

## IEA-DHC, Annex X

# Summary Final Report Universal Calculation Model Tool

Date: 2014-09-10

Authors:

Maria Justo Alonso, Frode Frydenlund and Jacob Stang

## IEA-DHC, Annex X: User Manual UMC Tool

This page is empty on purpose.



# Contents

- Contents..... 3
- Executive Summary ..... 4
- Universal Calculation Model Tool – quick guide ..... 6
  - 1.1 Delivered Energy..... 7
  - 1.2 CHP ..... 7
  - 1.3 DH-net ..... 7
  - 1.4 Chiller..... 7
  - 1.5 DC-net ..... 7
  - 1.6 More details CHP ..... 7
  - 1.7 Results and reporting ..... 7
- 2 Defining the CHP ..... 8
- 3 Defining the DH-net..... 8
 

More detailed calculations of the DH can be especified. Here one can define the pipes in the network and see the detailed losses for the design conditions. This condition is normally 100% flow ..... 8
- 4 Chiller..... 9
- 5 More details on the CHP ..... 9
  - 5.1 Fuel data..... 9
  - 5.2 Choosing the allocation method ..... 11
  - 5.3 Ash ..... 12
- 6 References..... 12
- Figures.....**Fehler! Textmarke nicht definiert.**
- Tables .....**Fehler! Textmarke nicht definiert.**

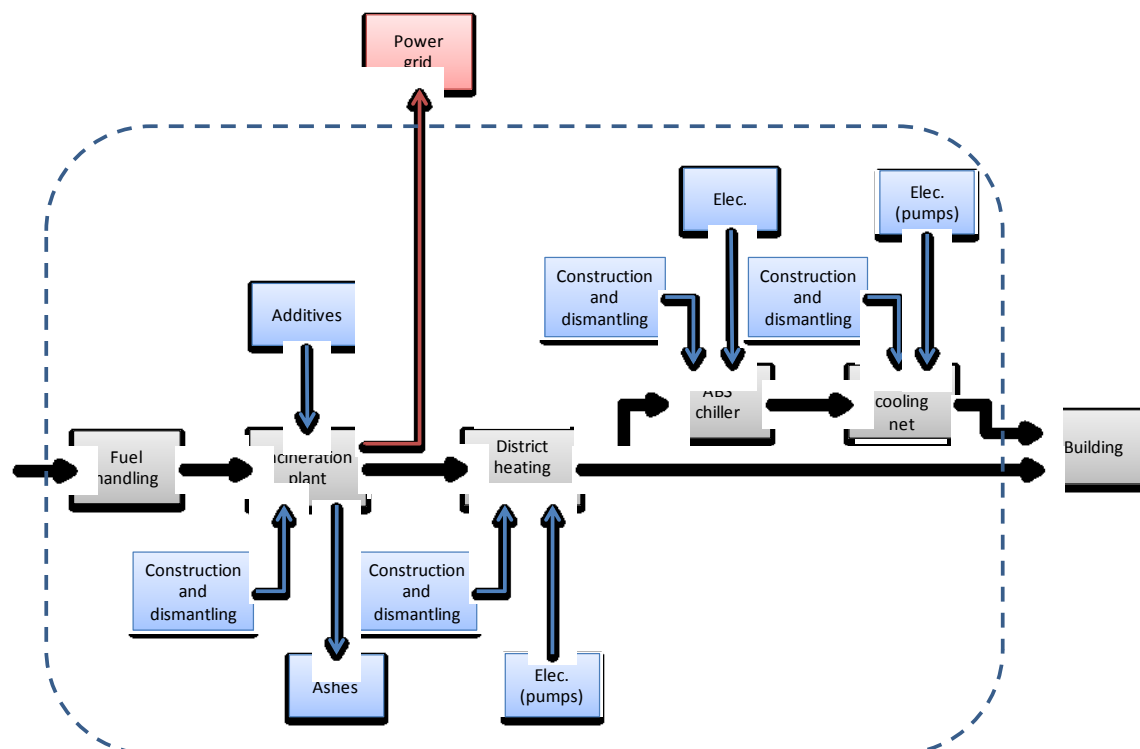
## Executive Summary

Directive 2010/31/EU on the energy efficiency of buildings emphasizes that the energy performance of a building shall be calculated by use of Primary Energy Factors (PEF). Furthermore its use is aiming to reduce the use of non-renewable energy, inciting the use of heat and electricity from CHP, and reducing the energy consumption in the building sector.

The objective of this project has been to develop a universal, well documented and transparent method for calculation of Primary Energy Factor (PEF) and Primary Energy Use (PEU) and emission of greenhouse gases (CO<sub>2</sub>-eq). A theory guide that presents the theory behind the method, a user guide that shows how to use the tool and the tool itself have been delivered to the IEA-DHC. The developed calculation tool has been validated by calculating the primary energy factors and the emission of greenhouse gases for selected case studies.

The overall aim of the UCM is to illustrate the environment potential and the potential of saving primary energy by DHC and/or CHP systems in a transparent and understandable way to the energy society.

The calculation tool is partly based on the previous works by Berner, Lindahl and Stang [1-3]. Here we have included sub-processes such as pipelines, trenches, additives and ash, as well as the building of the CHP-plant and fuel transport (see Figure 1 below). However all this is not mandatory in the standards related to Directive 2010/31/EU (Recast).



**Figure 1 Sub-processes included in the Universal Calculation tool.**

## IEA-DHC, Annex X: User Manual UMC Tool

Allocation, e.g. distribution of the environmental impact between produced heat/cool and electricity can be calculated by different methods. The following allocation methods are included in the tool:

- (1) **Power bonus method (PBM)**
- (2) **Power loss method (Dresden method)**
- (3) **Energy method**
- (4) **Alternative generation method**
- (5) **Exergy method**
- (6) **200% method**

It is possible to include additives and ash in the calculation; however this is not a mandatory input. As the standards [4] do not yet ask for introduction of additives and ash, the tool will give the possibility to remove them. It is further possible to include infrastructure like buildings for power plants, chillers, pipes/trenches etc.

Heat loss and head loss can be included as a factor related to the network's energy density. Alternatively, a more detailed calculation for a specific network based on the pipe diameter, flow, temperature levels, length, and seasonal load levels can be performed.

The yearly heat/cool distribution throughout the year is based on a load curve, simplified to four different seasons with appurtenant temperatures and flows.

The efficiency of the CHP will influence the values of PEF and CO<sub>2</sub> emission. Based on Lindahl [3] and Berner [2] mainly average efficiencies for the CHP have been applied. Several other reports [5, 6] demonstrate the impact of different part load levels. Therefore, a possibility to include plant specific efficiency values is included.

When the alternative generation method is applied for the allocation, harmonized reference values should be utilized [7]. By using non-standardized reference values, large variations in the result might occur.

## Universal Calculation Model Tool – quick guide

The calculation tool can be divided in several sub-parts which the user will be guided through and asked to provide information depending on the chosen level of detail. The user has a possibility to refine the calculation tool by introducing data from his own plant and system instead of using default values for the different parameters. Thus, the tool includes a set of predefined values for the majority of the parameters, but there is also a possibility to check out values and modify them upon request. The user will be provided with default values whenever lacking input information.

For all levels of detail, the output from the calculation tool will consist of:

- Total Primary Energy Factor ( $PEF_{tot}$ )
- Renewable Primary Energy Factory ( $PEF_{ren}$ )
- Emission coefficient -  $CO_2$ -equivalents [g/kWh]

for the district heating and/or district cooling delivered to the end customer.

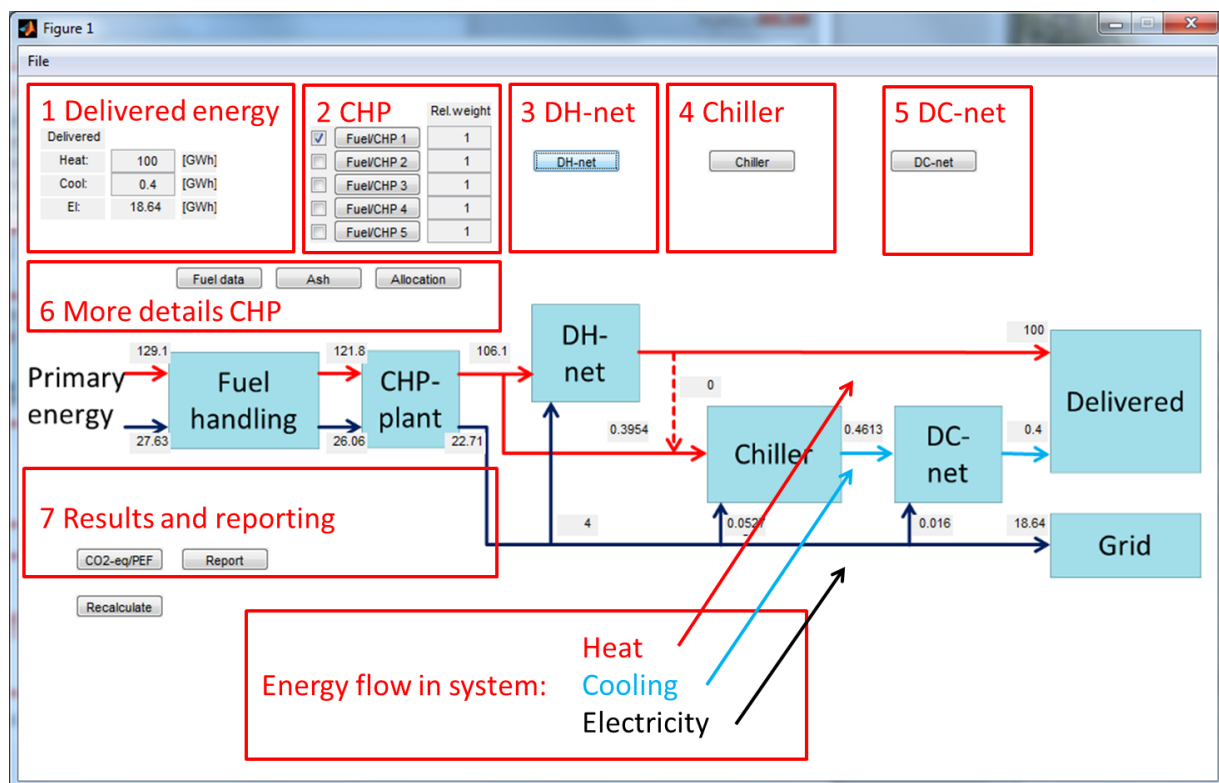


Figure 2 Main screen of the UCM tool.

Figure 2 shows the main screen of the UCM tool.

## 1.1 Delivered Energy

Enter the amount of heat and cooling you want to be delivered during a year. The electricity (EI) produced is calculated. If electricity is negative there is no production of electricity in the system, and the necessary amount is imported from the grid. At the start no allocation method is selected and that is often the reason for no electricity production. A proper allocation method can be selected using the button "Allocation".

## 1.2 CHP

This section specifies the CHP-plants: the fuel type and technology for each plant. It is possible to set the relative weight of the sum of heat and electricity, and select which plants are active.

## 1.3 DH-net

This section defines the district heating (DH) network for distribution of the heat. It is possible to use predefined values for the losses, or define a pipe network and calculate the losses in more detail.

## 1.4 Chiller

This section defines the type of the chiller for the cooling production. It is possible to combine several types and select the heat source if absorption chiller is used.

## 1.5 DC-net

This section defines the district cooling (DC) network for distribution of the cool from the chiller. It is possible to use predefined values for the losses, or define a pipe network and calculate the losses in more detail.

## 1.6 More details CHP

Fuel data: See the data behind each fuel. It is also possible to define your own fuel.

Ash: Give the transport length to the ash treatment/disposal site.

Allocation: Choose an allocation method for calculating the emission and resources for heat and electricity. Choose the mix of the electricity production.

## 1.7 Results and reporting

The energy flow through the system is shown in the figure of the main screen. The numbers by the arrows indicate the energy flows for heating, cooling and electricity.

CO<sub>2-eq</sub>/PEF: Breaks down the CO<sub>2-eq</sub> emissions and Primary Energy Factor (PEF) losses in more detail.

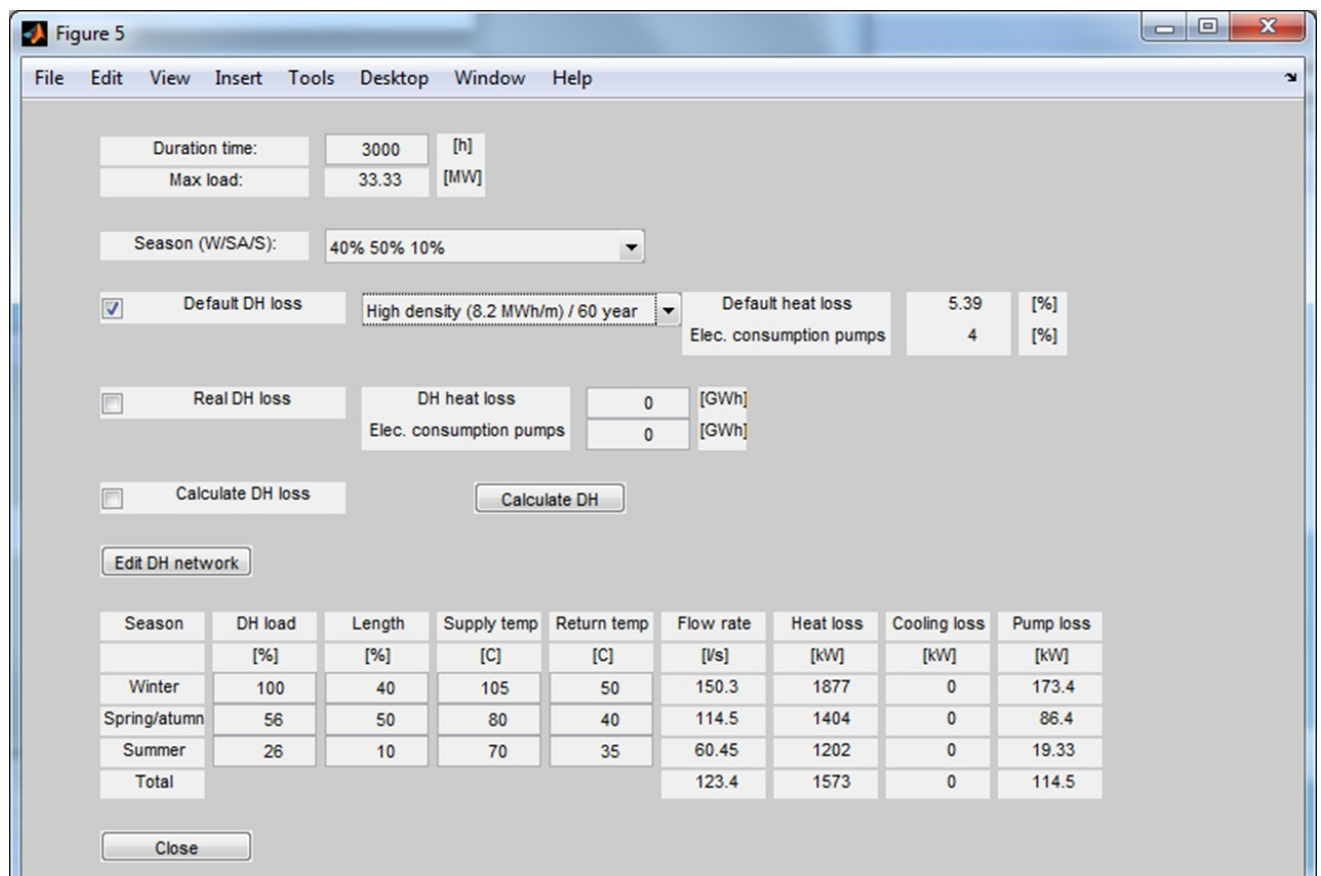
Report: Produce a HTML-file containing the input values and the results.

## 2 Defining the CHP

Figure 3 shows the screen for defining the CHP plant. The upper part of this screen defines a single CHP-plant. You can select a fuel type and the CHP technology, and the efficiency and the power to heat ratio ( $\alpha$ )

## 3 Defining the DH-net

Figure 4 shows the screen for defining the DH network and how the network performs during the seasons over a year.



**Figure 3** Screen for defining the DH network.

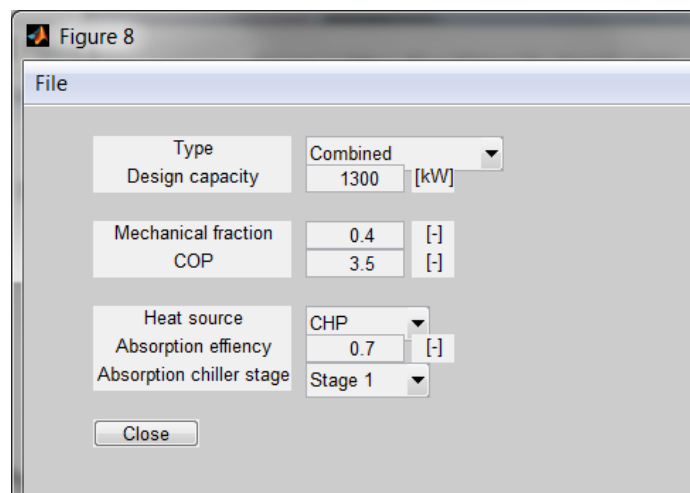
More detailed calculations of the DH can be specified. Here one can define the pipes in the network and see the detailed losses for the design conditions. This condition is normally 100% flow

The tool calculates also the losses for spring/autumn and summer season with reduced flow and lower flow temperatures. The average yearly losses are then used in the calculation of PEF.



## 4 Chiller

If the network produces also cooling, the chiller must be defined. By selecting 'Chiller' in the main screen, the screen shown in Figure 6 appears. The user must first define the type of chiller, being able to decide between mechanical, absorption, combined and free cooling (for further information please check [1]).



Type	Combined	
Design capacity	1300	[kW]
Mechanical fraction	0.4	[-]
COP	3.5	[-]
Heat source	CHP	
Absorption efficiency	0.7	[-]
Absorption chiller stage	Stage 1	

**Figure 4** Screen for specifying the chiller.

In combined cooling, both absorption and mechanical refrigeration are used. In this case user must also define the mechanical fraction, i.e., the fraction of the cooling that is produced by mechanical cooling. The COP is defined as the cooling power divided by the input power for the compressor in the mechanical chiller and for the pump in free cooling.

An absorption chiller uses a heat source to produce cooling and this can be selected to be either the CHP or the DH network. Two types of absorption chillers are available: single or two-stage. A single stage absorption chiller operates with a single generator and uses low-pressure steam, whereas the two-stage type has a second generator in the cycle and requires high-pressure steam for operation. Two-stage absorption chillers have typically higher efficiencies.

If mechanical cooling is selected and the need for cooling is high and electricity production low, electricity will be imported from the grid. In this case the delivered electricity will appear negative in the main screen.

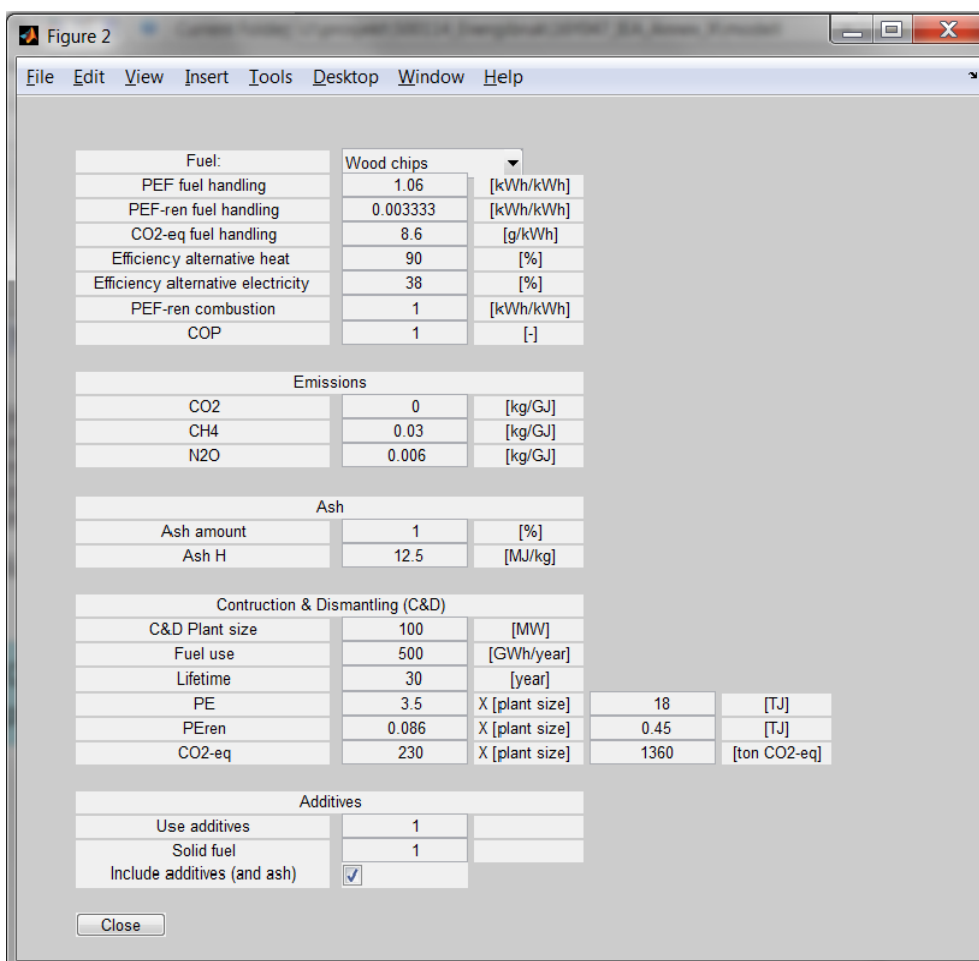
## 5 More details on the CHP

### 5.1 Fuel data

Given the case when the fuel data introduced as default do not correspond with the ones measured or known by the user, then the user has the possibility to define them in detail taking

## IEA-DHC, Annex X: User Manual UMC Tool

into account the fuel PEF and CO<sub>2</sub> emissions, the efficiency of its conversion, information regarding the ashes and/or the construction and dismantling of the plant. This is done by selecting 'Fuel data' in the main screen, at which time the screen shown in Figure 8 appears. Here, PEF<sub>ren</sub> (or PEF-ren) fuel handling refers to the renewable primary energy use related to the fuel handling process, and PEF<sub>ren</sub> combustion refers to the renewable primary energy use related to the combustion, etc. For the fuel combustion the lower heating value is used as default. For the default values, see Table 3. The choice of the PEFs for the different fuels is further explained in Appendix B of [1].



Fuel:		Wood chips	
PEF fuel handling	1.06	[kWh/kWh]	
PEF-ren fuel handling	0.003333	[kWh/kWh]	
CO <sub>2</sub> -eq fuel handling	8.6	[g/kWh]	
Efficiency alternative heat	90	[%]	
Efficiency alternative electricity	38	[%]	
PEF-ren combustion	1	[kWh/kWh]	
COP	1	[-]	

Emissions		
CO <sub>2</sub>	0	[kg/GJ]
CH <sub>4</sub>	0.03	[kg/GJ]
N <sub>2</sub> O	0.006	[kg/GJ]

Ash		
Ash amount	1	[%]
Ash H	12.5	[MJ/kg]

Construction & Dismantling (C&D)				
C&D Plant size	100	[MW]		
Fuel use	500	[GWh/year]		
Lifetime	30	[year]		
PE	3.5	X [plant size]	18	[TJ]
PEren	0.086	X [plant size]	0.45	[TJ]
CO <sub>2</sub> -eq	230	X [plant size]	1360	[ton CO <sub>2</sub> -eq]

Additives		
Use additives	1	
Solid fuel	1	
Include additives (and ash)	<input checked="" type="checkbox"/>	

**Figure 5 Fuel data screen.**

**Table 1 Default values for PEFs and CO<sub>2</sub>-equivalents for the different fuels.**

Fuel	PEF <sub>tot</sub> fuel handling (kWh/kWh)	PEF <sub>ren</sub> fuel handling (kWh/kWh)	CO <sub>2</sub> -eq fuel handling (g/kWh)	CO <sub>2</sub> -eq combustion (g/kWh)	PEF <sub>ren</sub> combustion (kWh/kWh)

Natural gas, steam cycle	1,09	1,24E-03	43	206	-
Natural gas, combined cycle	1,09	1,24E-03	43	206	-
Fuel oil 2-5	1,11	5,94E-03	21	280	-
Anthracite	1,15	1,38E-08	38	356	-
Lignite	1,02	1,25E-03	4	365	-
Peat	1,01	8,69E-04	40	383	-
Wood chips	1,06	3,33E-03	9	9	1,00
Wood chips, logging residues	1,03	3,33E-03	7	9	1,00
Waste (Polluter-Pays allocation)	0,04	3,00E-05	4	-	-
Waste (69% renewable)	1,04	3,00E-05	4	116	0,69
Electricity (for boiler)	2,84	8,00E-02	420	-	
Heat Pump	0,95	2,67E-02	140	-	
Industrial excess heat	-	-	-	-	-

To fill in the fields about the construction and dismantling, please check Appendix C.2 in [1]. How the PE use in the construction and dismantling is calculated is explained in the same appendix. The PE use follows the following expression:

$$PE=A \cdot (\text{Size of the plant in MW}) +B$$

However, if the user knows the precise value, the first part of the formula should be set to zero and the variable B (right-hand side field under Construction & Dismantling) to its precise value.

In context with additives, the user can choose whether or not to include additives and ash in the calculation by ticking? or unticking? the box "Include additives (and ash)". This can be performed also in the Ash screen (see below).

## 5.2 Choosing the allocation method

The allocation method is chosen by selecting "Allocation" in the main screen, at which time the screen shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** appears. No

allocation method is chosen by default. The assumptions behind the allocation methods are explained in detail in [1]. Some allocation methods need additional information:

### 5.3 Ash

After the choice of the allocation method, the user must define the transport of the ash, which is done by clicking 'Ash' in the main screen. As the transport of the ash is not standardized, the user can choose whether or not to use it in the CO<sub>2</sub> and PEF calculations by ticking or unticking the box "Include ash (and additives)" as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** This determines also if additives are included, and performs the same function as the "Include additives (and ash)" tick-box in the Fuel data window.

Previous studies have concluded that ash transport has a small effect on the final result [2, 3]. Emissions per km of transported ash are hence calculated using a default value.

## 6 References

- [1] B. M. Alonso M. J., Frydenlund F. Stang J., Lindahl M., Alsbjer M., Kyung K., "Calculation model - Documentation and user manual for "Universal Calculation Model" (UCM)," IEA-DHC Annex X 2014 (Unpublished).
- [2] M. Berner, "Primary Energy Efficiency and District heating," NTNU 2010.
- [3] S. B. Lindahl A., Eom J.-S., Eom K.-I., "The Potential for Increased Primary Energy Efficiency and Reduced CO<sub>2</sub> Emissions by DHC," IEA-DHC Annex IX 2011.
- [4] "Mandate M480 for the support of the EPBD, EN 15603 and EN 15316-4-5," ed, 2014.
- [5] M. Berner and R. Ulseth, "The primary energy concept," 2008.
- [6] M. Berner, R. Ulseth, and J. Stang, "Primary energy efficiency and system engineering," in *12th International Symposium on District Heating and Cooling, Tallinn, Estonia, 2010*.
- [7] "COMMISSION DECISION of 21 December 2006 establishing harmonized 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 (notified under document number C(2006) 6817)," ed: Official Journal of the European Union, 2007.