Technical insights into the DHAT tool

Danish Energy Agency

Executive summary

The DHAT Technical Guide is a comprehensive technical guide designed to facilitate users in navigating the DHAT tool effectively. By providing practical examples, this guide aims to assist users in initiating their experience with DHAT and conducting fundamental calculations. Its purpose is to enrich users' understanding of DHAT's diverse elements and tabs, fostering a deeper comprehension of the tool's design rationale and give an insight into the Danish heat planning methodology.

DHAT stands as a specialized tool crafted for the execution of pre-feasibility studies, with the primary objective of identifying and mapping economically and environmentally viable scenarios. Following this initial phase, feasibility studies can be conducted to further inspect the advantages and disadvantages inherent in the identified scenarios.

Rooted in the Danish approach to heat planning, DHAT places emphasis on promoting multiple scenarios and engaging in a holistic investigative process to recommend optimal technological solutions. The competency development aspect is important, as the creation of scenarios necessitates a blend of technological expertise and the ability to gather data and formulate assumptions, ensuring a realistic representation of real-world situations.

The structure of this technical guide aims to provide a comprehensive understanding of the DHAT tool, explaining its various functions and underlying principles. This approach aims to empower users with the knowledge required to navigate the tool effectively and appreciate the logic behind it.

Table of Contents

Danish Energy Agency

Figures

Tables

Danish Energy Agency

Abbreviations

[RE]	Renewable energy
[LCOE]	Levelised cost of energy
[NPV]	Net present value
[DH]	District heating
[DHAT]	District heating assessment tool.

Introduction

The technical guide aims to walk users through the key sheets in DHAT, providing examples to help them get started with DHAT and perform basic calculations. This technical guide is intended to enhance understanding of the various elements and tabs in DHAT, strengthening the reader's comprehension of the tool and providing insight into the rationale behind its design.

DHAT is a tool designed for conducting pre-feasibility studies, with the goal of identifying and mapping scenarios that are economically and environmentally feasible. Subsequently, a feasibility study can be conducted on these scenarios to further assess their advantages and disadvantages.

The tool is based on the Danish approach to heat planning, emphasizing multiple scenarios and a holistic investigative phase aimed at promoting the right technological solution. An additional outcome of this process is competency development, as scenario creation requires both technological knowledge and the ability to gather data and make assumptions, ensuring that the scenarios reflect the real-world situation as accurately as possible.

This technical guide is structured to provide insights into the composition of the DHAT tool, explaining its various functions and the underlying principles, with the aim of strengthening the reader's understanding of the tool and the rationale behind its design.

Disclaimer

The DHAT tool is intended for prefeasibility studies or to validate and support existing pre-feasibility analyses. It is not a substitute for detailed calculations on specific projects, as its results are indicative and require separate, project-specific calculations for application. The data within DHAT should be adjusted to local or national contexts to obtain meaningful results. Notably, the Excel version of DHAT is designed for training purposes, and the data it contains is also geared towards training. Consequently, results from this tool should be approached with caution, and its data should not be used in external calculations without verification.

1. User interface

This chapter delves into DHAT Interfaces through two distinct approaches. The main focus is on providing a comprehensive general walkthrough of both simple and technical interfaces, accompanied by practical examples through screenshots.

The Simple approach relies on predefined inputs and scenarios, offering a straightforward method for estimating the impacts of various initiatives.

On the contrary, the Technical approach allows users to customize and create their own scenarios and storylines, providing a higher level of detail, flexibility, and control in the analytical process.

Storylines

In storyline[1] you define which scenarios you want to include in your storyline. The storyline is the final result of the DHAT calculation and where you will be able to see a comparison of different scenarios.

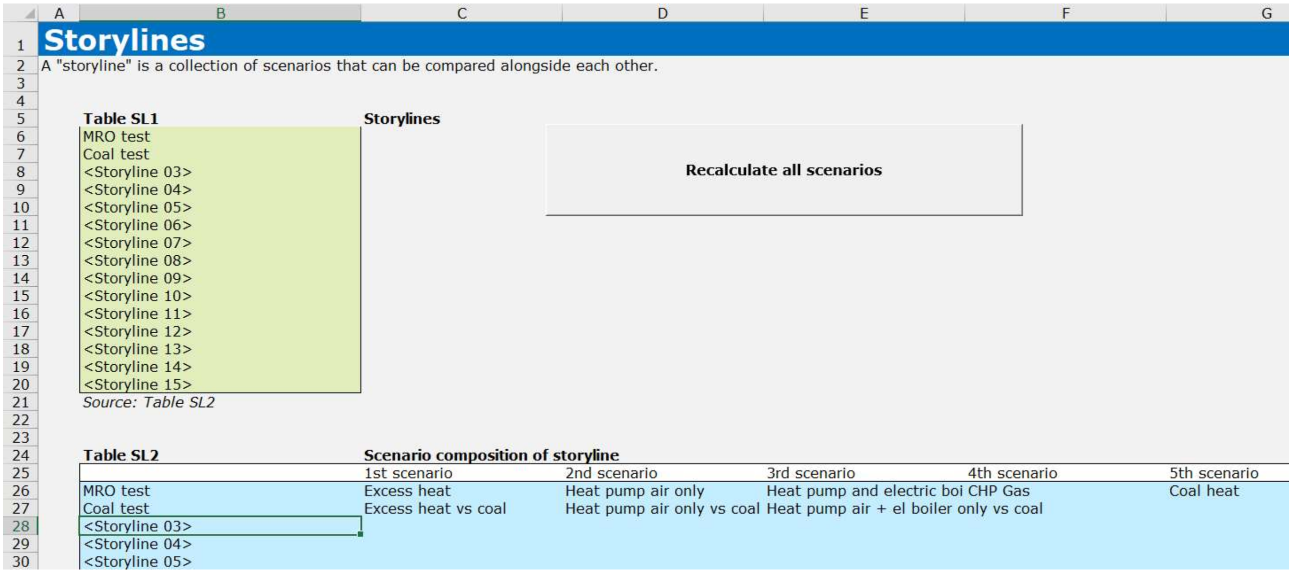


Figure 1. Overview of the Storyline tab

As you can see in the figure the storyline is given a name and up to ten different scenarios can be included in the storyline. To name the scenario simply type the name in Table SL2 column B. Then use the drop-down menu to choose which scenario to include in the storyline. Up to 15 different storylines can be included in one DHAT sheet. If further scenarios are needed then more excel sheets must be made.

---

[1] In the context of Excel or data analysis, a "storyline" typically refers to a narrative or sequence of events that is constructed or interpreted from the data. It involves organizing and presenting data in a way that tells a coherent story, helping the reader understand the context, trends, and insights revealed by the data. The term "storyline" in Excel is not about a feature or function of the software but about the approach to data interpretation and presentation.

To make the calculation of the scenarios and storylines press the Recalculate all scenarios on top of the page.

Scenarios

Below you can see an example from the scenario tab with the input box.

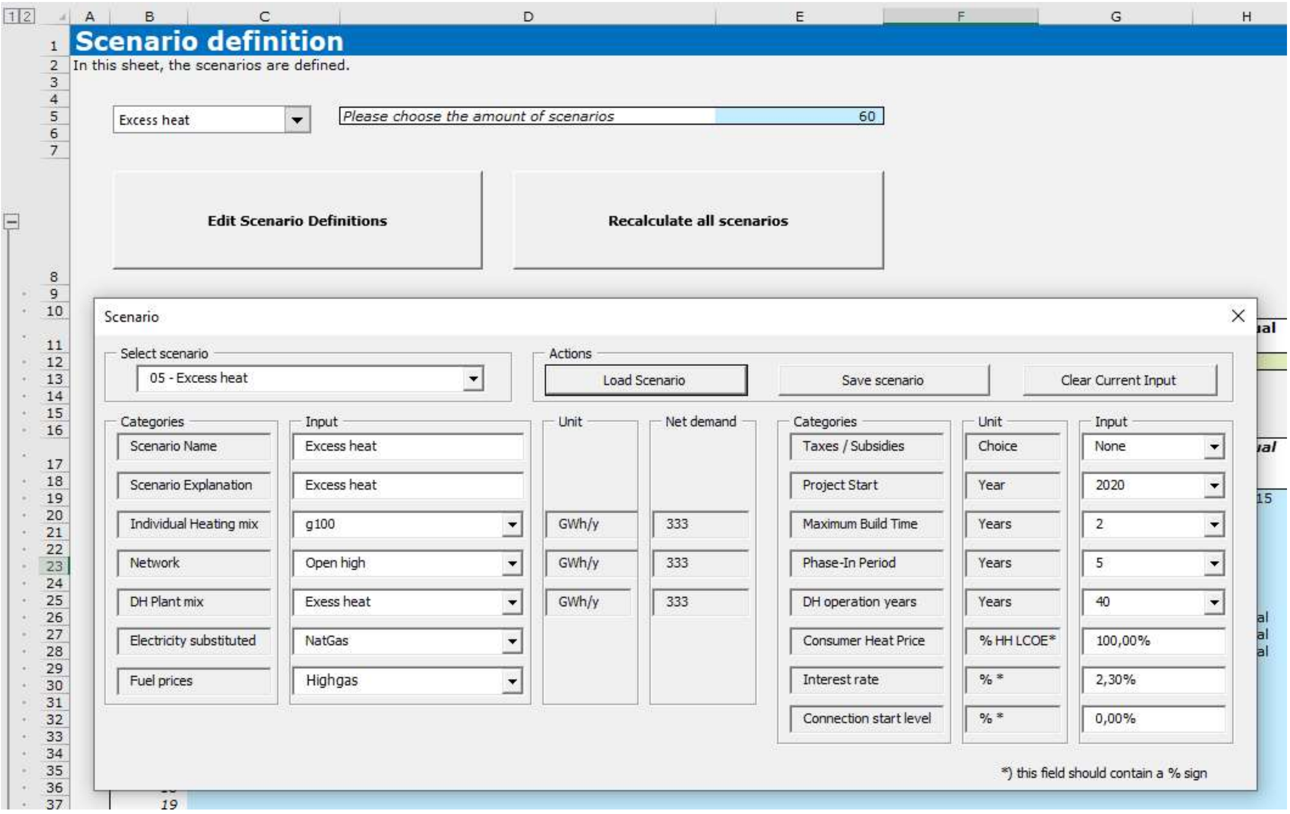


Figure 2. Overview of how to edit a Scenario

In the scenarios tab you can use the dialogue box to fill in the information required to calculate a scenario. For the Individual Heating mix, Network and DH Plant mix you can choose between the options defined in the according tabs.

The other input fields are used to choose which other assumptions should go into the scenario such as economic factors and building times. It is also possible to choose fuel price scenario, taxes and subsidies and electricity substituted. These options are defined in the blue sheets where the relevant data must be entered directly.

As a control the net demand used in the central, network and individual calculations can be compared.

Scenarios can be used to compare many different parameters. A typical Danish example will we conversion of an area heated with individual natural gas boilers to district heating. The baseline scenario is individual gas boilers as it is the existing option. That baseline is represented in the individual sheet. For the comparison different central mixes can be made which represent different option for district heating development. The results of the calculations will then show which options appear to be the most feasible.

Network

In the network tab the calculation on the cost of the district heating network is made.

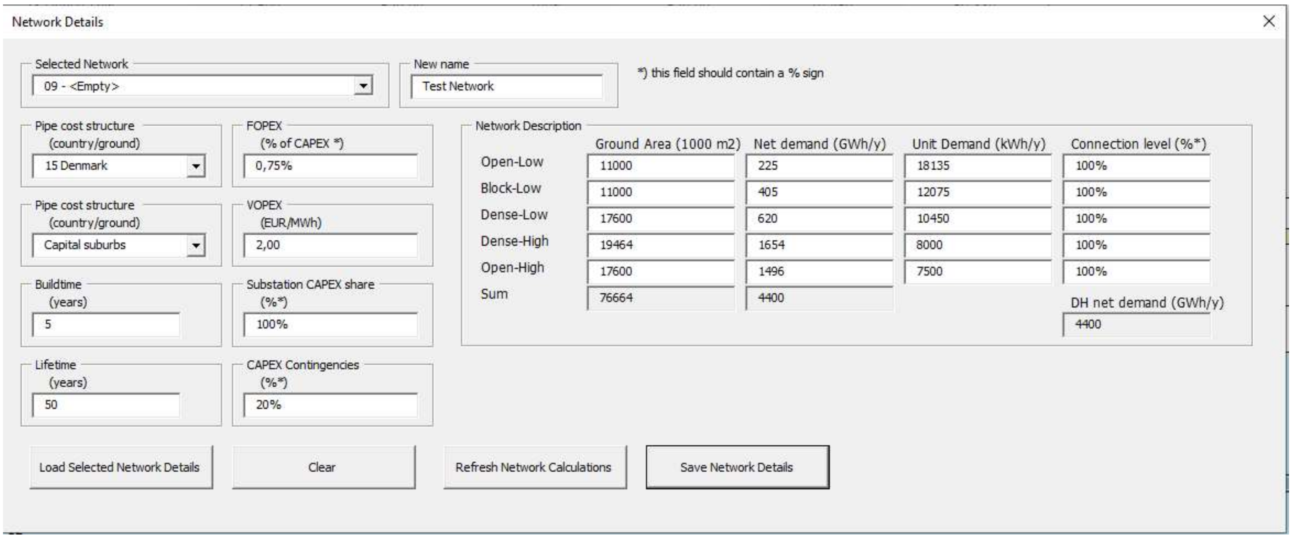


Figure 3. Overview of the Network details

In the network description, the ground area of five different categories of city building density is available. For each of the building densities the ground area and the net heat demand are entered. The unit demand is the heat demand of the single consumer. Connection level can be set to a number below 100% if not all consumers in an area are expected to connect to district heating. Again, here it is possible to make a control that the sum of the net demands equal the DH net demand.

FOPEX is Fixed OPEX. VOPEX is variable OPEX. Capex contingencies is a factor, which can be set as a percentage and will be added to the calculated CAPEX. The capex contingencies reflect the uncertainties of building a DH network and that there will usually be some unforeseen cost.

Individual

The individual tab is used to define a baseline calculation for an alternative to district heating.

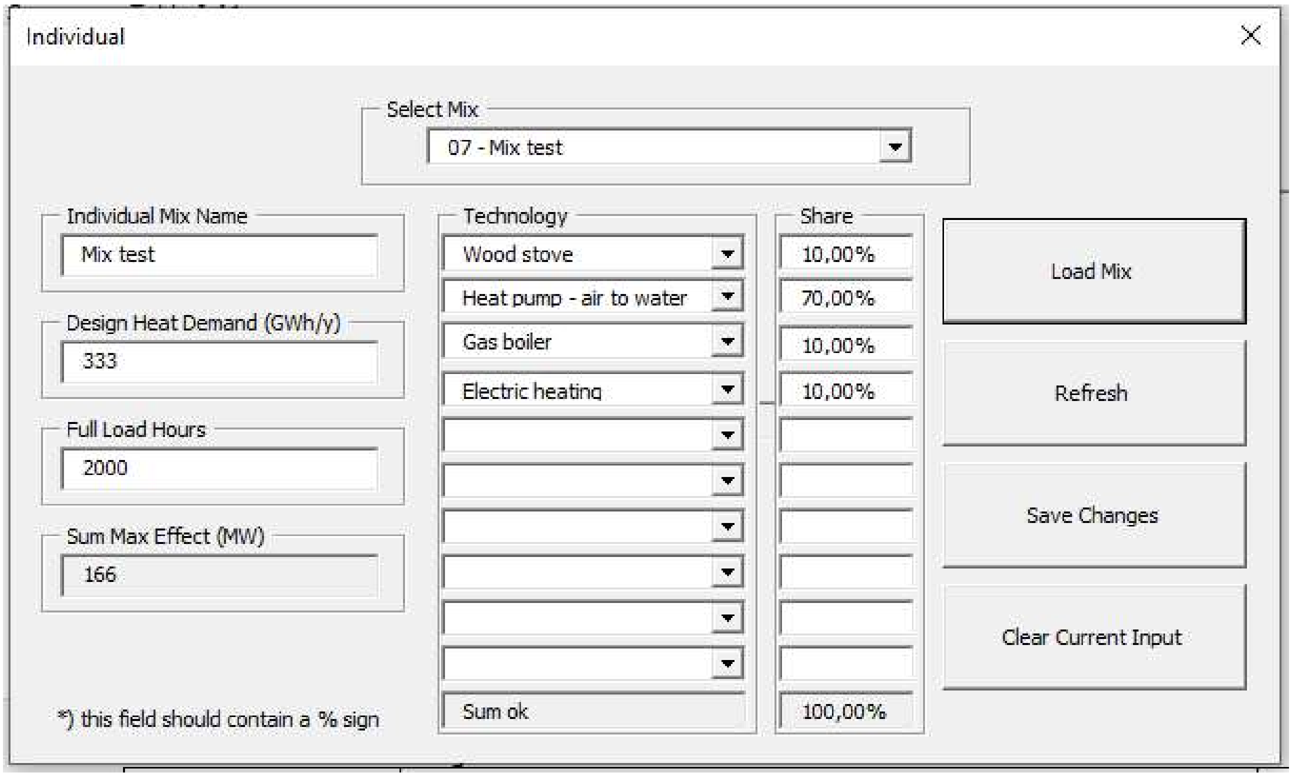


Figure 4. Overview of individual production units

A mix of technologies can be chosen in the list and defined as a percentage of the total demand. The idea is that it is possible to include an area in an existing city where there are different kinds of individual heating solutions. The sum of the shares must be 100% and this is controlled in the input box. The order of the technologies is not important.

Centralized

In the centralized tab you can define the demand and production for a district heating area.

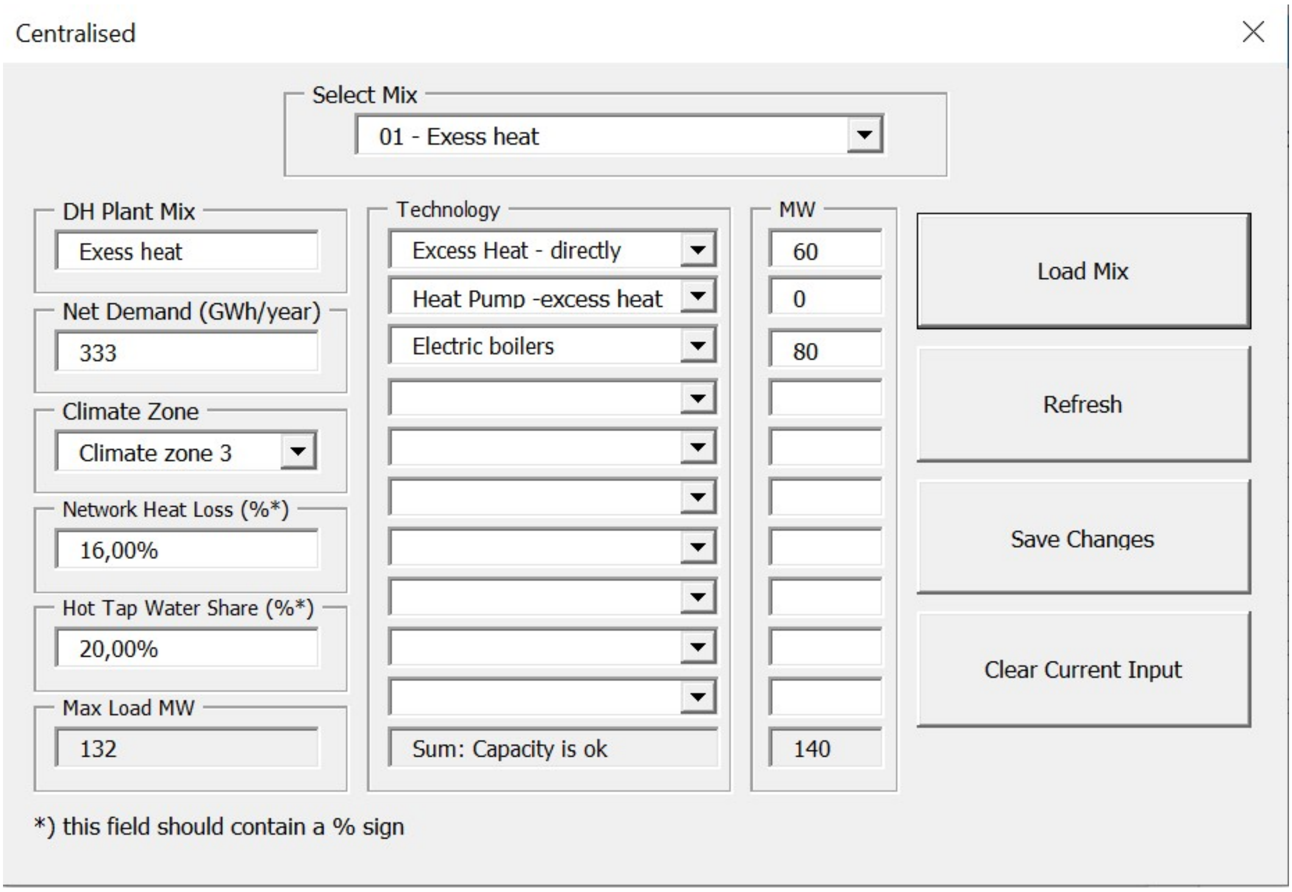


Figure 5. Overview over centralized production units

The production dispatch is simple as the first production technology produces full capacity as many hours as it can. If the demand is higher than the production then the second technology will produce as much as possible. Then the third and so on. So, in this input box the order of the technologies is important. The technologies are chosen from the drop-down list and the value entered is the production capacity in MW. The sum of the capacities can be compares to the Max Load MW as a control. The Max Load MW is calculated based on the net Demand, climate zone, Network Heat Loss and Hot tap Water Share. If any of these are changed then the Max Load will change although probably only a bit.

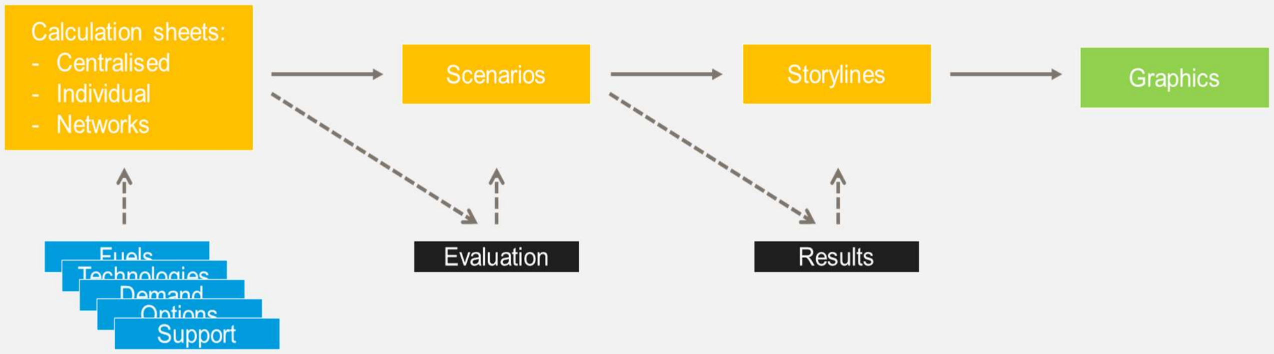
Net heat demand is the heat demand of the users in the district heating network. If a heat loss is entered it will be added to the net heat demand. The sum will be the gross heat demand. The hot tap water share is calculated as a percentage of the Net Demand, so it does not affect the gross heat demand.

Process flow

The process flow in DHAT can be seen in figure, which can also be seen in the introduction tab in the excel sheet.

<u>Introduction to the spreadsheet/model</u>
This sheet constitutes the District Heating Assessment Tool (DHAT). The user will mainly be working in the yellow calculation sheets. The primary results can be found in the green Graphics sheet and the secondary results can be found in the black Results and Evaluation sheets. The yellow calculation sheets are basing its calculations on input data and data found in the blue data sheets. The user should verify the data in the blue data sheets before using tool.
The most logical order to work through the yellow calculation sheets is:
- Centralised
- Individual
- Networks
- Scenarios
- Storylines
- Graphics

<u>Process diagram</u>



The work flow for creating a calculation is to first choose the relevant data in the calculation's sheets: centralize, individual and network. Then a relevant number of scenarios are defined and put together in a storyline. Each of the three calculation sheets should be filled out separately to ensure that the input is as desired. For everyday normal use of DHAT there should not be any need to change blue data sheets.

The color standards for sheets are:

Blue sheets indicate that the user should enter data or verify existing data.
White sheets are informational sheets for the user regarding the model.
Green sheets are primary results
Black sheets are the secondary results.
Orange sheets are calculation sheets.

The tab colors can be further examined. The main tabs for new users are the yellow tabs. Here you can choose many options for calculations and scenarios in drop down menus or by typing them in the input boxes. Some results are shown already when the data is put into the sheets. However, the main results are shown in the graphic sheet after all scenarios have been calculated.

The blue sheets contain all the data needed for the calculations. Price data for fuels, all data on technologies, climate data and much more is listed in these sheets. All data and values can be changed, but it should only be done by an experienced excel user. New data should be carefully evaluated before entered to replace the existing data. It can be of great importance and value to enter new data e.g. climate data or energy prices, which better reflect the conditions in the area that will be examined.

The black sheets are secondary results where the result and calculation can be examined more in detail. Normally these sheets are not used by a normal user.

Process and calculations outside of DHAT.

Some of the data required to make a DHAT calculation is comprehensive and not simple to collect. Depending on local conditions it can be difficult to find the net heat demand for an area, number of consumers or how the existing heat supply is just to name a few examples. To find these data may require calculations that are not possible in DHAT. The user may either add new sheets or tabs to the DHAT model or simply do the calculations in a separate sheet.

For the network calculations Google Earth can be a tool to measure ground area and if available use the street view function to make rough estimates of the building types and areas. This data can then be used in the network calculation.

Before starting the calculations, it might also be a help to go through the purpose a goal for the DHAT calculations. This can be done in several ways. One might start from the top from the storyline and go backwards. E.g. the goal is to compare three different DH production types with an individual gas boiler baseline scenario and then work into the detail of the different options. Another way is more bottom up where you start by defining the different components of the calculation and then put them together to a storyline in the end.

2. Data management and sensitivity

This chapter examine the data within the DHAT tool. The primary data source stems from the Danish technology catalogues, serving as a foundational cornerstone for analytical activities in Danish DH calculations. However, users are urged to exercise caution in adapting this data to align with local or national conditions. To view the sensitivity of the data inserted in DHAT an assessment is made, in order of how the data will be perceived in a Danish context.

This chapter unfolds with detailed procedures of the data needed and an assessment of the sensitivity of the data. The emphasis is particularly directed toward the technical catalogue, explaining its relevance within the context of Danish conditions. Additionally, attention is given to the complicated area of Data Sensitivity.

It is crucial to underline that each data within DHAT is accurately traced back to its sources. As new data is incorporated, maintaining the currency of these sources or referencing internal documentation becomes necessary. This practice serves to uphold a comprehensive understanding, ensuring an informed engagement with the tool for all users.

A list outlining the initial data requirements has been compiled, along with explanations of how they are interpreted within a Danish context.

List:

- Heat demand
- Capacity and efficiencies of individual production units
- Reinvestment and new investment in alternative individual production units
- Subsidies for individual production units
- Existing DH-production units – capacities, fuel and efficiencies
    - Operation strategy
- Future DH-production units - capacities, fuel and efficiencies
    - Operation strategy
- Subsidies for DH units
- Information of overall CAPEX (Investment cost), OPEX (Operation cost), and network cost in a Chinese context

1. **Determine the heat demand**

Regarding heat demand, it significantly depends on whether it is an existing area or a newly established one.

Expanding an existing district heating area relies on pre-existing data, accessible from utility companies in Denmark. However, this data may be considered sensitive, limiting general access. Expansion involves a mix, as network costs may connect to the existing district heating network, with variations based on the age of the network.

Concerning new areas, if there is no utilization of specific internal data from the utility company, it will not be categorized as sensitive data. This is because the accessible data will originate from a public source.

2. **Determine the individual production technologies**

Regarding individual heating sources, this topic is challenging to uncover. Despite the existence of central registers, such as BBR data, in Denmark, mapping individual production units and assessing overall efficiency is difficult.

In a Danish context, this would involve an estimate, ideally based on central registers where overall efficiency is derived from average lifespan or requires a general assumption. In the worst-case scenario, assumptions may need to be made, leading to a discussion about whether this constitutes sensitive data.

Since assumptions should ideally reflect reality, but there is no evidence that these assumptions align with actual conditions.

As a result, the DEA considers that anonymizing this data is not necessary. These calculations are built on assumptions, and replicating the real situation in the model is challenging. The best-case scenario would to simplify real-life data to meet the needs of the DHAT tool, which is deemed to pose no risk or impact on data sensitivity.

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

As nobody can predict future developments, assumptions about the future trends in the heating sector will be made using local and national plans. These assumptions will be based on already publicly available information.

Therefore, the DEA assesses that there is no need to anonymize this type of data.

4. **Insert subsidy payments to individual technologies**

Subsidies are considered public data since it is mandated by public regulation, and as such, there is no need to anonymize this information.

5. **Select district heat production technologies**

In a Danish context, information about production units and their efficiency would be considered sensitive data and not publicly accessible. While the overall capacity of different production units might be publicly available, finding information about efficiency, especially the operational plans of individual utility companies, could be challenging.

However, it should be noted that there is a distinction between input data for DHAT and real-world data. Consequently, it is still possible for DEA to access input data rather than actual data.

Therefore, the DEA assesses that in this case, there may be sensitive data, and it is necessary to establish a clear protocol for handling it. The significant difference between real data and input data in DHAT must also be taken into account. Hence, assumptions made to simplify the real data can be done by CABR to ensure that there is no risk of sensitive data becoming accessible through the model.

6. **Insert capacities and select how to perform the production simulation**

In Denmark this wouldn't be considered sensitive, most of the time the capacity of the production is publicly available.

Therefore, the DEA consider this non-sensitive

7. **Insert parameters for the development of the district heating network**

Since future developments are not predetermined, they will be based on assumptions, and therefore, these are considered not sensitive. However, it is essential to consider how the previous point regarding capacity is interpreted, as the foundation for future development relies on it.

In a Danish context, this would not be considered sensitive data, especially early in the process where no preliminary investigations into capacity sizes have been conducted. The DEA assesses that it cannot be categorized as sensitive.

8. **Insert subsidy payments to district heating technologies**

Subsidies are considered public data since it is mandated by public regulation, and as such, there is no need to anonymize this information

9. **Adjust technology data In the Technology Data to a Chinese context**

All of the adjustment of technology to match the Chinese standards would be something that can be considered non-sensitive since the data used would either stem from other projects or be standardized data.

10. **Adjust fuel prices, emission costs and taxes**

Projections will be based on publicly available forecasts, and if not, assumptions will be collectively made. Therefore, this information cannot be categorized as sensitive.

11. **Adjust the district heating network**

This has not nothing to do with real life data, but it is just to illustrate that this is continuous process

12. **Adjust heat consumption profile and solar production profile**

This has not nothing to do with real life data, but it is just to illustrate that this is continuous process

Scenarios and storylines

The Danish methodology for scenario development involves generating numerous scenarios, typically employing a systematic approach. This method entails mapping potential scenarios by considering technological advancements in the DH sector and aligning them with political objectives. This systematic approach ensures that the process is not constrained by the user's existing knowledge and, furthermore, facilitates the user's learning during scenario analysis.

When crafting scenarios, it is crucial to differentiate between scenarios involving the implementation of a new DH system and those related to an existing system. This section offers a comprehensive examination of the advantages and uncertainties associated specifically with the introduction of a new DH system.

Figure 6. Overview of the methodological approach to scenario creation

Demand

The initial phase involves a reverse construction of the scenario, starting with the estimation of the demand, typically derived from predictions related to connected users. Subsequently, factors such as energy savings, anticipated population growth spanning 20-40 years, and local building developments are considered and is highly valued to municipal planning in Denmark.

Technologies

Following an assessment of the demand, the focus shifts to identifying technologies capable of meeting the demand. Both short-term and long-term efficiencies are inspected, with a significant emphasis on cost considerations. The main goal is to determine the most cost-effective means of meeting demand, aligning with Denmark's objective of achieving the lowest possible heat price for consumers. While this approach might not be directly applicable in other countries, the idea of adopting a cost-effective heat production strategy remains relevant. Denmark's willingness to diversify technology usage, establishing multiple production units to fulfill demand, is a key consideration.

Fuel Mix

The examination of the fuel mix involves decisions on the type of fuel to be utilized, exploration of integrating RE into the system, and an evaluation of CO_2 emissions based on the chosen fuel mix.

Methodological Differences for Existing DH-Systems

In contrast, planning for existing areas involves accounting for already connected users and the presence of established technologies to meet current demand. Consequently, the emphasis on selecting suitable technologies is constrained by the pre-existing system, reducing flexibility. Avoiding sunk costs becomes pivotal, necessitating a holistic view of the system and an assessment of the dynamic between new and existing technologies. Consideration must be given to the near future, especially when existing technologies approach the end of their technical life.

There is also greater certainty regarding the degree of connected users in existing areas, which strengthens the business case and provides a better indication of the feasibility of the project.

The two methodological approaches share the hermeneutic approach, where one continually optimizes and evaluates the results until reaching a satisfactory outcome or the scenario cannot be further optimized.

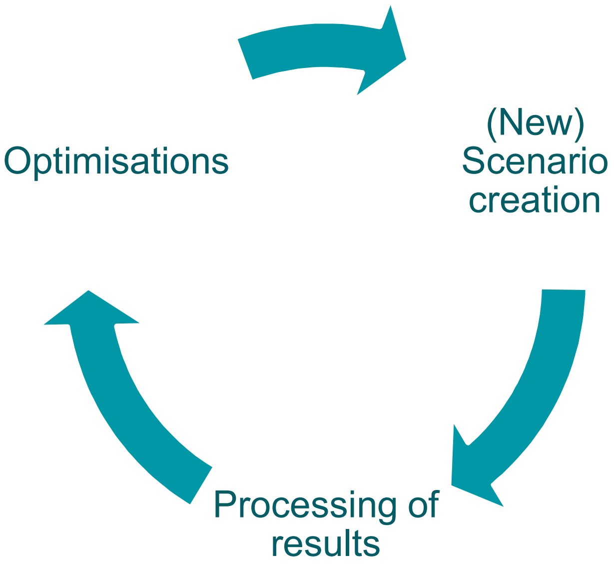


Figure 7. Illustration of the hermeneutic approach

Figure 7 illustrates the hermeneutic approach, where one continually optimizes and evaluates the results until reaching a satisfactory outcome or the scenario cannot be further optimized. In the figure, "new scenario creation" is indicated, and this should be understood as the initial creation of the scenario, with the argument that every time optimisation occurs, a new scenario emerges

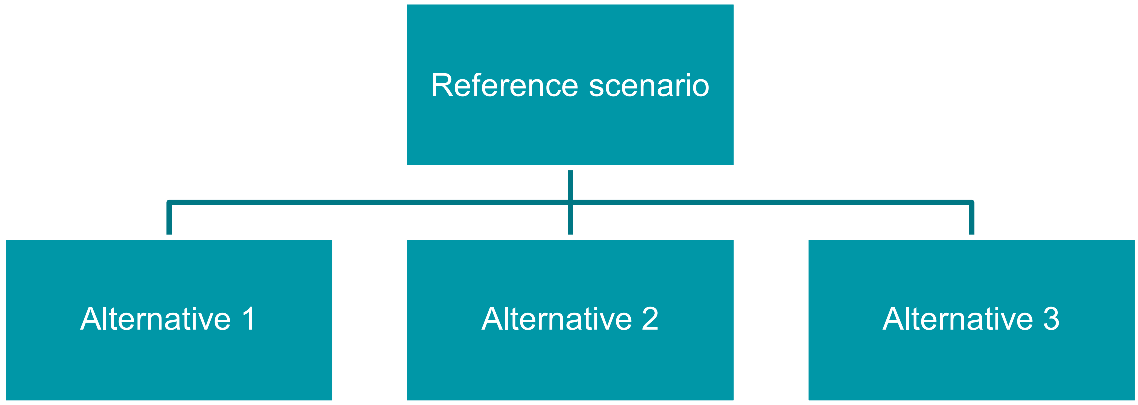


Figure 8. Overview of possible scenarios

As mentioned earlier, many scenarios are created, and an overview of these can be seen in Figure 8. This is a common approach to how scenario mapping can look in a Danish context. First and foremost, there is a reference scenario, the purpose of which is to map the existing production and needs. Depending on the purpose of the scenarios, either a frozen policy approach or an approach that considers planned changes and takes into account objectives for the time period is usually used. To enhance understanding, both of these approaches are included in Figure 9.

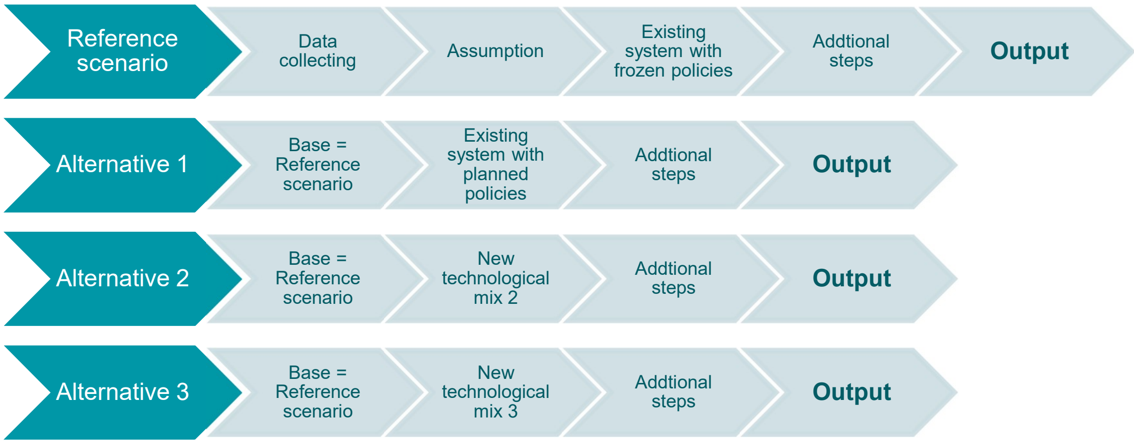


Figure 9. Overview of the structure of the different scenarios

In Figure 9, an attempt has been made to illustrate how the construction of the various scenarios takes place. It is a simplified version to promote understanding, but essentially, it starts with the reference scenario and how it is actually created. Under "Additional steps," sensitivity analyses are performed on relevant parameters, capacity optimizations, and more. Therefore, it is important that these elements are given priority, and the right amount of resources is allocated to them.

Processing of Results

This section provides guidance on interpreting the graphical representations of data within the DHAT tool. Another vital aspect covered in this section affects the comprehensive data input sheets in the DHAT system. These sheets allow users to tailor price prognoses, technology data, demand profiles, and more. Detailed instructions are provided for modifying input sheets, along with best practices to ensure accuracy and relevance in data input, thereby maximizing the utility of the DHAT tool.

Graphics, Evaluation and Results

The DHAT process integrates data input, scenario analysis, and storytelling to ultimately produce graphics that aid in decision-making. This methodical approach allows for a comprehensive understanding of the various factors influencing DH projects and presents them in a clear, visual format for stakeholders, see Figure 100.

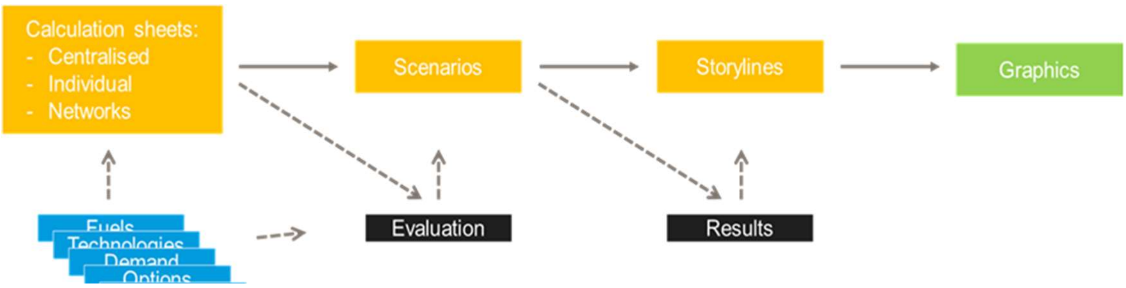


Figure 10. Workflow of the DHAT

The process begins with establishing scenarios, each defined by a set of assumptions and preconditions with inputting data related to fuels, technologies, demand, options, and support into the calculation sheets, which are categorized into centralized, individual, and network types. This information is used to evaluate and create different scenarios, each representing a unique set of conditions and assumptions that affect the DH system's performance. And these scenarios yield results like net present value (NPV), levelized cost of energy (LCOE), and emission values.

The user collects the scenarios that can be compared alongside each other, that is storyline, which are narrative descriptions of future scenarios that provide context and explanation to the resulting data. The storylines help stakeholders understand the implications of each scenario in real-world terms.

To translate the storylines and the associated data, the visual graphics are formed. These graphics are crucial as they provide a clear and immediate visual representation of the outcomes, such as the LCOE broken down by various cost components and displayed in an easy-to-interpret bar graph format. The purpose of these graphics is to communicate complex data in a straightforward manner, allowing decision-makers to quickly grasp the cost implications of different national impact scenarios and make informed decisions regarding DH planning and policy.

Graphics

	Visual presenting	Data source
Figure G1.1	The figure shows the LCOE cost breakdown for a Baseline scenario - including only non-DH costs and reinvestments - and a DH-scenario, where there are non-DH costs until the DH mix is fully phased in.	Table G1.1 Table G.A1.1
Figure G1.2	The figure shows the LCOE cost breakdown for the DH mix and the avoided non-DH costs for the same period.	Table G1.2 Table G.A1.2
Figure G2	The figure shows the LCOE cost breakdown for the DH mix only.	Table G2
Figure G3.1	The figure shows the greenhouse gas emissions for the DH mix and the avoided emissions from the non-DH mix. The white box indicates whether the there is a DH advantage (positive) og disadvantage (negative).	Table G3.1
Figure G3.2	The figure shows the greenhouse gas emissions for the DH mixes compared to one of the non-DH mixes.	Table G3.2
Figure G4	The figure shows the total CAPEX for the DH and non-DH mixes. For the DH mixes, the CAPEX is divided into network and plant.	Table G4
Figure G5	The figure shows the simple payback time and time untill the DH company begins to have a positive cummulative cashflow for each of the DH mixes.	Table G5
Figure G6	The figure shows the cummulative cashflow for each of the DH mixes.	Table G6
Figure G7	The figure shows the total consumer payment for the DH mixes and the corresponding avoided costs from non-DH. The white box indicates whether the there is a DH advantage (positive) og disadvantage (negative).	Table G7
Figure G8.1	The figure shows the LCOE costs for one Baseline Mix - including only non-DH costs and reinvestments - and a DH-scenario, where there are non-DH costs until the DH mix is fully phased in.	Table G8.1
Figure G8.2	The figure shows the LCOE costs for the DH mixes compared to the avoided costs of one non-DH mix for the same period.	Table G8.2

Figure 11. The function of the Figures in "Graphics" tab and their sources

Figure 11 outlines various figures and their corresponding data sources from the "Graphics" tab in the DHAT tool.

Each of these graphics and tables will provide a detailed analysis of the LCOE, broken down by various cost components, across different scenarios within DH networks. The names are indicative of the specific focus of each graphic or table and are meant to guide stakeholders in understanding the financial performance and implications of DH implementation.

For the LCOE tables and figures (G1.1, G1.2, G2, G8.1, G8.2), they typically break down the costs associated with producing energy through DH networks. These would show the capital expenditure (CAPEX), operational costs (OPEX), and any variable costs over the energy unit. They allow comparison between different network scenarios or against a baseline or individual mix, highlighting economic viability.

The greenhouse gas emissions tables and figures (G3.1, G3.2) would present the environmental impact of the DH scenarios, illustrating the emissions per energy unit and allowing for comparison against more carbon-intensive individual heating solutions.

Capital expenditure (CAPEX) figures (G4) show the initial investment required for DH infrastructure, important for understanding the financial scale of projects.

Payback times (G5) would indicate the period over which the initial investment in DH pays for itself through operational savings, a critical factor for long-term financial planning.

Cashflow figures for DH companies (G6) show the financial health of the operators over time, excluding externalities, which helps in understanding the sustainability of the business model.

Consumer payment graphics (G7) would reflect what consumers might expect to pay, offering insights into the affordability of DH for end-users.

Evaluation

The "Evaluation" tab is meticulously structured to assess the economic, technical, and environmental aspects of DH projects. This analysis unfolds across five key sections, each leveraging a suite of tables to present a view of the DH landscape. These tables are crucial in providing a detailed overview of the financial and environmental consequences associated with DH projects.

Through this multi-faceted approach, stakeholders gain access to pivotal insights for cost-benefit analysis, enabling well-grounded decisions that take into account a spectrum of economic, technical, and environmental factors. This structured evaluation supports a strategic framework for understanding the full scope and impact of DH projects.

The five sections are:

1. Evaluation of DH project costs + (individual until 100 % phased in)

The section delves into the DH project costs, exploring the phasing of technologies, electricity, and fuel pricing, alongside capital expenditures and emissions. This analysis is crucial in understanding the financial implications throughout the transition to fully implemented DH systems. And Table E1~E7 containing the relevant data information are presented in this section, which aim to calculate the financial impact during the transition to fully implemented DH systems, see Table 1. Explanations of Table E1~E7 in “Evaluation “tab. .

Table 1. Explanations of Table E1~E7 in “Evaluation “tab.

No.	Tables	Function
1	Table E1 Phase in of DH technologies	It tracks the implementation progress of DH technologies
2	Table E2 Electricity	It assesses electricity costs associated with DH

3	Table E3 Fuel price by technology, EUR/GWh	It provides the fuel prices by technology.
4	Table E4 Fuel costs by technology, DH plants, million EUR	It outlines fuel costs for DH plants.
5	Table E5 Capital Expenditure accounting DH plants, million EUR	It calculates capital expenditures for DH plants.
6	Table E6 Emissions, all DH technologies, ton/year	It measures emissions from all DH technologies.
7	Table E7 Cost breakdown, all DH technologies, million EUR/year	It breaks down the costs associated with DH technologies.

2. Evaluation of on-DH costs for the entire period

In this section, the focus shifts to non-DH costs, considering heat consumption, fuel pricing, and the associated financials throughout the project's lifecycle. This comprehensive perspective is vital in assessing the full cost implications over time. Table E8~E14, analyzes the heat consumption, fuel prices, fuel costs, capital expenditures, emissions, and cost breakdown for non-DH scenarios, providing a full cost perspective over the entire period.

Table 2. Explanations of Table E8~E14 in "Evaluation "tab.

No.	Tables	Function
1	Table E8 Heat consumption	It looks at heat consumption in non-DH scenarios.
2	Table E9 Fuel price by technology, EUR/GWh	It lists fuel prices by technology for non-DH.
3	Table E10 Fuel cost by technology, non-DH with DH-project, million EUR	It shows fuel costs for non-DH scenarios with a DH project.
4	Table E11 Capital Expenditure accounting non-DH with DH-project, million EUR	It accounts for capital expenditures in non-DH scenarios.
5	Table E12 Emissions, non-DH with project, ton/year	It tracks emissions for non-DH scenarios.
6	Table E13 Cost breakdown, non-DH with DH project, million EUR/year	It analyzes the cost breakdown for non-DH with DH project.
7	Table E14 Fuel distribution costs, million EUR/year	It calculates fuel distribution costs

3. Financial evaluation by agent

The section offers a financial evaluation from the standpoint of different agents. It details the economic advantages for consumers and the financial outlook for the DH company, reflecting the direct economic impact on different stakeholders. Table E15 "Consumers DH advantage million EUR/year）， calculates the financial advantage for consumers of DH. Table E16 "DH company", evaluates the financial impact on the DH company.

4. Taxes/Subsidies:

Table E17 Price subsidy / tax, considers the effects of taxes and subsidies on the project. This part focuses on the influence of price subsidies or taxes on the overall financial evaluation, reflecting on how government policies influence the financial feasibility of DH.

5. Evaluation of DH and non-DH costs for the entire period

This section extends the evaluation of emissions, costs, and distribution expenses over the entire period for both DH and non-DH scenarios, offering a comprehensive view of the long-term environmental and economic impact.

- Table E18 details annual emissions from all DH technologies over the entire period.
- Table E19 provides a cost breakdown for these technologies in millions of EUR per year.
- Table E20 lists emissions associated with non-DH scenarios that include the project, measured annually.
- Table E21 breaks down costs for non-DH scenarios with the DH project in millions of EUR per year.
- Table E22 details the fuel distribution costs annually for the entire period.

Each table offers critical data for assessing the environmental and economic impacts of DH and non-DH technologies over time.

The Tables from E1 to E22 within these segments is purpose-built to distill complex data into actionable insights, enabling stakeholders to make well-informed decisions.

Results

To identify the most socio-economically viable scenario for a heat supply project, it's essential to calculate and compare the socio-economics of the project, including reference and relevant alternatives. This comparison involves calculating and ranking their NPV, which are derived by summing all costs and revenues over the study period and then discounting them at a specified rate for comparability. The scenario with the lowest overall socio-economic costs, which reflects the cost-effectiveness of the heat delivered, is determined by comparing the project against its alternatives, thus pinpointing the most advantageous heat supply option socio-economically. The DEA's Guidance in socio-economic analyses in the energy sector presents the calculation method of NPV.

In the "Result" tab, the tool displays both User and Company economic impacts among scenarios. Below Table 3 provides a Danish example, showcasing the calculation of company economic costs in present value over the study period. This serves as a framework for evaluating the financial dimensions of energy projects from a company or user perspective, helping users understand the tables in the "Result" tab effectively.

The "Results" tab in the DHAT tool, is structured to analyze different heating scenarios. It features Table R1, which presents a comprehensive view of User and Company economic impacts. This includes an array of financial metrics such as NPV, capital expenditure (CAPEX), operational expenditure (OPEX), energy costs, and greenhouse gas (GHG) implications, both for DH and non-DH scenarios. The tab's purpose is to offer a detailed comparison of these scenarios, highlighting the financial and environmental advantages or disadvantages, aiding in informed decision-making for heat supply projects.

Table 3. Denmark's example of company economic costs in present value

	project	The reference (current situation)	Alternatives
Cost of capital (DKK)	In total	In total	In total
Fuel/electricity costs (£)	In total	In total	In total
Taxes, quotas and subsidies (DKK)	In total	In total	In total
Operation and maintenance (DKK)	In total	In total	In total
Electricity sales (DKK)	In total	In total	In total
Total (DKK)	**In total**	**In total**	**In total**

Inputs

In Denmark, the preparation of heat supply project proposals must comply with the Heat Supply Act and the project executive order's requirements. In accordance with the Heat Supply Act, a socio-economic analysis for a proposed project is required and must adhere to a set of calculation principles. In the socio-economic analysis, the proposed project must be compared with other types of heat supply that are relevant alternatives to the project, and the socio-economic analysis must demonstrate that the project, based on a specific assessment, is the most socio-economically advantageous project.

Furthermore, in addition to the socio-economic assessment, an account must also be given of the company's economic effects and economic consequences for consumers, as well as of the project's energy and environmental impacts.

To support the implementation of these socio-economic analyses for a heat supply project proposal, three documents published and regularly updated by the DEA provide valuable guidance.

- Technology catalogues, offers comprehensive data on various energy application technologies. This data is essential for assessing developments in the climate and energy field.
- Socioeconomic assumptions for energy prices and emissions (Samfundsøkonomiske beregningsforudsætninger for energipriser og emissioner), establishes a uniform basis for socioeconomic calculations across the energy sector to create a uniform and consistent basis for socioeconomic calculations across the energy sector, thus ensuring fairness and meaningful comparisons of project proposals.
- And the socioeconomic assumptions must be used in conjunction with the DEA's Guidance in socio-economic analyses in the energy area, which describes the method for preparing socio-economic analyzes of projects in the energy field. In addition to the socio-economic assessment, an account must also be given of the company's economic effects and economic consequences for consumers, as well as of the project's energy and environmental impacts.

In the heat planning of Denmark, economic calculations for a project begin with a technical description, including alternative solutions, assumed heat demand, and expected electricity and fuel input for heat production. It's vital for the project proposal to precisely outline resource consumption, outputs, and environmental impacts for comparability. Data should reflect actual conditions, with substantiated investment costs and local data for heat demand and installation lifespans. Additionally, uncertainty should be addressed through sensitivity analyses. Table *4* provides the overview of heat planning alternatives and assumptions.

Table 4. Overview of Heat Planning Alternatives and Assumptions in Denmark

Data Collection Process	• Initiate with stakeholder meetings to define project scope
Defining Project Area	• Outline the heating needs of current and future buildings.
Heat Demand Coverage	• Use local data for current heat demand, or model based on standard figures for new constructions.
Identifying Alternatives	• Compare the proposed project against other feasible alternatives.
Non-Fossil Fuel Proposals	• Consider the exclusion of fossil fuel scenarios in analyses.
Supply Infrastructure	• Document the costs and configurations of district heating networks.
Production Facilities	• Detail the energy sources, capacities, and efficiencies of heating plants
Connection and Replacement Procedures	• Define timelines for connecting to or transitioning from existing heat supplies.
Environmental Impact Assessment	• Account for emissions and other environmental effects of the project and alternatives.

To ensure quality and transparency in socio-economic analyses for projects that involve changing energy supply types, it's crucial to clearly state and accurately determine all assumptions, particularly regarding costs. These assumptions are vital for local council heat planning and project approvals. The analysis includes two key elements: defining the assumptions used for financial calculations, and identifying the costs involved in constructing and operating the project. Table *5* shows the source of assumption in the analysis and documentation, which all provide the data basis for the heat planning in Denmark.

Table 5. Sources of assumptions in the analysis and documentation[2]

Element	Prioritised sources for pricing
Investment costs	• Binding offer • Key figures from construction accounts from previous projects (documented experience figures) • Technology catalogues
Operation and maintenance costs	• Binding offers (concrete price lists) • Key figures from previous projects (documented experience) • Technology catalogues
Fuel prices	• *Socio-economic calculation assumptions for energy prices and emissions* • Other documented locally determined prices in the years in which they apply, cf. *Socio-economic calculation assumptions for energy prices and emissions*
Electricity prices	• *Socio-economic calculation assumptions for energy prices and emissions*
Air emissions pricing	• *Socio-economic calculation assumptions for energy prices and emissions*
Taxes and tariffs	• Ministry of Taxation website (www.skm.dk)
Subsidies	• The Danish Energy Agency's website (www.ens.dk)

[2] A "binding offer" in the context of "investment cost" refers to a formal and legally binding proposal or quotation made by a contractor, supplier, or service provider to provide specific goods, services, or construction at a fixed price

With this understanding of the economic calculations and related assumptions for heat planning in Denmark, users can select appropriate data in the input tab of DHAT to achieve meaningful results.

In the “input” section of the DHAT tool, including Fuels, Technologies, Demands, Options, Network, and Support, the data is sourced partly from the three aforementioned files. This also offers international DHAT users’ clear explanations and references for data sources. Regarding the fuel character data in the Fuels sheet, it can be reviewed, verified and inserted new data in accordance with the proposal developed in the country out of Denmark.

Fuels

The “Fuels” tab in DHAT provides information on fuel characteristics as well as historical and projected data on fuel prices and transport costs based on the relevant input data from Table F1 to Table F6.

- Table F1 details the prices of various fuels used in DH plants, measured in EUR/GJ and used for calculating the operational costs associated with different types of fuels.
- Table F2 lists the prices of fuels under different scenarios, which includes variations in market conditions, supply scenarios, or policy changes and helps in assessing the financial impact of these scenarios on the cost of fuels.
- Table F3 shows the CO_2 content of electricity in kg/MWh, and used to assess the carbon footprint of electricity consumption in DH plants.
- Table F4 provides the additional transport costs for delivering fuel to individual sites compared to DH plants, which can influence the overall cost-efficiency of the DH system.
- Table F5 specifies the CO_2 content of different fuels on a per gigajoule basis (ton/GJ), which is important for calculating the greenhouse gas emissions from fuel combustion in DH plants.
- Table F6 indicates the sulfur dioxide (SO_2) content of fuels, measured in kg/GJ, and the data is used for environmental impact assessments.

Together, these tables allow for a holistic view of both the economic and environmental aspects of fuel use in DH systems, crucial for planning and decision-making.

In addition, in energy modeling with tools like DHAT, "high gas/electricity price" and "low gas/electricity price" represent scenarios for future energy costs impacting DH project feasibility. These price variations in DHAT facilitate robust planning by considering market uncertainties and their implications on both the economy and broader sustainability goals in energy policy, crucial for countries like Denmark.

And "world market price" refers to the global rates for fuels like natural gas, oil, and biomass, crucial for DH systems. It encompasses global supply-demand dynamics and geopolitical factors affecting fuel costs. These prices are used in DHAT to evaluate the economic impact of global market fluctuations on the viability and sustainability of DH projects, aiding in scenario analysis and informed decision-making for energy policies and DH strategies.

In the **Fuels** tab, users need to input essential fuel-related data. This includes historical fuel prices for benchmarking, future fuel price projections under various scenarios, costs for energy plants and technologies, emission factors for assessing environmental impact, and efficiency rates and lifetimes of

---

for an investment project. In other words, it’s an offer that, once accepted, becomes a contractual commitment.

heating technologies. Users are encouraged to customize these values according to their specific region or country, as DHAT's default data is based on Danish standards and may not align with other areas.

Technologies

In the "Technologies" tab, the tables provide detailed information on the various components of heating systems:

- Table T1 - Individual Technologies: lists the technical and economic parameters of individual heating technologies such as boilers or heat pumps that can be used in buildings not connected to the DH network. Users can define specifics like efficiency, capital cost, operational cost, and lifespan.
- Table T2 - DH Technologies: presents technologies used within DH networks, such as large-scale CHP plants. Data typically include similar parameters as for individual technologies but adjusted for the scale and context of DH.
- Table T3 - Pipe Information: contains the specifications for the pipes used in the DH network, including diameter, pipe cross-sectional area, recommended optimal velocity. The technical data is used for calculating heat loss and the efficiency of the heat distribution network.
- Table T4 - Pipe and Digging Costs: outlines the cost per meter for both the pipes themselves and the installation process, which includes excavation. This cost data is vital for budgeting and financial planning of the network's infrastructure.
- Table T5 - Pipe Costs in EUR/m: provides a breakdown or additional details on the costs associated with the pipes, excluding the digging aspect to give a clearer picture of the material costs.

In the “Technologies” tab, the user would need to input data like the chosen technology types, the required lengths and specifications of pipes for the project, and local cost figures for installation.

Understanding these tables involves interpreting the data to inform decisions about which technologies to use, how to design the network for optimal efficiency, and what the financial implications of these choices are. The tables can also be used to compare different technology and infrastructure options to determine the most cost-effective and efficient setup for a particular DH project.

Demands

The design of a new DH system is based on a load duration curve that represents the yearly cycle of heat production requirements. This curve is created when we arrange the hourly heat production demand of a DH plant from the highest to the lowest value over the year's 8760 hours, as shown in Figure C2. Effect use by ordered hour, MW in Centralized tab. To develop this curve, it's important to evenly spread the peak load hour by hour throughout a total 8760 hours of the whole year. This spread should include the needs for both space heating and domestic hot water (HTW used in DHAT), shown as a percentage of the overall demand.

This tab features three tables that provide essential data related to heat demand, as utilized in the DHAT framework.

- Table D1 - Chosen climate zone: Users select the climate zone that applies to their DH project, which affects how much heating is needed. And climate zones information used in DHAT presents in Table 6.
- Table D2 - Climate zones demand profile: shows how much heat is needed throughout the year in each climate zone. It helps to plan how much heat the DH system should be ready to supply.
- Table D3 - Pct of max solar prod: indicates the percentage of maximum possible solar energy production. It's about how well solar panels might work in each climate zone.

Table 6. Explanation of climate zones

Climate zones	Explanations
Climate zone 1	A hot coastal area with hot summers and mild winters.
Climate zone 2	Cooler coastal area.
Climate zone 3	Inland climate with hot summers and cold winters.
Climate zone 4	Inland cool climate with cold summers and cold winters.
Climate zone 5	Inland climate - User defined based upon heat degree days
Climate zone 6	Inland climate - User defined based upon heat degree days

In addition, FLH, in “Demands tab”, refers to Full Load Hours and is used in energy production, including solar energy. It indicates the number of hours a solar panel or other power-generating unit would need to operate at its maximum capacity to produce the same amount of energy it actually generates over a year. FLH accounts for variability factors like geographic location, weather patterns, and the panels' efficiency. This metric is essential for estimating solar energy yield and comparing the performance of solar installations across different conditions.

Options

The "Options" tab in the DHAT, is designed to facilitate scenario analysis in DH planning. It allows users to define and compare different scenarios based on a set of specific assumptions, such as a mix of technologies or a series of fuel price projections. Table O3 - Composition of condensing plants substituted and resulting unit emission, which focuses on the composition of condensing plants and the resulting unit emissions, plays a crucial role in this process. It provides data essential for assessing the environmental impact of various heating options. By utilizing this table, users can analyze the emissions implications of different technology mixes, enhancing their ability to make informed, sustainable decisions for DH projects.

And Table O1 - Damage costs (EUR/ton) and Table O2 - CO_2 equivalent factors, evaluate environmental and economic aspects of DH options. Table O1 addresses the environmental impact of various pollutants by listing their damage costs and prices, offering a financial perspective on environmental impacts crucial for assessing the economic viability of different heating technologies. Concurrently, Table O2 provides CO_2 equivalent factors for assorted greenhouse gases, it is instrumental in determining the overall environmental footprint of diverse heating technologies.

Network

To accurately determine network construction costs for DH, several key assumptions need to be considered. These include the configuration and tracing of transmission and distribution lines, the dimensions of individual pipe sections, and the laying classes or surfacing conditions for each section. These factors collectively provide a detailed framework for estimating the total construction costs of a DH project.

In the DHAT's “Network" tab, Tables N1 to N6 form an integrated framework for DH network analysis. Table N1 lists key network figures for the targeted district and area. Table N2 details network configuration basis. Table N3 covers network-specific assumptions for the current scenario, while Table N4 compiles assorted scenarios' assumptions and results. Tables N5 and N6, serving auxiliary and support roles, enhance data management and calculations. In synergy, a calculation page in this tab uses the data from these tables to assess network performance, costs, and efficiencies.

Support

The “Support” tab in the DHAT, contains a series of miscellaneous support tables (Table SUP.A1 - Table SUP.A14). These tables provide relevant supporting information to aid users in tailoring the DHAT tool to their specific country or area. They cover a range of topics such as monetary units, energy units, climate zones, fuel substitutes, and more. The data support enables users to accurately reflect local or national conditions in their analyses, ensuring that the results are relevant and applicable to the specific context.