Heat Act). May 2017.

1 Introduction

Energy consumption in the Netherlands

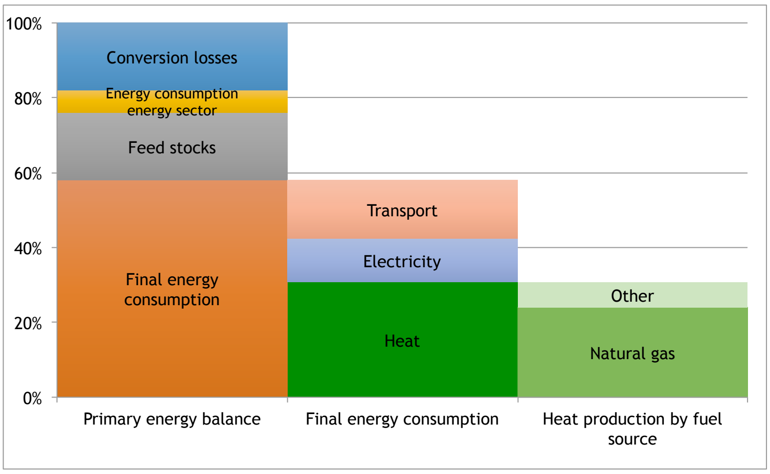

Figure 1: Energy balance for the Netherlands in 2015. ECN, CBS (2017)

Total energy use amounted to over 3000 PJ in 2015 in the Netherlands. Approximately 60% was used for final energy consumption by industry, transport, households, the service sector and agriculture. Figure 1 shows that around 30% of primary energy use is utilized for heat product that is primarily (~78%) produced with natural gas. Production of low temperature heat for space heating and hot water consumption in the build environment is even more dominated by natural gas. Over 90% of this heat is locally produced in the buildings with natural gas fired boilers (ECN, CBS, 2017)[2].

Role of districting heating in the Netherlands

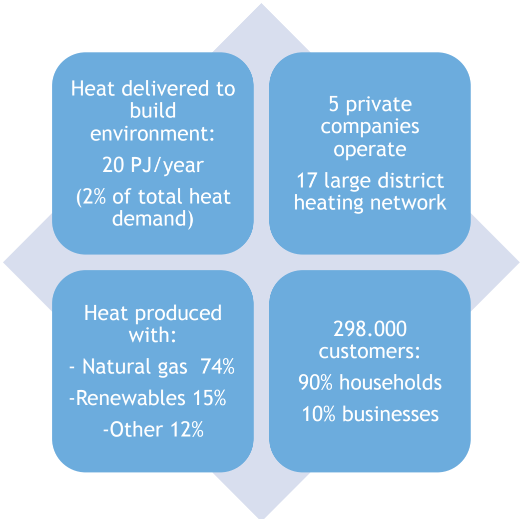

Figure 2: Status of district heating networks in the Netherlands in 2015. ECN, CBS (2017)

About 2% of heat demand in the build environment in the Netherlands is provided through district heating networks. Five private companies that together operate 17 district heating networks currently deliver over 90% of the heat supplied through district heating networks. The Netherlands is aiming for a climate neutral build environment in 2050, in line with the EU goals. This amongst others requires a shift away from the use of natural gas for the production of low temperature heat. The Dutch government sketched various directions to arrive at a climate neutral build environment. One of these directions comprises expanding and greening of districting heating systems (Min EZ, 2015)[3]. This has triggered a debate in the Netherlands on the actual sustainability of heat delivered through these networks.

Reporting obligation on the sustainability of delivered heat

The Dutch government therefore introduced a reporting obligation for district heating suppliers to annually report on the sustainability of the heat supplied to their customers. The obligation affects heat suppliers subject to licensing under the Heat Act. The Act protects consumers who are unable to switch suppliers (about 90% of the customers) amongst others against being charged too high prices. With the introduction of the a revised Heating Act mandatory reporting under the Act will be extended with information on the sustainability of the delivered heat. Suppliers will be need to report on the following indicators:

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[2] ECN, CBS (2017) Monitoring Warmte 2015 (Monitoring Heat 2015). ECN-E--17-018, April 2017.

[3] Min EZ (2015) Kamerbrief Warmtevisie (Letter to the Parliament. Heat Strategy). Ministry of Economic Affairs, April 2015.

- CO_2 emissions (kg) per unit of delivered heat,
- Primary fossil energy use (GJp) per unit of delivered heat,
- Share of renewable heat (%).

Suppliers are furthermore obliged to provide a clear outline of their heating network including: (i) type and number of sources supplying the heat, (ii) type and number of customers, (iii) amount of auxiliary energy, (iv) amount of heat produced and supplied and, (v) volume of heat losses. Voluntarily heat suppliers can include other information on the sustainability of their product such as emissions of local air pollutants or indirect energy use.

With this obligation the Dutch government anticipates proposed revisions under the Renewable Energy Directive. Article 24 encourages Member States to put regulation in place ensuring that district heating and cooling suppliers provide information to end-consumers on their energy performance and the share of renewable energy in their systems (EC, 2017)[4].

2 Definition of a district heating network

Reporting on individual district heating networks

For the purpose of the Dutch heating Act a district heating network is defined as: "the complete set of interconnected pipelines, associated installations and other devices capable of transporting heat, except pipelines, installations and utilities that are part of an indoor heating system". Heat suppliers are obliged to report on each of their individual district heating networks.

Large district heating networks, consisting of a transport grid, a primary and secondary distribution grid, are considered as one network. Currently in most cases the heat supplier that holds a license under the Heat Act operates the transport grid, the distribution grid as well as the heat production installations. This implies that the supplier reports on the sustainable of the complete network.

Connected heating networks

There are district heating network in the Netherlands where the transport grid, the distribution grid, the heat production units and heat supply to the consumers are the responsibilities of different entities. In these cases different networks are connected. A single supplier is therefore not able to report on "the complete set of interconnected pipelines, associated installations and other devices capable of transporting heat". In this case the supplier reports on the sustainability of heat for which he/she signed contracts with heat producers that feed into the grid. Consumption of auxiliary energy and heat losses in parts of the heating network that are not operated by the supplier are allocated in proportion to the amount of contracted heat. As a consequence in these cases heat suppliers will need to make arrangements on annual delivery of data by the operators of the transport grid and the heat producers in order to be able to produce their report.

3 Principles in developing a uniform calculation method

In developing the method the following principles were applied:

- The method should, to the extent possible, be based on *existing methods* that are already accepted and recognised by the Dutch stakeholders. The method therefore builds on:
  - Approaches and calculations rules applied within the national *EMG standard* (Energy performance standard for provisions at district level) (NEN 7125, 2017)[5]. The EMG was developed to create transparency and a common ground on the calculation of the energy performance of measures at the district level. Results of these calculations are used to

[4] EC (2016) Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast). COM (2016) 767 final/2

[5] NEN (2017) Energieprestatienorm voor maatregelen op gebiedsniveau (EMG) – Bepalingsmethode (Energy performance standard for provisions at district level - Determination method)

rate the performance of these measures on the level of individual building applying the building standards. Building on these standards amongst other implies that not a full LCA method is applied but only energy use and CO_2 emissions in the use phase are considered.

- The definition of renewables within the European Directive on Renewable energy (EC, 2016) and the practical guidance on the calculation of renewable energy production for various sources in the Dutch Protocol Monitoring Renewable Energy (PMHE) (RVO, 2014)[6].
- The calculation rules developed to determine the share renewable energy for nearly zero energy buildings (RVO, 2017)[7].

- Methods should preferably be in line with *EU standards and guidelines*. The EMG is in line with the European Standard EN 15316-4-5 (CEN, 2007)[8] on heating systems in buildings. The standard offers Member States of lot of freedom to use their own method and apply country specific energy and emission factors.
- The calculated indicators should provide insight on the *actual sustainability* of supplied heat by making use of data annually measured and collected by the heat suppliers as well as actual monitoring data on e.g. the energy and CO_2 performance of the electricity production sector in the Netherlands and the CO_2 emission factors of fossil fuels.

It was furthermore decided that Green Certificates (either for electricity or gas) procured by the heat supplier to “green” their operations and heat supply are not rated in the three mandatory indicators. To provide incentives for heat suppliers to green their energy consumption it was, however, recommended to do rate green energy production for which it can be demonstrated that is physically linked to the operations of the heat network.

4 Considered heat supply sources

For the most widespread energy sources that supply energy to district heating networks in the Netherlands calculation rules were established. These sources include:

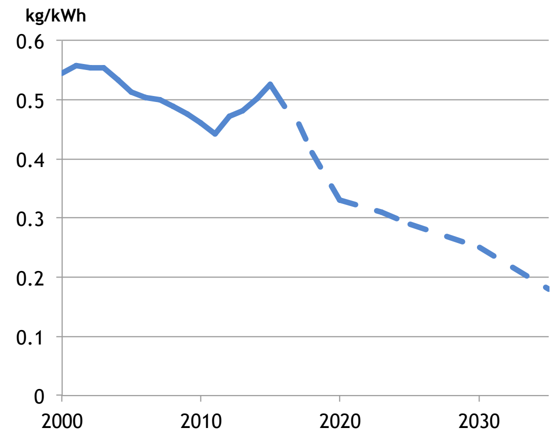


Figure 3: Realised and projected CO_2 emissions for the Dutch electricity mix calculated according to the Integral method (CBS, 2017), ECN et al (2016)

Electricity

Electricity is utilized as (auxiliary) energy to operate pumps to transport heat or drive heat pumps. Primary fossil energy use and CO_2 emissions associated with the consumption of electricity are calculated using the most recent numbers on the primary fossil energy use and CO_2 emissions of the national electricity production mix applying the “Integral method”. This method considers the full mix of electricity production facilities - renewables as well as fossil sources, base load as well as peak load facilities – to determine primary energy use and CO_2 emissions per kWh (CBS (2017)[9] Harmelink et al (2014))[10]. Note that an improvement in the efficiency of the national electricity mix results in an "autonomous"

[6] RVO (2014) Protocol Monitoring Hernieuwbare Energie. Herziening 2015 (Protocol Monitoring Renewable Energy. Recast 2015).

[7] RVO (2017) Wettelijk eisen BENG (Legal requirements NZEB)

[8] CEN (2007) CSN EN 15316-4-5

[9] CBS (2017) Rendementen en CO_2 emissie (Efficiencies and CO2 emission).

[10] Harmelink M, L Bosselaar (2014) Assessment of CO_2 emissions of electricity and heat used at industrial plants. Proceeding of the ECEEE Industrial Summer Study.

improvement of the sustainability of supplied heat, while in the "real world" no physical changes take place at the heating network. Figure 3 shows results from the national energy outlook revealing that this effect can be substantial in the future (ECN et al, 2016)[11].

Heat supplied by heat driven CHP installations

Heat driven CHP (Combined Heat and Power) installations have the primary objective to fulfil a heat demand, and electricity is more or less considered a by-product. It is assumed that the produced electricity is fed into the national grid and that the heat is fed into the district-heating network. This implies that in order to be able to determine the sustainability of supplied heat the (fossil) fuel consumed by the CHP installation and the emitted CO_2 need to be allocated to the produced heat and electricity.

The EMG standard applies the "power bonus method" for this allocation. This "Power Bonus" method assumes that central electricity production decreases as a consequence of the production of electricity with a decentralised CHP installation. This leads to savings on primary energy and CO_2 reduction, which are allocated to the heat produced by the CHP installation. Savings and CO_2 reductions are calculated using the primary fossil energy use and CO_2 emission factor for the national electricity production mix applying the "Integral method".

Heat supplied by electricity driven CHP installation

Electricity driven CHP installations have the primary objective to fulfil electricity demand but besides produce a relatively small amount of heat. Installations typically embody large natural gas or coal fired *power stations*. Operators driving these installations knowingly choose to either produce less or no electricity with the aim to produce more heat when this results in a positive business case for the systems as a whole. This heat is fed into district heating networks. Because the customer only purchases the heat a choice needs to be made on how much CO_2 emissions should be allocated to the heat and the electricity produced with these installations.

Next to the power stations there are various *waste incinerators* that operate as electricity driven CHP installations. The core activity of these plants is, however, burning waste and the electricity and heat are by-products. As there is currently no accepted method for the allocation of CO_2 emission to these three functions, the EMG standard treats waste incinerators similar to electricity driven CHP installation.

Table 1: Primary fossil fuel and CO_2 emission factor for various fuels

	Primary fossil fuel factor	CO2 emission factor (kg/GJprimary)
Coal	1,00	90
Fuel oil	1,00	69
Natural gas	1,00	51
Municipal solid waste	0,46	38
Biomass	0,00	0

There has been a lot of debate among stakeholders in the Netherlands on the method and emission factors that should be applied to rate the sustainability of heat from electricity driven CHP installations. Stakeholder *agreed* that it's plausible to assume that losses in electricity production are offset by additional production in other power stations that feed into the grid, and that fossil fuel use and CO_2 emissions associated with this additional production should be allocated to the produced heat. They, however, could *not agree* on the way the amount of primary fossil energy and CO_2 emissions associated with this additional production should be calculated. Some stakeholders strictly wanted to follow the line of reasoning that losses in electricity production are offset in other power stations and apply the primary fossil energy use and CO_2 emission factors for the Dutch electricity mix. In this way heat supplied by a coal-fired power plant is indistinguishable form heat delivered by a natural gas fired plant. Other stakeholders argued that the fact that they are applying fuels with low carbon content should be rated in the sustainability of the delivered heat. Finally a compromise was reached to use the primary fossil fuel

[11] ECN, CBS, PBl, RVO (2016). National Energy Outlook 2016.

factor of the Dutch electricity mix applying the "Integral method" to calculate the amount of fuel that is required to compensate for the additional electricity production tot off-set electricity production in the CHP installation. Next the primary fossil fuel and CO_2 emissions allocated to the produced heat are calculated by applying the specific primary fossil energy factors and CO_2 emissions factors for the fuel used in the installations (see table 1). In the proposal for the law, the government decided on this compromise.

Heat supplied by a boiler

Boilers are amongst others deployed to provide heat in periods of peak demand. Calculations rules are in this case straightforward as the CO_2 emissions associated with burning the fossil fuels in the boilers are fully allocated to the produced heat.

Residual heat

Residual heat is defined as heat, which is released as a by-product of a (industrial) process. This means that: (i) this heat otherwise would be discharged and (ii) no additional fuel injection is required for the production of the residual heat. Primary fossil energy use and CO_2 emissions associated with the electricity that is needed to extract this heat from the production process and deliver to the end-consumer is allocated to the residual heat.

Heat from geothermal sources

When using energy from geothermal sources, either through the direct use of deep geothermal energy or use of shallow geothermal energy with a heat pump, electricity is used to: (i) operate the heat pump (optional), (ii) operate circulation and source pumps to transport warm and cold water, and (iii) regenerate the geothermal source (i.e. actively ensuring that the stored warm and cold water are balanced).

General principle for the calculation method is that all electricity consumed within the system boundaries is allocated to the either the utilized heat and / or cold, and both should be included in the mandatory reporting. In case shallow geothermal energy is used with a heat pump three situations can be distinguished:

- The heat pump is mainly used to deliver warm water. All the electricity used by the heat pump (and related use of primary energy and CO_2 emissions) is allocated to the heat.
- The heat pump is part-time used to simultaneously deliver warm and cold water. Electricity used by the heat pump is allocated in proportion to the heat and cold delivered with the heat pump.
- The heat pump is mainly used to deliver cold water. Heat is a considered a residual product that is only used occasionally. Also in this situation the electricity used by the heat pump is allocated in proportion to the heat and cold delivered with the heat pump.

5 Calculation of the indicators

Annex holds 3 examples in which the methods and calculation rules are applied to calculate the 3 mandatory indicators for

6 Conclusion and discussion

In this paper we have shown how for the Netherlands we have developed a method to calculate the sustainability of district heating systems for three indicators. The method is in line with European guidelines and anticipates on the proposed revisions of the Renewable Energy Directive.

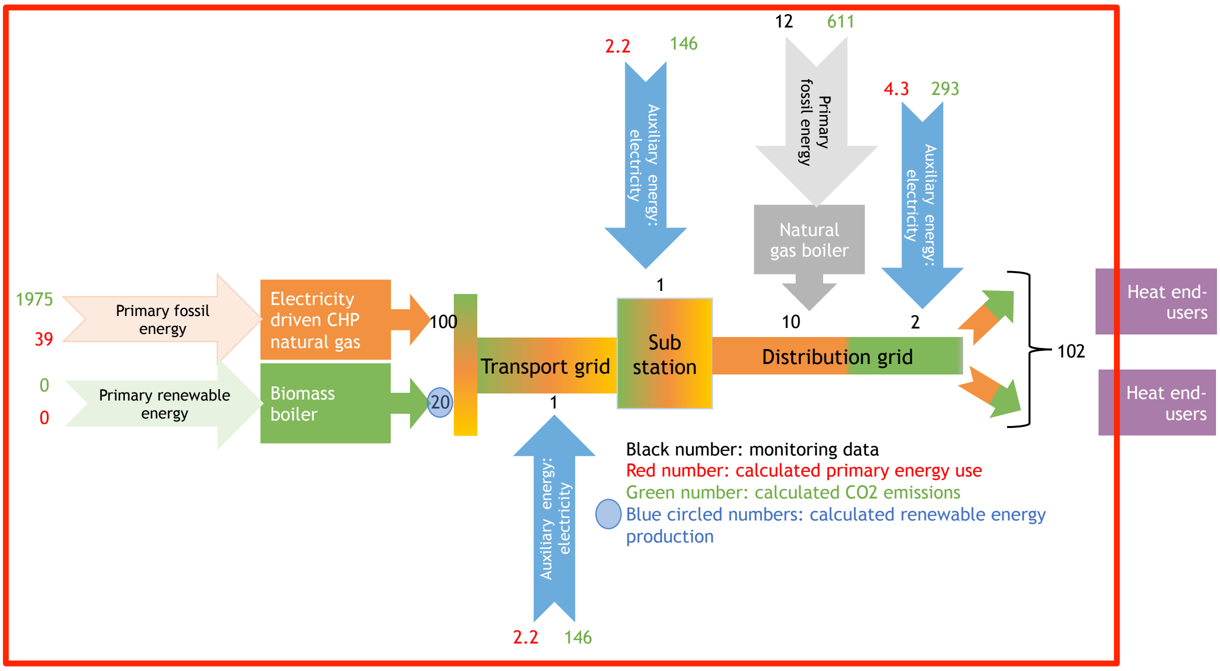
This paper shows that a method can be developed by building on existing standards and employing data sources that are either publically available or already annually gathered by the stakeholders with a reporting obligation.

The calculation methods can be used as a basis for a calculating method for other European countries to determine the sustainability of district heating systems. However, discussion on harmonisation of methods around Europe is probably necessary to address issues like: how to deal with a growing share of renewables and how to rate this in the sustainability of district heating.

Annex: Examples

Example #1:

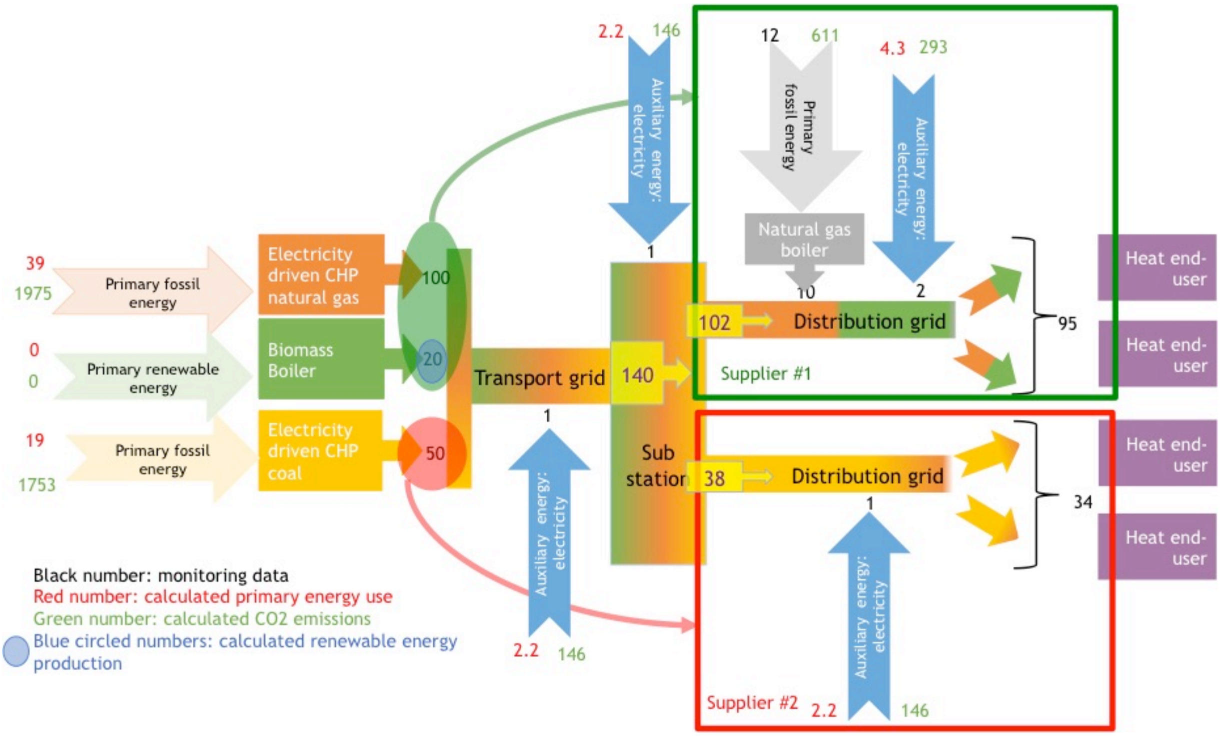
A supplier operates the district-heating network pictured below. The supplier is operating the transport as well as the distribution grid and is the only one delivering heat to the end-users. The heat is produced by three sources: (i) a natural gas fired electricity driven CHP installation and a (ii) biomass boiler that both feed into the transport grid, and (iii) a natural gas boiler that feeds into the distribution grid. Besides the supplier buys electricity to operate his district-heating network. The red lines mark the reporting boundaries for the heat supplier.



	Unit	Value
Heat delivery to end users	GJ_{heat}	102
Heat losses in the grid	GJ_{heat}	28
Heat production natural gas fired electricity driven CHP installation	GJ_{heat}	100
Primary fossil energy use	$GJ_{primary}$	39
CO_2 emissions	kg	1975
Heat production biomass plant	GJ_{heat}	20
Primary fossil energy use	$GJ_{primary}$	0
CO_2 emissions	kg	0
Renewable energy production	$GJ_{renewable}$	20
Heat production natural gas fired boiler	GJ_{heat}	10
Primary fossil energy use	$GJ_{primary}$	12
CO_2 emissions	kg	611
Subsidiary energy: electricity	$GJ_{electricity}$	4
Primary fossil energy use	$GJ_{primary}$	9
CO_2 emissions	kg	586
INDICATORS		
Primary fossil energy use	$GJ_{primary}/GJ_{heat}$	0,6
Renewable energy production	$GJ_{renewable}$	20
Share of renewable energy	%	25%
CO_2 emissions	kg/GJ_{heat}	31
CO_2 reduction	%	46%

Example #2:

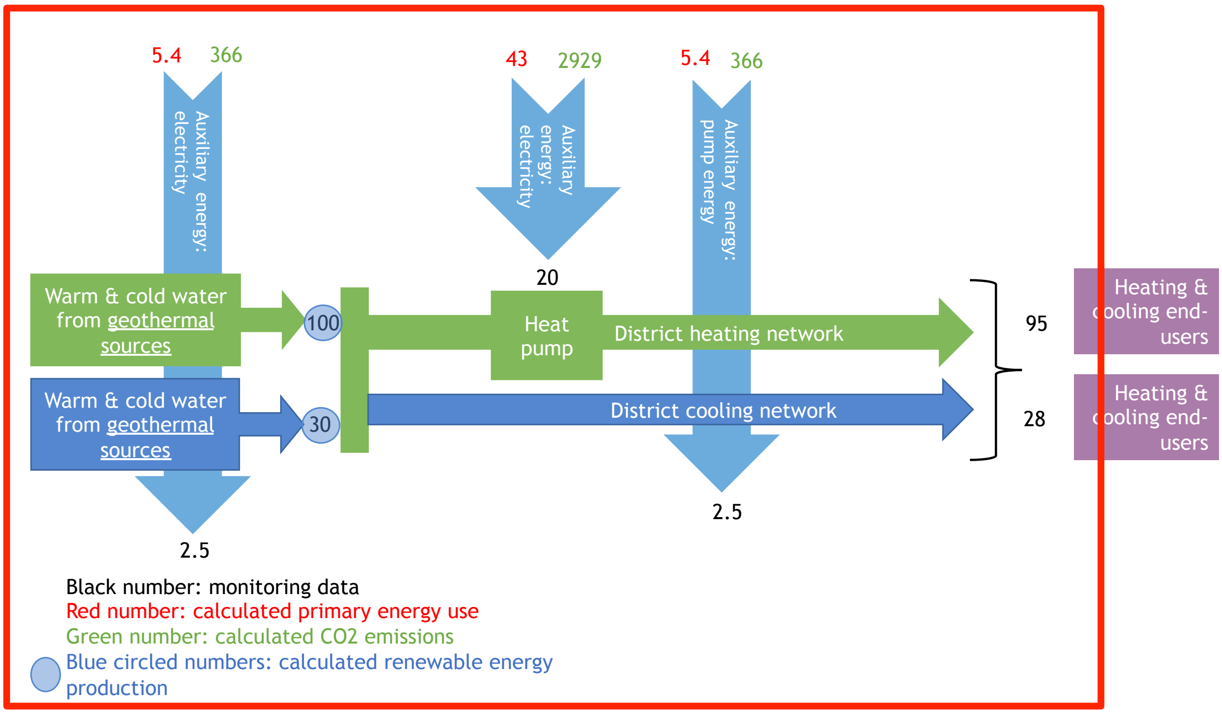
A district-heating network includes a transport grid and two distribution grids. The transport grid and the two distribution grids are operated by different entities. The suppliers delivering heat to the end-users share the same transport grid. Heat is delivered to the transport grid by three types of installations. Supplier #1 has a contract with the operator of the natural gas fired electricity driven CHP installation and the biomass boiler, and supplier #2 with the operator of the coals fired electricity driven CHP installation. The green lines mark the reporting boundaries for heat supplier #1, and the red lines the boundaries for heat supplier #2.



	Unit	Supplier #1 Value		Supplier #2 Value
Heat delivery to end users	GJ$_{heat}$	95		34
Heat losses transport grid	GJ$_{heat}$		30	
Heat losses transport grid	GJ$_{heat}$	21		9
Heat losses distribution grid	GJ$_{heat}$	17		6
Heat production natural gas fired electricity driven CHP installation	GJ$_{heat}$	100		0
Primary fossil energy use	GJ$_{primary}$	39		0
CO_2 emissions	kg	1975		0
Heat production biomass plant	GJ$_{heat}$	20		0
Primary fossil energy use	GJ$_{primary}$	0		0
CO_2 emissions	kg	0		0
Renewable energy production	GJ$_{renewable}$	20		0
Heat production coal fired electricity driven CHP installation	GJ$_{heat}$	0		50
Primary fossil energy use	GJ$_{primary}$	0		19
CO_2 emissions	kg	0		1753
Heat production natural gas fired boiler	GJ$_{heat}$	10		0
Primary fossil energy use	GJ$_{primary}$	12		0
CO_2 emissions	kg	611		0
Subsidiary energy: electricity distribution grid	GJ$_{electricity}$	2		1
Primary fossil energy use	GJ$_{primary}$	4		2
CO_2 emissions	kg	293		146
Subsidiary energy: electricity transport grid	GJ$_{electricity}$		1	
Primary fossil energy use	GJ$_{primary}$	1,5		0,6
CO_2 emissions	kg	103		43
INDICATORS				
Primary fossil energy use	GJ$_{primary}$/GJ$_{heat}$	0,6		0,7
Renewable energy production	GJ$_{renewable}$	20		0
Share of renewable energy	%	26%		0%
CO_2 emissions	kg/GJ$_{heat}$	31		57
CO_2 reduction	%	46%		1%

Example #3:

A supplier extracts warm and cold water for heating and cooling from geothermal sources. The warm water is upgraded to a higher temperature using a heat pump before it's delivered to the end-users. The cold water is directly used for cooling. The red lines mark the reporting boundaries for the supplier. In this case electricity used to operate the network needs to be allocated to heat and electricity.



	Unit	Total Value	Heating Value	Cooling Value
Energy delivery to end users	GJ_{final_energy}	123	95	28
Energy losses in the grid	GJ_{final_energy}	7		
Total electricity use heating and cooling system	$GJ_{electricity}$	25		
Primary fossil energy use	$GJ_{primary}$	54		
allocated to heating	$GJ_{primary}$		47	
allocated to cooling	$GJ_{primary}$			7
CO_2 emissions	kg	3661		
allocated to heating	kg		3495	
allocated to cooling	kg			167
Renewable energy production	$GJ_{renewable}$	130	100	30
INDICATORS				
Primary fossil energy use	$GJ_{primary}/GJ_{final\_}$	0,4	0,5	0,2
Renewable energy production	$GJ_{renewable}$	130	100	30
Share of renewable energy	%	71%	68%	82%
CO_2 emissions	kg/GJ_{final_energy}		37	6
CO_2 reduction	%		36%	