

Guide to the CO₂ emission calculator



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About HeatNet NWE

This document has been developed as part of the HeatNet NWE project, which is part-funded through the Interreg NWE programme and aims to increase the uptake of 4DHC networks across North-West Europe. As part of this project, the partners are developing the HeatNet Model, which will help the public sector to begin implementing 4DHC networks, and the Transition Roadmaps, which will outline the partners’ experience in developing six district heating pilots across North-West Europe. The HeatNet Guide to Financing is also currently being developed and will give a broad overview of the various sources available to finance district heating schemes.

For further information on these reports and on the HeatNet NWE project, please visit www.guidetodistrictheating.eu.

Table of contents

Introduction.....	4
Danish District Heating Assessment Tool	5
Input data	5
Result sheets.....	6
HeatNet District Heating Assessment Tool.....	6
Climatic data	7
Technology data	8
Prices and emissions.....	9
District heating network.....	10
Additional data: annual heat demand	11
Conclusion and further developments	12

Introduction

This document is a guide to the CO₂ emission calculator of the Interreg HeatNet North West Europe project, included in Work Package 3.

The emission calculator is based on the District Heating Assessment Tool developed by Ramboll for the Danish Energy Agency (DEA). This tool allows assessing the economic feasibility of district heating projects, by comparing a reference situation to the district heating project. The data available in the tool was then adapted to fit to the situation in each project partner's countries. The Danish model is based on MS Excel, and includes no hidden data or VBA code, which makes it easy to handle and modify if needed.

Along with the District Heating Assessment Tool, the Danish Energy Agency released a guide in order to clarify how the tool works, what data can be changed according to the country, and what assumptions are made.

The present guide will quickly describe the original DHAT, and then focus on the changes and adaptations made to fit it to the five countries taking part in the HeatNet NWE project.

The task was led by Cerema, with additional input from the Amsterdam University of Applied Sciences.

Danish District Heating Assessment Tool

The District Heating Assessment Tool, developed by Ramboll for the Danish Energy Agency (DEA), allows assessing the economic feasibility of district heating projects. It is based on MS Excel and is freely available, and since it does not contain any hidden data, it is possible to modify all inputs and variables.

The model, using a wide range of data, allows comparing a reference situation, that is, with individual heating in the concerned buildings, and a district heating situation. The comparison is about economic and environmental parameters: comparison of total costs, Levelized Costs of Energy (LCOE), emissions of air pollutants, for example.

This report will concisely describe the model, since Ramboll and the DEA have already published a report on the structure, variables and results of the model. The full report and the District Heating Assessment Tool are available using the following link:

<https://ens.dk/en/our-responsibilities/global-cooperation/district-heating-assessment-tool-dhat>

Input data

The model uses two 'types' of input data:

- Input data related to the project:
 - o What is the amount of heat consumed every year?
 - o What are the heating technologies used in the reference situation (that is, before any district heating network project)?
 - o Which district heating technologies will be used?
 - o Are there any subsidies for the reference or the district heating project technologies, and what are the other economic parameters (VAT, taxation, and loan rate)?
 - o Etc.

These data related to the project is in the excel sheet 3 called "Input data" and has to be filled by the user.

- Standard data based on the DEA or on empirical data from Ramboll:
 - o Technology data (investments costs, O&M costs, efficiencies),
 - o Fuel prices (based on projections by the IEA),
 - o District heating network prices,
 - o Production profiles,
 - o Etc.

The standard data can be adapted if needs be and are in the sheets:

- 8. Technology data;
- 9. Price & emissions;
- 10. DH network;
- 11. Heat production.

Using these input data (project related and standard data); the model computes the economic feasibility and the amount of avoided pollutant emissions of the project in sheets 5, 6 and 7. Since these sheets contain mostly formulas, the boxes must not be modified.

Result sheets

The sheet number four ('Output') displays the results in the form of a set of graphics. The sheet number twelve ('Report') displays the most important results in a printable version.

The result sheet number four, shows a variety of results:

- Levelized Cost Of Energy (LCOE) for the reference and district heating situations, regarding the base load and peak load technologies;
- Societal and marginal costs, for the reference and district heating situations;
- The project evaluation, which is a comparison of the reference and district heating situation (costs, investments and reinvestments, revenues, average heat production price);
- The district heating production curves (heat production curve, heat production duration curve, solar production profile and storage level, if solar is used in the district heating situation);
- Emission comparison between reference and district heating situations (carbon dioxide, methane, nitrous oxide, nitrogen oxide emissions).

Note: the Levelized Cost Of Energy is the complete price of a kilowatt-hour of energy produced by an equipment on its overall lifetime. It integrates the initial investments costs, the operation and maintenance costs, and fuel costs. It is useful to compare lifetime operational costs between different heat production technologies.

HeatNet District Heating Assessment Tool

Adapting the tool to the NWE countries consists in changing some particular standard data:

- Climatic data: exterior temperature and solar irradiance, on an hourly basis;
- Technology data: investments costs and O&M costs;
- Prices and emissions: emission prices and emission taxes (Denmark is currently one of the countries that has the most energy and environmental taxes).

To let the user chose whatever standard data is the most adapted to its case and to be sure that none of the calculations implemented by the Danish Energy Agency are altered, it is proposed that these new data are gathered on one new excel sheet for each country. Each country sheets contain the following tables:

Table number	Table name
Table 1	Climatic data
Table 2	Individual technologies
Table 3	District Heating technologies
Table 4	Investment costs for district heating ducts
Table 5	Emission taxes - District heating stations
Table 6	Emission taxes - Individual stations
Table 7	CO ₂ emission factors
Table 8	Emission taxes

Table 1: Country sheets structure

The colour code used in the HeatNet emission calculator is the following:

Colour code		
Input data	1	Feel free to modify it!
Standard data	1	Can be modified on this sheet
Standard data, country-related	1	Can be modified, but on the country sheet
Calculation	1	Do not modify! /!\

Table 2: Colour code

Climatic data

The solar heat production and heat demand (sheet 11) are computed using climatic data.

The table that can be adapted regarding the localisation is “table 1: climatic data”.

The data that the user can change is the percentage of total heat demand and the percentage of maximum solar production. The heat demand depends on the exterior temperature; for each location considered, this hourly data will change. The solar production depends on the global solar irradiation. Exterior temperature and solar irradiation are easily accessible for each site.

Indeed, the climatic data is available on the website: <http://re.jrc.ec.europa.eu/pvgis5/tmy.html>, which is a tool provided by the European Commission, and developed by the Joint Research Centre. If the user wishes to change the climatic data, the steps are the following:

- Select location: insert the city name;
- TMY options and results: choose the period (either 2005-2014 or 2006-2015) and the relevant data. In this case, the relevant data is dry bulb temperature and global horizontal irradiance.
- Click on ‘Download csv’: downloads a csv file containing the hourly data over a typical meteorological year.
/!\ the data is presented with a point, and not with a coma! Do not forget to replace them!

Once extracted, it is possible to insert these data into the HeatNet DHAT, in the corresponding column of table 1 (Climatic data):

- Dry bulb temperature in column C;
- Solar irradiation in column F.

The climatic data currently inserted in the country sheets of the tool is the following:

- For Belgium: location Kortrijk (TMY from 2006 to 2015);
- For France: location Boulogne-sur-Mer (TMY from 2006 to 2015);
- For Ireland: location Dublin (TMY from 2006 to 2015);
- For Netherlands: location Heerlen (TMY from 2006 to 2015);
- For the United Kingdom: location Plymouth and Aberdeen, in two different sheets (TMY from 2006 to 2015).

The following paragraphs clarify the calculation implemented to acquire the percentage of total heat demand and the percentage of total solar production.

Percentage of total heat demand: calculation

$$\text{Heat Degree – Days (HDD)} = 18 - \text{exterior temperature}$$

$$\text{Percentage of total heat demand} = \frac{\text{HDD}}{\text{Total HDD}}$$

Percentage of total solar production: calculation

$$\text{Percentage of solar production} = \frac{\text{Irradiance} * \text{Efficiency}}{\text{Max (Irradiance} * \text{Efficiency)}}$$

The user can also change the solar efficiency value; usually comprised between 65 to 80% (depending on the technology used and orientation of the panels).

Table 1 Climatic data	Dry bulb temperature deg, C	HDD	Pct of total heat demand	Solar irradiance W/m ²	Efficiency W/m ²	Pct of solar production
Hour 7	4,99	13	0,0175%	0,00	0	0,00%
Hour 8	4,95	13	0,0176%	0,00	0	0,00%
Hour 9	5,27	13	0,0172%	0,00	0	0,00%
Hour 10	5,89	12	0,0163%	14,00	14	1,53%
Hour 11	6,50	12	0,0155%	90,00	90	9,84%
Hour 12	7,12	11	0,0147%	171,00	171	18,69%
Hour 13	7,28	11	0,0145%	207,00	207	22,62%
Hour 14	7,45	11	0,0142%	164,00	164	17,92%
Hour 15	7,61	10	0,0140%	100,00	100	10,93%

Table 3: Climatic data example, South Dublin (Ireland)

Technology data

The technology data is inserted in the tool in the sheet 8 (technology data); it is used in the sheets 5 and 6; project evaluation and technology evaluation.

The data can be adapted regarding the localisation in table 2 (individual technologies) and table 3 (district heating technologies).

The available data in the DHAT are investments costs, operation and maintenance costs (O&M), efficiency, lifetime and emission factors. It is assumed that efficiency, lifetime and emission factors are the same among the participating countries; thus, the data that is available in the HeatNet DHAT concerns investment costs and O&M costs.

The heating technology investment costs come from the European project Mapping and Analyses of the Current and Future Heating and cooling fuel deployment (MACFH). This project aims to assess the heating and cooling sector in the EU. The Work Package 2 and 3 of this European project, in particular, gathers information on the heating and cooling technologies, and predicts the investments costs of these technologies in 2020 and 2030.

This European project made it possible to get investments costs for the following technologies (using the 2020 assessed data):

- Individual heating:
 - o Oil boiler, gas boiler, heat pumps (air to air, air to water, brine to water) and electric heating;

- District heating:
 - o Oil boiler, gas boiler, coal boiler, electric heating;
 - o Solar thermal, geothermal, large heat pumps, CHP waste and waste to energy boiler.

The missing data are:

- Individual biomass boiler (pellet and chips) and gas engine drive HP (brine to water);
- District heating biomass boilers (wood pellets, wood chips and straw), CHP (medium to large, fuelled by biomass, natural gas and coal).

It was not possible to find any consistent data for these technologies, either due to its nonexistence, or due to the different classifying (usually by power ranges, and not by fuel ranges). Thus, the data provided by Ramboll and the DEA will fill the missing data. If the user should possess these data, he is free to insert them in the tool.

Nonetheless, annex 1 of the present report consists in a table listing these different technologies with a different classification, as an additional source of information for the user.

Unavailable data, indicated with “n/a” in the country sheets is replaced with data from the Danish sources automatically. If you have accurate data, please change N/A with your data but respect the units used in this tool.

Table 3: District heating technologies

Technology	Source name	Investment mio, EUR/MW-heat	Fixed O&M EUR/MW-heat/year	Var, O&M EUR/MWh-heat
Medium CHP - wood chips		n/a	n/a	n/a
Medium CHP - straw		n/a	n/a	n/a
Medium CHP - natural gas SC		n/a	n/a	n/a
Large CHP - wood pellets		n/a	n/a	n/a
Large CHP - coal		n/a	n/a	n/a
Large CHP - natural gas CC		n/a	n/a	n/a
Large CHP - natural gas		n/a	n/a	n/a
Oil boiler	MACFH	0,07	2370,64	n/a
Gas boiler	MACFH	0,07	2370,64	n/a
Coal boiler	MACFH	0,04	2428,46	n/a
Solar	MACFH	0,46	14042,14	n/a
Small Gas Engine		0,90	9401,44	n/a
Heat Pump	MACFH	0,77	1422,39	n/a
Medium CHP - waste	MACFH	7,62	47,48	n/a
Electric boilers	MACFH	0,24	n/a	n/a
Wood chips boiler		n/a	n/a	n/a
Wood pellet boiler		n/a	n/a	n/a
Straw boiler		n/a	n/a	n/a
Geothermal	MACFH	0,66	20410,67	n/a
Medium boiler - waste	MACFH	0,07	56710,00	n/a

Table 4: District heating technologies, investments and operation and maintenance costs (Belgium, Kortrijk)

Prices and emissions

Prices and emission taxes are inserted in the sheet 9. It can be changed according to the location in table 5, 6, 7 and 8 in the country sheets.

This part of the tool is important to modify, since the Danish taxation system on carbon and other pollutant emission is quite complex. In other countries, the carbon emission taxation is based on the amount of carbon

that is emitted when burning the fuel. The amount of the tax is expressed in € per ton of CO₂, thus it differs for each fuel, since each have a different carbon content.

First, the following paragraphs are an overview of the different carbon pricings in the participating countries.

France

The Energy Transition for Green Growth law introduced carbon taxation in 2015¹. A clear amount is set for 2022, adding up to 86.2 Euros per ton of CO₂; the tax amount will reach 100 Euro per ton of CO₂ by 2030. This increase between 2022 and 2030 was set as linear in the tool.

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2030
€/t CO ₂	7	14.50	22	30.50	44.60	55	65.4	75.8	86.2	100

Table 5: Current and future amount of carbon taxation in France.

Of course, present or future contestation regarding taxes could always happen and modify those figures.

Ireland

In addition to the EU ETS cap and trade system, the Irish government has set a carbon pricing on carbon emissions for solid fuels, natural gas and mineral oils². This tax is set at 20 Euros per ton of CO₂, and the vote of the 2019 Budget chose not to increase it.

Netherlands, United Kingdom and Belgium

These countries are also part of the cap and trade EU ETS scheme; however, the Dutch, English and Belgian governments have not chosen to implement carbon pricing.

The table 8 in the corresponding country sheets in the tool are nevertheless available; the user can therefore insert a carbon tax, should the countries' laws change.

The data in Table 7 (emission factors) comes from the database constituted by the French national energy agency (ADEME). It is considered as a first approximation, since most data is collected on the French territory, and thus may not be consistent with each countries' situation. Nevertheless, this database also contains data on the considered countries' electricity mix, so this particular box differs from one sheet to another, reflecting the difference in electricity production technologies.

The tables 5 and 6 present the amount of carbon taxation per MWh of fuel consumed both for district heating and for reference situation). The following formula, used in each box, allows obtaining the tax amount:

$$\text{Tax [EUR/t CO}_2\text{]} * \text{Emission factor [t CO}_2\text{/MWh]} = \text{Tax amount [EUR/MWh]}$$

District heating network

The data relative to the pipe network is in sheet 10. It can be changed according to the location in table 4 in the country sheet.

The table in sheet 10 presents a lot of different data: velocity, flow, power, heat losses and investment costs for example. In the scope of the HeatNet NWE project, it was not considered relevant to change the technical data (heat losses, power, flows). The user is of course able to change them if there is something specific.

¹ <https://www.ecologique-solidaire.gouv.fr/fiscalite-carbone>

² <https://www.seai.ie/blog/carbon-taxes-for-ireland/>

On the other hand, the important parameter to modify according to the location is the investment cost per linear meter of pipe. The investment cost used in the tool is all included, that is, cost of the pipe, excavation, designing and administration. Nevertheless, this is a very location-dependant data, given that it varies according to the type of road surface, whether it is located in a rural or urban area (moderately or very densely populated).

The HeatNet project was not able to gather significant and robust data for this part of the tool; so the data gathered by Ramboll and the DEA will be used in the tool.

The table below gives an order of magnitude of pipe network investment costs. The data comes from feedback and experience of AMORCE, a French association for local authorities. These might be used during the first planning steps of a district heating project; otherwise it is necessary to lead a study on the local conditions and with local companies. In addition, the data below is only on the investment for the pipes; it does not accounts for the digging.

DN	€HT/ml
15	91.1
20	92.3
25	94
32	96
40	96.4
50	97
65	110
80	123
100	148
125	177
150	212
200	244
250	276
300	308

Table 6: Investment costs for network pipes.

Additional data: annual heat demand

An additional sheet was added to the tool, in order to assist the user in determining the annual heat demand of the buildings.

The tables in sheet 3.5 “Heat Demand” allow computing the annual heat demand based on the surface of the buildings, using heat demand ratios from feedback from Cerema.

Tertiary building			
	Surface (m ²)	Annual heat demand	Heat demand ratio
New hospital	1500	155 250	104
New office building		-	29
Refurbished office building	850	38 845	46
New school		-	65
Refurbished school	500	46 550	93
	Total surface	2 850	m²
	Total heat demand	240 645	kWh

Table 7: Heat demand assessment for tertiary buildings (example)

The ratios are mostly based on the consumption levels set by the French thermal regulations, and on feedback from building study that was conducted by Cerema. An experienced user can change these ratios.

Conclusion and further developments

The changes made to the original District Heating Assessment Tool, allow adapting the tool to other countries than Denmark. The standard data now available in the tool concern climatic data, technology data and emission prices, which allows refining the results of the tool.

However, some of the standard data remain unchanged according to the different countries and locations:

- Technology data (sheet 8): heat efficiency, life time and emission factors of the corresponding heat production technologies;
- Prices and emissions (sheet 9): fuel prices, emission prices (for the socio-economy evaluation), price adjustment;
- District heating network (sheet 10): diameters, thickness, flow and losses of the pipes.

While some of these data do not depend on the country, especially considering a restricted geographical area such as North West Europe, others may strongly vary considering the location. For example, the fuel prices vary strongly according to the location of a district heating project, its stakeholders and procurement procedures. Like the pipework investment costs, these data were not changed; they ought to be thoroughly researched for every project.

Further developments on the tool could concern for instance introducing storage (and not just solar-related storage), both regarding the economic data of the result sheet, but also the production curves. This is relevant because many district heating networks rely on energy storage to ensure energy is provided continuously to the users; it is even more the case for 4th generation district energy.

Lastly, introducing district cooling in the tool is a very interesting development; especially since cooling is getting more and more looked upon.

Annex: Additional Data

	Technology	Size / type	Investment costs (mio€HT/MW)	O&M costs (€HT/MW)	Comments	Source
France	Biomass Boiler		0,94	22,7	Investment costs are all included (boilers + energy centre + hydraulic installations + studies). No differentiation according to the fuel (wood chips, wood pellets, straw)	"Etude des coûts d'investissement et d'exploitation associés aux installations biomasse énergie des secteurs collectifs et industriels", ADEME, May 2015 ³
	Gas CHP	Medium CHP	0,91	10		"Evaluation des externalités de la filière cogénération gaz", Artélyls, 2018 ⁴
		Large CHP	1,24	22,4		
	Biomass CHP	Rankine Cycle	5000 ≤ Inv < 6500	n/a	0,5 ≤ Pelec < 1	"Etude sur l'analyse économique des installations biomasses en Europe", ADEME, November 2011 ⁵
			4500 ≤ Inv < 6000	n/a	1 ≤ Pelec < 2	
			4500 ≤ Inv < 5500	n/a	2 ≤ Pelec < 3	
		Vapor Compression	4000 ≤ Inv < 5500	n/a	3 ≤ Pelec < 5	
			3500 ≤ Inv < 4500	n/a	5 ≤ Pelec < 7	
	3000 ≤ Inv < 4000	n/a	7 ≤ Pelec < 10			

³ <https://www.ademe.fr/etude-couts-dinvestissement-dexploitation-associes-installations-biomasse-energie-secteurs-collectifs-industriels>

⁴ http://atee.fr/sites/default/files/ATEE/Images/rapport_detudes_dartelys-club_coge_sur_les_externalites_du_parc_de_cogenerations_gaz_a_horizon_2030.pdf

⁵ https://www.propellet.fr/templates/propellet/file_upload/files/130108ADEME-cogenerationbiomasse-synthese.pdf