Danish Energy Agency

District Heating Assessment Tool

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Description: Report describing the District Heating Assessment Tool (DHAT)

Tool: The report is complemented by an excel model – district heating assessment tool

External Tools: The DHAT model can be supplemented by additional models for GIS, hydraulic analysis and load dispatch

1. INTRODUCTION

The district heating assessment tool (subsequently referred to as the model) can be used by heat planners to calculate the economic feasibility of establishing district heating in areas currently supplied by individual heating. Technical data and price projections can be adjusted, making it easy to use in different countries. The user is encouraged to vary central parameters to observe and explore the economic and environmental benefits and costs of district heating.

The model includes all relevant factors to compare and propose heat planning options, and can be used in cooperation between professionals and local planners. Among others, the model performs a cost-benefit analysis considering the local society, district heating consumers and the district heating company, as well as, calculating the socio economics of the project following Danish standards, along with a Levelized Cost Of Energy (LCOE) calculation. Economy of local society refers to all involved entities and socio economy refers to the respective country as a whole.

The model is developed by Ramboll for the Danish Energy Agency and is freely available to everyone interested. The model is recommended to be used for screening projects and not as result for a final heat planning project, without a more detailed analysis. Although, provided accurate inputs, the model will give strong indications on whether to continue the heat planning project or follow a new direction.

The model is a MS Excel based tool with no hidden data or VBA code – the user is free to modify all data inputs and variables – for easy access and quick overview of the model and formatted in a way, making it possible to include local conditions for a specific area. Comprehensive user guidance is provided throughout the model and this report.

Standard inlaid data, based on the Danish Energy Agency´s technology catalogs, can provide the user with a quick overview of the feasibility of a heat planning project, without having to adjust cost estimates.

1.1. Presentation of the Involved Partners

The Danish Energy Agency, governed by the Danish ministry for energy and environment, is in charge of the economic control of the Danish energy sector including telecommunication, water and waste. In cooperation with Danish companies, universities and public entities, the agency is also working to create and strengthen the contact between Denmark and partner countries, to further develop and collaborate on ideas and concepts on renewable energy solutions.

Ramboll has completed projects within energy master planning in Denmark since 1979, with many projects concerning investments in district heating systems. All projects have been based on the same basic methodology on energy master planning and economic assessment that the district heating assessment tool is constructed upon.

1.2. Purpose of the Report

This report describes the structure and methodology applied in the district heating assessment tool and includes discussions of key assumptions and parameters. The report will also work as user guidance for the model. References to the spreadsheet tabs in the model are made throughout the report in purple.

1.3. Structure of the Report

The report is structured as follows: **Chapter 1** presents the introduction, involved partners in the model development, purpose and structure of the report, as well as providing a short description of the model structure, the standard inlaid data, limitations of the model and how to use the results from the model. **Chapter 2** presents the methodology used to calculate the LCOE calculation, feasibility study of the proposed heat planning project and the socioeconomic analysis. **Chapter 3** introduces the prerequisites to the calculations with focus on standard inlaid data and how to adjust these accordingly. **Chapter 4** describes how to use the results from the model for assessment of the project and communication purposes. **Chapter 5** reviews how the user can further develop the model and the inlaid data. And finally, in **Appendix 1**, a description with a case study of how to adjust the model is provided.

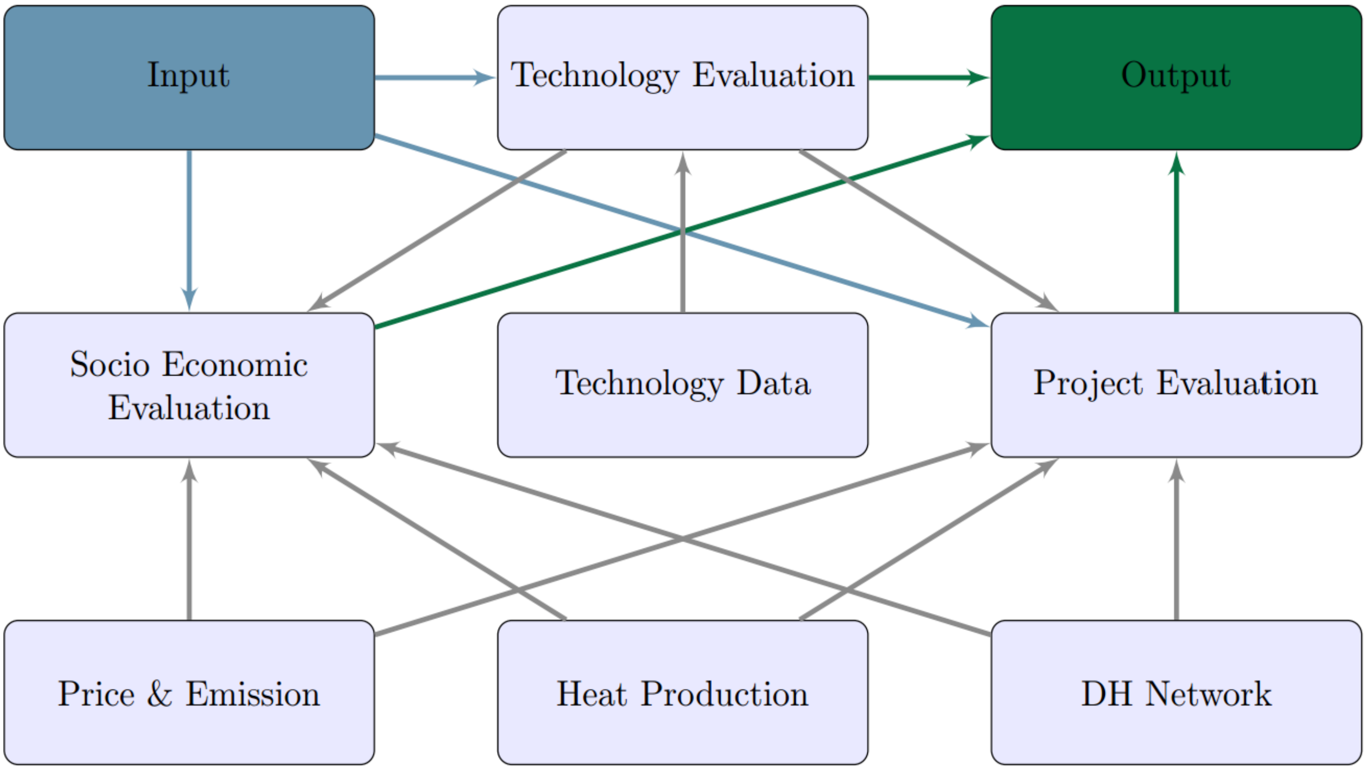
1.4. Model Structure

The model consists of eleven sheets, with the following names and purposes:

1. Introduction: Provides an introduction to the model and contact information for relevant persons.
2. User guide: Describes how and where to find results and adjust calculations. The cell and tab formatting are also described.
3. Input: Changes to central parameters can be performed. The user is provided with a thorough description of how to change input in explanatory complementary boxes.
4. Output: Results are displayed on figures with explanatory complementary boxes.
5. Project Evaluation: Calculates the feasibility study of the heat planning project.
6. Technology Evaluation: Calculates the LCOE and marginal heat production costs.
7. Socio Economic Evaluation: Calculates the socio economic analysis based on Danish standards.
8. Technology Data: Data on individual and district heating technologies can be inserted. Data based on cost estimates from the Danish Energy Agency are inlaid as standard.
9. Price & emission: Price projections on fuel and emissions, emission factors and price adjustments can be inserted. Data from the Danish Energy Agency are inlaid as standard.
10. DH network: An external detailed network calculation is required to construct the district heating network with its associated investment costs. Standard inlaid data is based on Danish empirical values from Ramboll.
11. Heat production: A simple heat production distribution is calculated using Excel.
12. Report: Printable report comprising the most important results

The structure of the model is presented on Figure 1-1. The flow of data and calculations is displayed by arrows. The user will specify central inputs to the model in the **Input** sheet and the results are displayed in the **Output** sheet.

relatively high it is considered a conservative estimate.



1.1: Structure of the model

1.5. Standard Data in the Model

The model has inlaid data on cost estimations, fuel price projections, emission price projections and emission factors based on data from the Danish Energy Agency.

Empirical Danish cost estimates on district heating network construction from Ramboll are also inlaid as standard. From experience these cost estimates vary greatly, but since the average prices in Denmark are

The possibility to modify parameters, cost estimates and price projections is fundamental for the model, as it can be adjusted for use in all countries. The standard data is further described in Chapter 3.

1.6. Model Analyzes

The results of the analyzes comprises the cost-benefit in net present value (NPV) for the local society, district heating company, district heating consumers and the socio economy.

First, the result for the local society shows the immediate cost-benefit of implementing district heating in favor of individual heating. The local society is perceived as every involved entity as one unique. One can think of drawing a border around the respective area and evaluate the total costs of individual heating compared to the total costs of district heating. Comparing the project with the reference provides the immediate result.

Secondly, the cost-benefit for consumers and producers of district heating relates to the district heating price defined by the user. A high heat price provides a profit for the company and a loss for consumers. In case, the NPV for local society is positive, the user must adjust the heat price accordingly to ensure a positive NPV for both consumers and producers of district heating.

Lastly, the socio economic result is calculated based on Danish standards, performing an economic impact assessment of implementing the heat planning project on the entire society´s economy. The results are further explained in Chapter 4.

1.7. Model Limitations

The model is intended to provide an overview and insight on how to perform a heat planning study. Provided the right inputs, the model will give strong indications on the profitability of implementing district heating in a specific area. Nonetheless, input quality is also the limitation.

In order to provide very detailed input, it is required, that the user makes a detailed analysis of the input variables and data. For example, detailed analysis of the district heating network, local energy price projections and local cost estimates on construction of power plants and district heating network.

The model is limited to only include the revenue from sales of heat and fixed electricity sales, not considering the possibilities of optimizing the operation according to the apparent value of fluctuating electricity prices. The linkage between the district heating sector and the electricity-, gas- and district cooling sectors is not included as a cost minimization problem in the model.

The LCOE heat production costs calculation, distributing the socio economic heat production costs over the life-time of the selected technologies, also possesses certain limitations. The approach considers the costs evenly distributed over the life-time and the revenues from electricity sale revenues equally. In order to improve the comparison between the selected plants, a base-load comparison, with 5000 full-load hours, and a peak-load comparison, with 200 full-load hours, is calculated by default.

However, considering that the costs are evenly distributed over the lifetime of the technologies, and that tax, subsidies and project specific financial costs are not included in the LCOE calculation, the results may change, when a cash flow calculation is performed.

2. METHODOLOGY

The model is intended to be a multipurpose model. It includes all relevant factors to compare and propose heat planning options, with varying level of detail. The model can be used in close cooperation between professionals, provide detailed analysis of heat production strategies and be used by planners to calculate the economic consequences of various factors.

The results can be used as an important communication tool between stakeholders in the heat planning project. To support that an LCOE calculation including marginal cost calculations, a feasibility study of the heat planning project and a socio economic analysis are calculated.

2.1. LCOE Calculation

The levelized cost of energy (LCOE) methodology discounts all projected expenditures and revenues to their net present value in a specific year – equivalent to the average expected price for consumers in order to repay all costs. The methodology is useful from a societal perspective comparing alternative heat generation technologies.

The LCOE calculation use the same technology data and costs estimates, as the remaining calculations in the model. Therefore, the LCOE results will automatically be adjusted to local conditions, when changing the cost estimates and price projections. For comparison of the cost structure, the LCOE is calculated for all technologies with 5000 full-load hours and 200 full-load hours by default, representing base-load plants and peak-load plants respectively. Still, the user can specify the number of full load hours.

In this way, the user can easily see the difference in cost composition of plants with high investment costs and low marginal costs, typically base-load plants, and plants with low investment costs and high marginal costs, which are typically peak-load plants.

Moreover, the user can develop ideas about which technologies to promote, and thereby, create a political incentive to change the framework conditions to ensure private investors select the best technologies from a societal perspective. Usually, the optimal societal decisions differ from the private entities optimal decision.

The socio economic marginal cost and private economic marginal cost are also calculated, but excludes the annualized investment costs and fixed operation and maintenance costs. A marginal cost comparison showing the societal benefits of CHP (combined heat and power) plants in favor of condensing power plants and boilers is furthermore calculated following [1].

2.2. Feasibility Study

The feasibility study method follows the standard cost-benefit analysis evaluation method. The cost of the reference, continuation of individual supply including reinvestments in new individual heat production technologies, is compared to the project, which is establishing district heating with its associated production technologies and district heating network.

The development of the district heating network will take place over a couple of years. In that time, individual technologies will still produce heat to some households, which is also included in the project.

The reference includes operation cost of individual technologies and investment cost for new individual technologies that are to be replaced. The user can select the district heating technologies and the share of the individual supply that is converted to district heating. In both the reference and the project the residual value of assets is included, as the evaluation period is fixed to 20 years.

Positive NPV and IRR for the local society indicate a benefit of implementing the project. Given a positive result for the local society, the heat price must be set so that both the district heating company and district heating consumers will have a positive NPV and IRR.

2.3. Socio Economic Calculation

The socioeconomic evaluation follows the method used in Danish energy planning projects and is described in guidance from the Danish Energy Agency [2]. The method takes into account the impact of the project on all of society.

The calculation method follows the overall same approach of the feasibility study, comparing a reference against a project. Again, the reference is individual supply and the project is implementation of district heating. However, the societal costs of heat production including emission costs are considered – not taxes for emissions.

3. PREREQUISITES

The model has some standard inlaid cost estimates and price projections. These are, to the extent possible, based on the Danish Energy Agency. Empirical data from Ramboll are also used.

3.1. Technology Data

The inlaid district heating production technologies are based on technology data from the Danish Energy Agency´s Technology Data Catalog for Energy Plants [3][4][5], and the individual technologies are based on technology data from the Danish Energy Agency´s Technology Data for Individual Plants [6][7].

The following properties are included for each technology: Investment cost, operation and maintenance cost (fixed and variable), life-time, CB (for backpressure and extraction plants) and CV (for extraction plants), efficiencies and emission factors.

The inlaid data must be examined and adjusted before taking on a heat planning project in countries with a different price structure. Furthermore, the inlaid emission factors are low, due to flue gas cleaning and the same standards may not be valid in other countries.

3.2. Fuel Price Projections

From 2012 to 2016 historical prices can be inserted and from there on, the user is free to specify projected fuel prices.

The standard inlaid price projections can be found in the Danish Energy Agency´s LCOE calculator [5], which has price projections embedded based on IEA projections. Three different fuel price projections; new policies scenario, current policies scenario and 450 scenario are displayed in the LCOE calculator.

The new policy scenario price projections are inlaid in this model as standard, as the prices reflect the medium between low prices (450 scenario) and high prices (current policies scenario). Generally, higher energy prices will favor collective solutions like district heating and vice versa with lower energy prices.

3.3. Emission Price Projections

The emission price projections are the socio economic costs of emitting CO2, SO2, NOx and PM2.5, which can also be found in the LCOE calculator [5]. The standard inlaid emission costs in the model are the following:

- SO2-price of 19 EUR/kg
- NOx-price of 8 EUR/kg
- PM2.5 of 66 EUR/kg

The CO2-emission cost is the projected CO2-quota price in the European emission trading scheme, even as this cost presumably is much higher. All emission costs can be adjusted to local conditions.

The taxes of emissions for each fuel can also be specified in the model. The Danish taxation level is inserted as standard. The tax is the price paid by heat producers for heat production, whereas, the emission costs are the socio economic costs of emissions from heat production.

3.4. Price Adjustment and Discount Rate

The user can insert an inflation index, reflecting the expected inflation in the country, used to calculate the financial projection for the district heating company. The projected Danish inflation index is inlaid as standard. Similarly, the discount rate is set to 4% in accordance with Danish standards. However, in the IEA projected costs of generating electricity [8], the discount rate is varied from 3% to 7% and 10%. The user is encouraged to make a sensitivity analysis on the results based on changing the discount rate.

3.5. Electricity Price

The value of the power (electricity) production/consumption is based on a projected Danish electricity price from the Danish transmission system operator Energinet.dk [9].

Further benefits from balancing ability, reduction of power grid expansion, system reliability and so forth are not included, as it is not the scope of this project to perform a comprehensive analysis of the projected value of electricity production. Thus, the inlaid electricity price projection is assumed to reflect the entire value of electricity production.

3.6. District Heating Network

The investment costs of the district heating network are based on Danish empirical data from Ramboll. Nevertheless, the user is required to explore the costs of district heating pipes and the construction costs of establishing the district heating network in the respective country.

The excavation price for district heating pipes differs based on population density, soil conditions, regulatory approval from local authorities and costs of labor. The user also has to design a district heating network layout for the investigated area or specify a total investment cost.

The layout and pipe dimensioning of a district heating network is very complex and requires a detailed analysis for every new network and network expansion. Among others, the network design depends on heat density, temperatures, hot water usage and the accumulated heat demand and heat profiles, as these in some cases level out.

The process of estimating the heat demand and calculating the layout and dimensioning of the district heating network usually consists of the following steps:

1. The first step is getting an overview of available data on individual heat demand from data-bases. If not available, the user has to estimate a heat demand in every building included in the heat planning project area.

2. Second step is to make a heat map of the area with every consumer and its consumption plotted onto a map. This provides an overview and displays the location of large consumers.

3. Third step is to draw a map of the district heating network considering roads, buildings, rail road crossings, ground cables and so forth.

4. Lastly, the district heating network layout can be used to make a hydraulic analysis calculating the required pipe dimensions to serve the load at each location.

These four steps are required to provide the correct input to the model. Depending on the area of the heat planning study and number of consumers, the analysis can become very cumbersome and involve large amounts of data. In case the user does not have the time or ability to perform a full district heating network dimensioning, total expected investment cost can be specified instead.

3.7. Production Profiles

The standard inlaid production profiles for solar heating and district heating demand are based on empirical data from Denmark. The heat demand profile primarily depends on the outside temperature. Therefore, the user can advantageously insert a new heat demand profile. Also, the solar production profile will change according to solar irradiation and the user must consequently insert another solar production profile.

4. RESULTS

The results from all calculations are presented in the Output sheet, which includes results from the LCOE calculation, the feasibility study and the socio economic calculation. In Appendix 1, a case study of how to adjust the model is examined.

4.1. LCOE Calculation Results

LCOE is calculated for all selected district heating- and individual plants. The LCOE calculation for the ten individual heat production technologies using the standard inlaid data is presented in Figure 4.1. The user must be aware that additional benefit and cost of each standard inlaid technology exists and that the LCOE calculation is not fully comprehensive. Nevertheless, using Figure 4.1, one can argue that the use of heat pumps, in favor of other technologies for individual heating, must be promoted, knowing that the projected Danish electricity prices are low.

The private- and socio economic marginal costs are too calculated considering taxes and emission costs respectively. The results from the marginal cost- and LCOE calculations can be used to compare the societal costs of heat production to the actual marginal heat production cost experienced by the district heating company and individual heat producers.

4.2. Feasibility Study Results

The feasibility study results display the cost-benefit analysis for the local society, district heating consumers and the district heating company. The costs of the reference (individual heating) are compared to the costs of the project (district heating), and are displayed as NPV and IRR (Internal Rate of Return). A positive NPV for the local society indicates that district heating is favorable compared to individual heating.

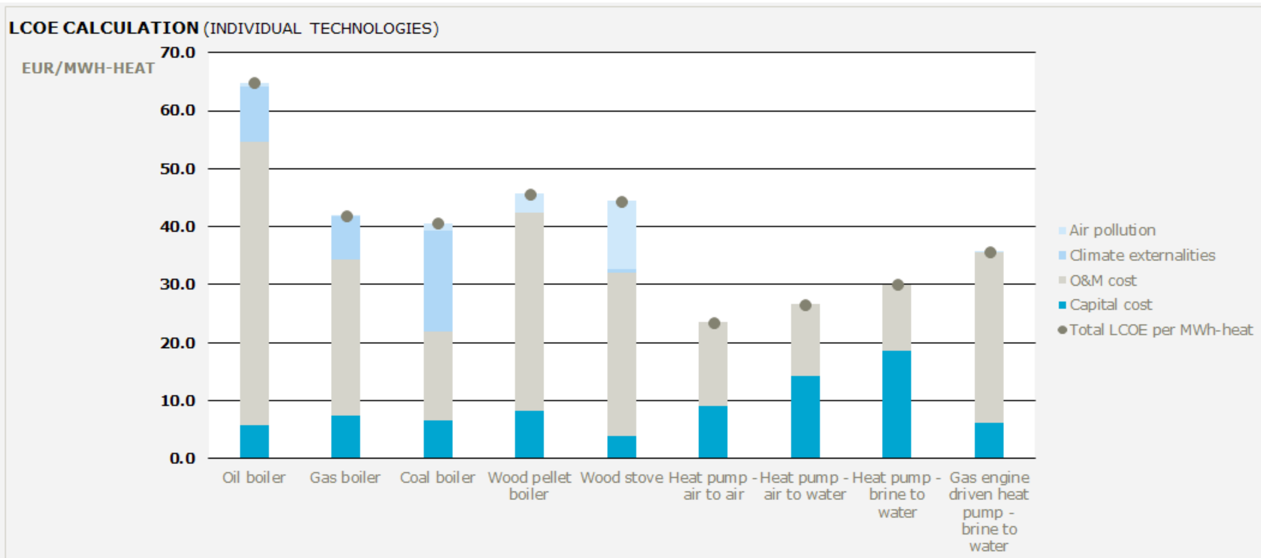


Figure 4.1: LCOE calculation for individual technologies

Moreover, an average levelized heat production cost is calculated for all individual- and district heating, calculated by summarizing all costs in the reference and project, returned to the chosen price-level, and dividing them with their respective total heat production.

4.3. Socio Economic Result

The socio economic result, calculated following Danish standards, is displayed as a cost-benefit for all of society. The calculations are required for completing projects within the Danish energy supply sector. However, in countries with a different legislative framework, the calculation may be excessive and the result can be disregarded.

5. FURTHER DEVELOPMENT

The foreseeable structure provides a good foundation for further development of the model. Provided the user has good skills within programming, especially in Excel, the following suggestions on how to further develop the model and its associated results are listed.

- **Standard inlaid data from more countries:** Currently, the standard inlaid data is based on projections from the Danish Energy Agency. However, to improve the user friendliness of the model, data for several countries can be included in the model. This includes emission costs, technology data, tax schemes, fuel price projections, etc. The user may construct a type of database, to which the model can be linked.

- **District heating network design:** In the model, the user is required to perform a detailed district heating network calculation to estimate its layout and total costs. This detailed type of analysis is required, when a decision has been made to construct district heating. However, for a simple overall project evaluation, this level of detail is not required. A statistical analysis of district heating network size and dimension in relation to heat density for example, would allow the user to perform an improved overall assessment of the required district heating investment costs based on statistics. This task, however, is complex regarding data analysis.

- **Advanced production simulation:** A simple heat production distribution based on plant-type is currently included in the model. However, this approach does not account for the variable marginal heat production costs from concurrent sources, taking into account electricity and fuel prices, and neither is the optimal utilization of heat storages included. The inclusion of advanced optimization algorithms for heat production cost minimization requires that the user is familiar with programming languages like Matlab, Python, C#, etc. The user must keep in mind that its inclusion will limit the user friendliness of the model and hamper the model´s easy-to-understand results.

- **Assessment of electricity value:** In case, the user does not wish to implement an advanced optimization algorithm, an investigation of the average value of electricity must be performed. The system value of electricity production from CHP plants and the system value of electricity used by heat pumps is arguably not the same. Separate data for each technology inlaid in the model reflecting the benefits from electric capacity, flexibility, etc. can improve the results from the model.

- **Improved user interface:** The model is intended to include the user as much as possible. For users, who do not possess detailed technical knowledge a simpler input/output interface may be desired. This task is not complicated and the model can easily be adjusted.

6. APPENDIX 1: DUNDEE CASE STUDY

The set-up of the model is described using an example. The user may return to this example, if questions arise during the set-up of the model. At first, the case study is presented. Second, the set-up of the model is presented, and thirdly, the main results from the example are presented.

6.1. Description

"A local Scottish heat planner from Dundee is interested in assessing the possibility of replacing the individual heating with district heating. To evaluate the proposed project she uses the district heating assessment tool to evaluate the profitability of replacing individual gas boilers and heat pumps by a new gas-fired single-cycle plant, with combined heat and power production, and establishing a district heating network. Furthermore, new district heating gas boilers are used as back-up/peak production units."

All cost estimates and price projections are based on the standard inlaid data in the model. It is assumed that existing individual gas boilers, where reinvestments are not performed, have a remaining life-time equal to the evaluation period (i.e. 20 years).

6.2. Setting up the Model

The **Input sheet** provides the central inputs to the model. The tasks in the **Input sheet** are described in the same order, as in this appendix. The first four tasks are mostly related to the reference (individual heating) and the last six tasks are related to the project (district heating).

Task 1: Determine the heat demand (also for district heating)

The annual heat demand for comfort heating excludes by default the hot water share. In some district heating networks, the hot water share is covered by individual electric heaters at the consumer installation, boosting the temperature of the water from district heating to that of hot water. Depending on the design of the district heating network (temperatures), the district heating company may also deliver hot water. Thus, the user can specify the hot water share of total demand, which is covered by district heating.

Table 1		
Heat consumption		
Annual heat demand (comfort heating)	200	GWh
Hot water share of total demand (excl. loss)	10.0%	
Heat loss in the system of annual heat demand (excl. loss)	20.0%	

Table 2		
Hot water demand and total heat demand		
Heat demand, hot water (excl. loss)	20	GWh
Production to DH network (incl. loss)	275	GWh

Figure 6.1: Heat demand specification

In Figure 6.1 it is displayed how to insert the heat demand. The user must specify total annual heat demand for comfort heating, the hot water share of total demand and the heat loss in the district heating system. Average losses in Danish district heating systems are 20 – 25 % of total production.

The heat demand for hot water and the total required heat production including losses is dis-played in Figure 6.1 (Table 2). The values are red, since they are calculated and not entered manually.

Task 2: Determine the individual production technologies (reference)

Two types of individual supply are selected to meet the individual heat production equally; gas boilers and heat pumps (air to water). In Figure 6.2, the "percentage of total" shows how much of the total individual heat production is currently covered by each technology. Often it is a qualified guess, due to data availability. The "full load hours" can be adjusted and the corresponding total capacity is displayed. A higher number of full load hours gives a smaller capacity and vice versa. A good approximation of total capacity factor (total capacity over maximum heat demand) for individual heating is around 1.2 to 1.4.

Table 3		Percentage of total	Full load hours	Capacity [MW]
Individual production technologies	Oil boiler	0%		0
	Gas boiler	50%	2000	55
	Coal boiler	0%		0
	Wood pellet boiler	0%		0
	Wood stove	0%		0
	Heat pump - air to air	0%		0
	Heat pump - air to water	50%	2000	55
	Heat pump - brine to water	0%		0
	Gas engine driven heat pump - brine to water	0%		0
	Electric heating	0%		0
	Total	**100%**		**110**
	Total capacity factor:		**1.4**	

Figure 6.2: Individual supply

Task 3: Determine how much of the existing individual heat production technologies that must be replaced (reinvestments)

In the reference, a part of the gas boilers and heat pumps must be replaced, due to attrition. It is assumed that old gas boilers are replaced with new gas boilers, and so forth. In Figure 6.3 this is indicated as the "percentage of reinvestments". For example, a 100 % percentage reinvestment of gas boilers indicates that every old gas boiler is replaced by a new gas boiler. The percentage can only be varied between 0% and 100 %.

The "years of transition" indicates over how long a period, starting from year 1, the old individual technologies are replaced with new individual technologies. The transition period is assumed the same for every technology.

It is assumed that 10% of old gas boilers and heat pumps are replaced with new units. The efficiency improvement and fixed O&M reduction, assumed the same for all reinvestments, are set to zero, as seen in Figure 6.4.

Table 4		
Heat planning project (individual heating)		
Years of transition	6	year
Percentage of reinvestments		
Oil boiler	0%	
Gas boiler	10%	
Coal boiler	0%	
Wood pellet boiler	0%	
Wood stove	0%	
Heat pump - air to air	0%	
Heat pump - air to water	10%	
Heat pump - brine to water	0%	
Gas engine driven heat pump - brine to water	0%	
Electric heating	0%	

Figure 6.3: Determine reinvestment in individual technologies

Table 5		
Heat planning project (individual heating)		
Efficiency improvement of new technologies (reinvestments)	0%	%-point
Fixed O&M reduction of new technologies (reinvestments)	0%	%

Figure 6.4: Efficiency improvement and O&M reduction

Task 4: Insert subsidy payments to individual technologies

Subsidy payments to new individual technologies can be inserted per MWh-heat produced over a number of years provided. The individual technologies will not receive a subsidy – all fields are zero – as seen in Figure 6.5.

Table 6
Individual technologies, subsidy payments

	Subsidy		Years provided
Oil boiler	0	EUR/MWh	0
Gas boiler	0	EUR/MWh	0
Coal boiler	0	EUR/MWh	0
Wood pellet boiler	0	EUR/MWh	0
Wood stove	0	EUR/MWh	0
Heat pump - air to air	0	EUR/MWh	0
Heat pump - air to water	0	EUR/MWh	0
Heat pump - brine to water	0	EUR/MWh	0
Gas engine driven heat pump - brine to water	0	EUR/MWh	0
Electric heating	0	EUR/MWh	0

Figure 6 5: Subsidy payments to individual technologies

Task 5: Select district heat production technologies

A dropdown list is presented, allowing the user to select between the 20 standard inlaid district heating technologies. It is important that the user selects the intended base-load plants as baseload, and the peak load plants as peak load, which ensures that, the model can calculate the heat production distribution properly.

Notice in Figure 6.6 that the Medium CHP – Natural gas SC is selected as base-load plant and the Gas Boiler is selected as peak load plant, as its marginal heat production cost is higher than that of the CHP plant. Notice that the heat production capacities are entered later, but are displayed in Table 7 (Figure 6.6).

Table 7
Production units selection and results

Production type		Heat capacity MW	Heat production GWh	Pct of total pct.	Production type
Solar	Solar	0	0	0.0%	
Base1	Medium CHP - natural gas SC	40	249	90.4%	Base1
Base2		0	26	9.6%	Base2
Base3		0	0	0.0%	Base3
Base4		0	0	0.0%	Base4
Intermediate1		0	0	0.0%	Intermediate1
Intermediate2		0	0	0.0%	Intermediate2
Intermediate3		0	0	0.0%	Intermediate3
Intermediate4		0	0	0.0%	Intermediate4
Peak1		0	0	0.0%	Peak1
Peak2	Gas boiler	120	0	0.0%	Peak2
Total		**160**	**275**		

Figure 6 6: District heating production technologies

Task 6: Insert capacities and select how to perform the production simulation

The following description refers to Figure 6.7. The capacities of the selected technologies must be inserted. The user has an option to choose between "advanced production simulation" or "Excel" in the dropdown list next to "select simulation type". In this case, the Excel production distribution is selected and the user must insert the capacities of the production facilities. If the user instead selects the advanced production simulation, the user has to insert the capacity and total annual heat productions from the respective program.

If solar is included (capacity above zero), the user can specify a heat storage capacity. It is only the solar plant, which can utilize the heat storage.

The total capacity factor and the N-1 calculation, with the largest base-load out for maintenance, is also displayed. Under normal circumstances, the N-1 must be above 1, so that peak-load capacity can meet the demand even on the coldest day, with the largest base-load unit out of operation. The capacity factor will as a result be even larger. In this case study, the N-1 is 1.2 and the capacity factor is 1.6.

In Figure 6.7, the capacities of the Medium CHP – natural gas SC is set to 40 MW-heat and the Gas Boilers are set to 120 MW-heat. Notice that the capacities of the undefined units must be set to zero. Notice also that, the heat storage is set to zero, as there is no solar plant included.

Select simulation type: *Excel*

Table 8
Distribution of heat production from calculations in an advanced program for production simulations

	Capacity MW	Heat Prod. GWh	Pct of total pct.
Solar	0	0	0.0%
Medium CHP - natural gas SC	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
Gas boiler	0	0	0.0%
Total	**0**	**0**	

Table 9
Capacities for simple Excel heat production distribution

	Capacity MW	Heat Prod. GWh	Pct of total pct.
Solar	0	0	0.0%
Medium CHP - natural gas SC	40	249	90.4%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
0	0	0	0.0%
Gas boiler	120	26	9.6%
Total	**160**	**275**	

Table 10
Solar pit storage

Storage capacity	0	MWh
Level at beginning	0	MWh
Charging capacity	0	MWh/h
Maximum production	0	MW

Figure 6.7: Capacities of production facilities

Task 7: Insert parameters for the development of the district heating network and sale of district heating

The next inputs to the model define central parameters of the heat planning project. The inputs are showed in Figure 6.8 and a walkthrough of each input is made in the following:

- **Expected development of heat demand per year:** The user specifies how the heat de-mand is expected to develop during the evaluation period. In this example, the heat demand is expected to reduce with -2% per year, due to better insulation in all buildings.

- **Expected development time of the district heating network:** The user must insert the time in years it takes from year 1 to develop the district heating network (5 years).

- **Expected connection time of all district heating consumers to the network:** The user can define how many years it takes to connect all consumers to the network. Naturally, this period must be longer than it takes to develop the district heating network (8 years).

- **Expected amount of consumers converted from individual supply:** The user must specify how many of the individual producers that are subsequently converted to district heating. The percentage can be somewhere between 0-100%. However, if set below 100 %, the project still includes individual supply.

- **Total expected number of connected district heating consumers:** In this example, 2500 consumers (buildings, not persons) are expected to be connected

- **Fixed operation and maintenance costs of the district heating network:** Typically, this is somewhere between 0.5 – 1.0 % of the assets under Danish conditions.

- **Variable operation and maintenance costs of the district heating network:** The varia-ble O&M costs are set to 0.5 EUR/MWh-heat produced, which can be taken as a default value.

- **Expected operational lifetime of the district heating network:** Between 50-80 years.

- **Have the user performed a detailed network analysis? (Yes/No):** The user can select between yes or no. If selected no, the user must insert an estimate of total investment costs in the cell below. If selected yes, the user must have performed a detailed network analysis, as described subsequently in Task 13, and with results displayed in Figure 6.9. The district heating network layout is calculated based on the approach described in Section 3.6.

Table ## **Heat planning project (district heating)**		
Expected development of heat demand per year	-2.0%	per year
Expected development time of the district heating network	5	year
Expected connection time of all district heating consumers to the network	8	year
Expected amount of consumers converted from individual supply	100%	of total present consumers
Total expected number of connected district heating consumers	2500	consumers
Fixed operation and maintenance costs of the district heating network	0.75%	% of assets
Variable operation and maintenance costs ofthe district heating network	0.5	EUR/MWh-heat
Expected operational lifetime of the district heating network	50	years
Has the user performed a detailed network analysis? (Yes/No)	Yes	
If "No", then insert the estimated total district heating network investment cost	0	mEUR

Figure 6.8: District heating planning project inputs.

In Figure 6.9, the DH Network is the overlaying district heating network with transmission and distribution pipes. The DH branch network is the smaller branch connections between consumers and the overlaying DH network.

Input to the district heating network calculations			
DH network		*DH branch network*	
Pipe dimension	Length of pipes	Pipe dimension	Length of pipes
D_N		D_N	
mm	m	mm	m
DN15	581	DN15	0
DN20	253	DN20	0
DN25	387	DN25	2925
DN32	377	DN32	0
DN40	326	DN40	2800
DN50	602	DN50	575
DN65	551	DN65	0
DN80	1381	DN80	0
DN100	494	DN100	0
DN125	426	DN125	0
DN150	424	DN150	0
DN200	197	DN200	0
DN250	95	DN250	0
DN300	77	DN300	0

Figure 6.9: Results from the detailed district heating network analysis

Task 8: Insert the economic parameters to perform the project evaluation

Table 12 **Input for Economic Calculations (LCOE)**		
Beginning year of calculations (discount)	2020	
Discount rate	4%	%
Annual number of full load hours	5000	hours/year

Table 13 **Input for Socio Economic Calculations**		
Net tax factor	1.17	
Calculation rate	4%	
VAT	25%	%
Distortion loss	20%	%

Table 14 **Input for Taxes**		
Net price index	0.70%	%/year
Use Danish taxation level? (Yes/No)	Yes	

Table 15 **Financial projection of district heating company**		
Heat price (business as usual)	80	EUR/MWh
Connection fee for district heating	0	EUR/MW
Long-term loan	4%	%
Short-term loan (debt)	7%	%
Short-term loan (profit)	4%	%

Figure 6.10: Economic parameters

The economic parameters for the project evaluation calculations are inserted in the tables displayed in Figure 6.10. The input to the tables is described in the following:

- **Table 12:** The starting year of calculations can be selected between 2017 and 2030 and the discount rate can be set by the user. Annual full-load hours are set to 5000 hours per year as default.

- **Table 13:** The default values used for the socio economic analysis based on the Danish standard calculation are displayed.

- **Table 14:** The net price index is used to extrapolate the taxation level, if the user selects to use the Danish taxation. If the user does not wish to apply the Danish taxation level, the local taxation level must be specified in Table 5 in the **Price & Emission sheet.**

- **Table 15:** The heat price is the price paid by the consumers for heat and received by the district heating company. The connection fee is paid by the consumers in order to be connected to the district heating network. The short-term loan is paid to the bank for the loan of money and the long-term loan is used to calculate the interest paid by the bank.

Task 9: Insert subsidy payments to district heating technologies

Subsidy payments to district heating technologies can be inserted per MWh-heat produced over a number of years provided. The district heating technologies will not receive a subsidy – all fields are zero in Figure 6.11.

Table 16 District heating technologies, subsidy payments		Subsidy		Years provided
	Solar	0	EUR/MWh-h	0
	Medium CHP - natural gas SC	0	EUR/MWh-h	0
	0	0	EUR/MWh-h	0
	0	0	EUR/MWh-h	0
	0	0	EUR/MWh-h	0
	0	0	EUR/MWh-h	0
	0	0	EUR/MWh-h	0
	0	0	EUR/MWh-h	0
	0	0	EUR/MWh-h	0
	0	0	EUR/MWh-h	0
	Gas boiler	0	EUR/MWh-h	0

Figure 6.11: Subsidy payments to district heating technologies

Task 10: Observe results

The NPV results from the example are displayed in Figure 6.12. The results indicate that there is an economic disadvantage of introducing district heating for the local society. With the defined heat price, the district heating company and the consumers will also obtain a loss. The socioeconomic result furthermore indicates that the project is unprofitable.

The user can change the heat price in task 8 and see the influence on the NPV for the district heating company and consumers. However, the results for the local society and socio economic result will not change, as these are not influenced by the heat price.

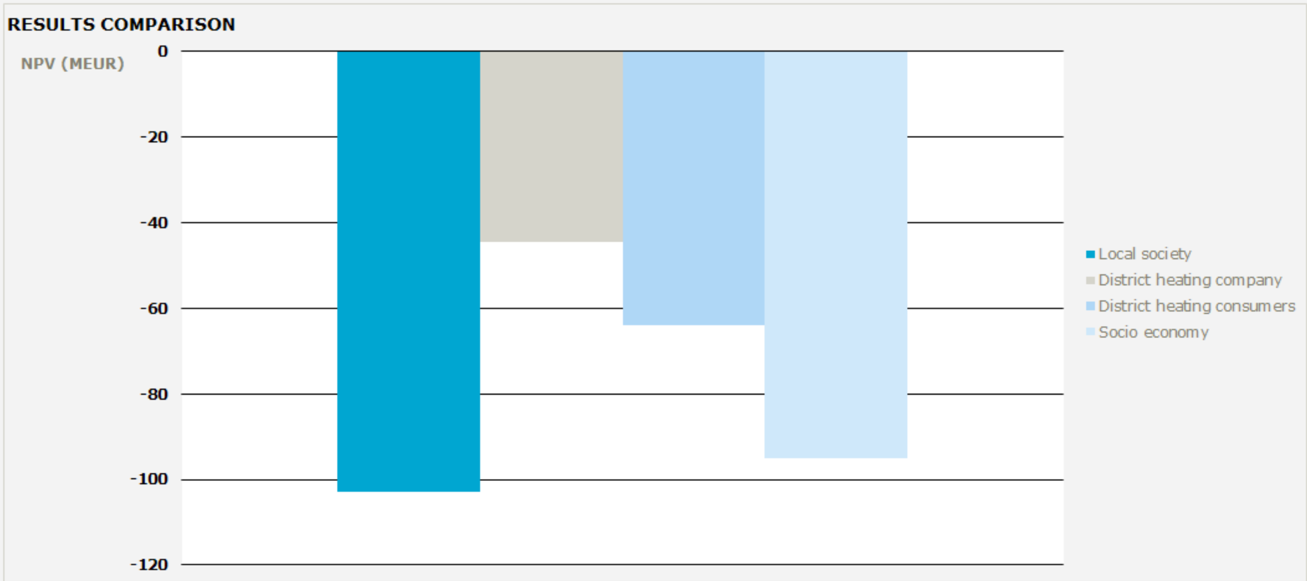


Figure 6.12: Results comparison

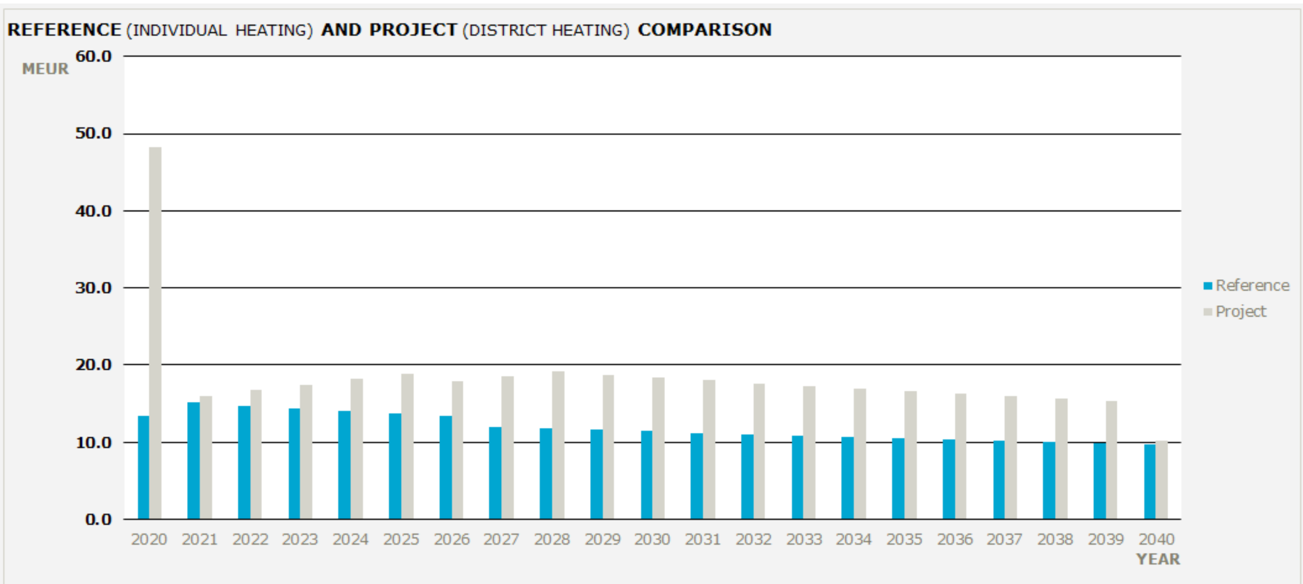


Figure 6 13: Comparison between the project and the reference

Figure 6.13 displays a comparison between the annual costs of district heating and individual heating. The major difference is the high up-front investment costs of the district heating system, which includes the production facility, with investments made in year 1, and a gradual investment of the district heating network over the first five years, compared to the almost constant operational costs of individual heating. In contrast, the operational cost of the district heating system is higher, but includes a residual value after 20 years. In cases, where existing power plants can be refurbished to deliver district heating, the up-front costs will be even lower, providing a possible economic benefit of district heating. The user must keep in mind, the standard inlaid Danish electricity price projection, which is very low, due to high amounts of renewable energy production. As a sensitivity analysis, the user may try to change the Medium CHP - Natural gas SC to a heat pump, or insert local energy price projections.

The following tasks, task 11 to 13, describe how to adjust detailed input in the model.

Task 11: Adjust technology data

In the **Technology Data** sheet source name, fuel, investment, fixed O&M, variable O&M, effi-ciency, life-time and emission factors can be defined. There is as standard inlaid data on different individual and district heating technologies based on cost estimates from the Danish Energy Agency.

Task 12: Adjust fuel prices, emission costs and taxes

In the **Price & Emission** sheet fuel prices, emission prices, emission factors and price adjust-ment can be defined. The fuel prices can be inserted for district heating technologies and individual technologies. Fuel prices are typically higher for individual producers than for larger energy producers. The inserted fuel price excludes taxes, charges and subsidies. These are later inserted as costs of emissions and subsidies to specific heat production technologies.

Task 13: Adjust the district heating network

In the **DH network** sheet district heating pipe cost estimates can be adjusted. Empirical data based on Ramboll's Danish experience are inlaid as standard. The results from a detailed hydraulic analysis can be inserted in the Input sheet in Task 13. The length of the pipes, the duct factor and the hole factor can also be adjusted. The duct factor adjusts the amount of dirt to be removed. If the pipe is 0.1 m in diameter, then 0.1 m x duct factor is the width of the duct. The hole factor determines how deep the pipe shall be lowered down into the ground.

Task 14: Adjust heat consumption profile and solar production profile

In the **Heat Production** sheet heat demand profiles and solar production profiles can be adjusted. The standard inlaid hourly profiles for heat demand and solar production are based on a Danish climate. Adjustment to other climates is required for a detailed analysis.

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Learn more on our website:
www.ens.dk/en/our-responsibilities/global-cooperation

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