LowTEMP

31.03.2020

Performing Life Cycle Cost Analysis on (LT)DH systems

Manual for the excel based calculation tool

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1 Introduction

With the Excel based *LowTEMP_life-cycle cost analysis LTDH_V0-9* tool, hereafter referred to as the tool, users are able to determine the life-cycle costs (LCC) of an investement in a low-temperature district heating (LTDH) system as well as in a conventionell district heating (DH) system. It considers costs for four stages of a life-cycle, namely construction, operating, maintaining, and end-of-life.

With the tool, users are able to consider everything of a (LT)DH system that is part of the investment and not belonging to DH costumers but DH providers such as utilisation companies.

1.1 Purpose of the tool

LTDH has a huge potential to achieve substantial environmental gains while reducing primary energy use and creating possibilities to use surplus energy and distrib-uted renewables as sources in DH networks. Using local energy sources also in-creases flexibility and energy security.

The major challenges when it comes LTDH are not so much related to technical issues but often connected to economic or organisational aspects. Not only, because DH systems are monopolistic by nature, i.e. strictly regulated in terms of prices and tariff models. Also, investments in LTDH seem to be a financial burden in the first realization phase due to higher investment costs for newer technology especially in the field of renewable energy.

Very often, environmentally friendly products prove to be the most economical option, even if they come with higher initial investment costs. Often, non-evironmentally friendly solutions are the least expensive ones at the beginning of a life cycle. However, in most cases they are not the most economical over their whole life cycle because of e.g. their operating costs. They can consume more energy during utilisation, have higher disposal costs or a shorter longevity.

Life cycle cost analysis (LCCA) is a method for assessing the total costs and, at the same time, the economic performance of a construction or building over its entire life cycle. With the help of LCCA, a product or infrastructure system like a low-temperature district heating system can be compared in its cost-effectiveness considering all occuring costs. This tool is able to calculate LCC for one investment which can be compared with other investment alternatives. It is recommended to use it as an assistance during the planning process of (LT)DH systems but not as a final result of the planning.

1.2 Target groups

Target groups of this tool are public authorities, heat suppliers, operators of DH networks, investors as well as planners and engineers.

1.3 Structure of the tool

The tool is Excel based and neither has hidden spreadsheet nor is it secured by a password. It does not use Macros or Visual Basic for Applications (VBA) in order to reach a broader audience.

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The user has to give inputs to certain topics. Blue cells highlight the input cells or dropdown menues where action is needed by the user.

All other cells as well as the structure of the tool are protected by Excel's "protect workbook command", see figure 1.

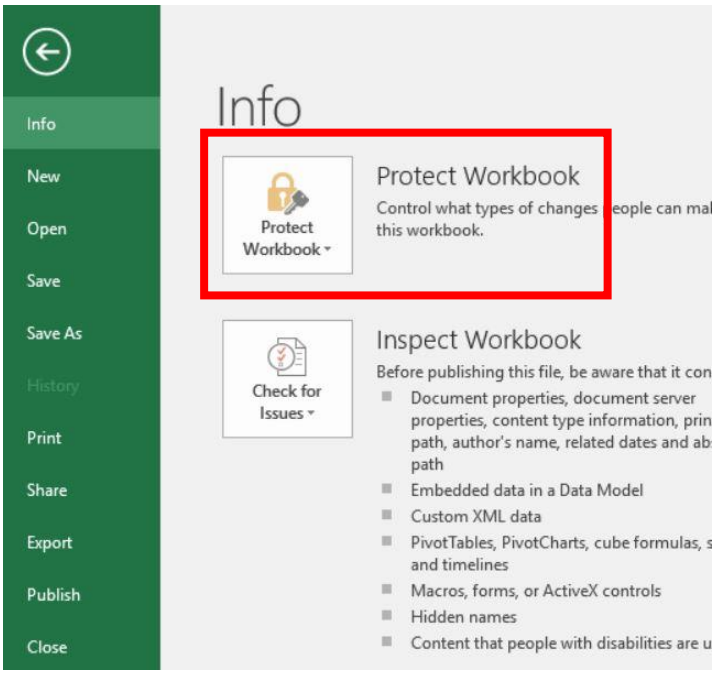

figure 1: protect workbook set-up (own source, 2020)

The tool consists of nine spreadsheets that are described in the following subsections. The prerequisites that are needed to fill out the following inputs are described in *3 Prerequisites* as well as their determination.

1.3.1 Input 0_general input

The spreadsheet "input 0_general input" is the first input spreadsheet. The following input needs to be given and known by the user:

- Discount rate
- Length of considered life cycle (optional). IfIf no setting is typed in here, the tool will automatically consider the technical lifetime of the component with the longest technical lifetime as the life cycle length.

figure 2 shows the input cells.

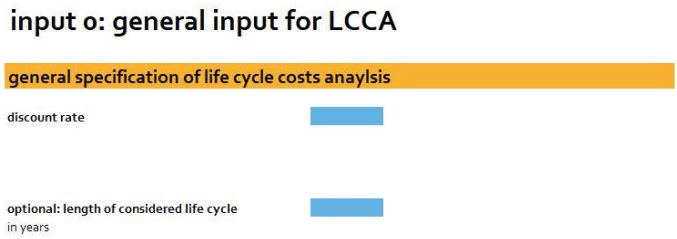

figure 2: input 0 – general input for LCCA (own cource, 2020)

1.3.2 input 1_construction

In this input, all costs that occur during the first life cycle stage, namely construction, are calculated. In order to do so, the user has to give detailed information (if possible) on each major component that is going to be installed. All prices / costs need to be given net without VAT. figure 3 shows the required input for the tool:

- additional costs
- year of commissioning of component
- specification of component
- technical lifetime of component
- information on dimension / size (optional)
- quantity
- costs

The user can type in up to 35 components. By deactivating the workbook protection, it is possible to insert more components, but all subsequently linked cells need to be updated on this change.

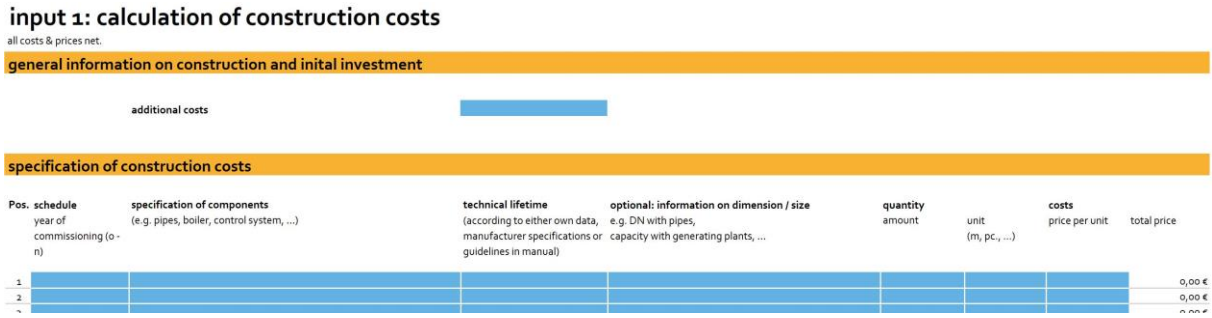

figure 3: input 1 - construction (own source, 2020)

1.3.3 input 2_operating and maintaining

operating and maintenance costs

figure 4 shows the required input for costs that occur durings the second and third life cycle stages, namely operating and maintaining, and after the initial investment / construction: costs for fuel or purchased heat, costs for maintenance, and general operating costs.

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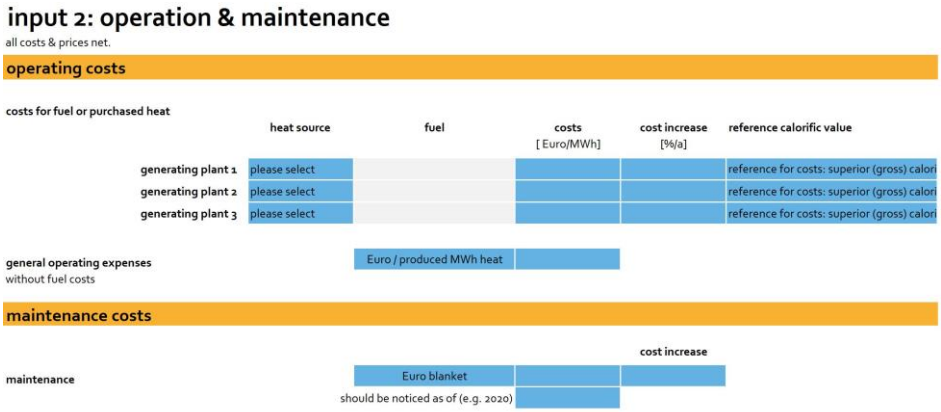

figure 4: input 2 - costs (own source, 2020)

The user can specify up to three different generating plants for DH. Via a dropdown menue in each cell, the user can select from a wide range of different types of generating plants or heat sources:

- Boiler: natural gas, biogas, biomethane, oil, brown coal, black coal, or wood/pellets/straw
- Cogeneration unit: natural gas, biogas, biomethane, oil, brown coal, black coal, or peat
- Heat pump: brine, air, natural gas, biogas, or biomethane
- Solar collector
- P2H
- External heat

By selecting one, two, or three different generating plants, the tool will automatically select the appropriate fuel. The user has to define the purchase price and the expected cost increase.

General operating expenses are all operating costs considering the project objective except of fuel costs, e.g. costs for labour, power, insurance, or imputed taxes.

Costs for maintenance can be defined by either lump sum or percentage of the investment. The expected cost increase and the point of time as of costs for maintenance should be noticed of has to be given by the user.

heat distribution and other system data

In input 4, more information on the DH system and its heat distribution is needed: the number of hours of full utilisation per year, the average heat losses and the increase in heat capacity that is expected thorugh the project over the whole life cycle. The tool will automatically choose the length of the life cycle by either user specification in input 0 or by the component with the longest technical lifetime, see input 1.

Besides that, the thermal efficiency of the generating plant(s) needs to be defined. If CHP is used, electrical efficiency is calculated automatically. If more than one generating plant is part of the investment, the share of plant 2 and/or 3 in the generation of heat needs to be defined.

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figure 5 shows these inputs.

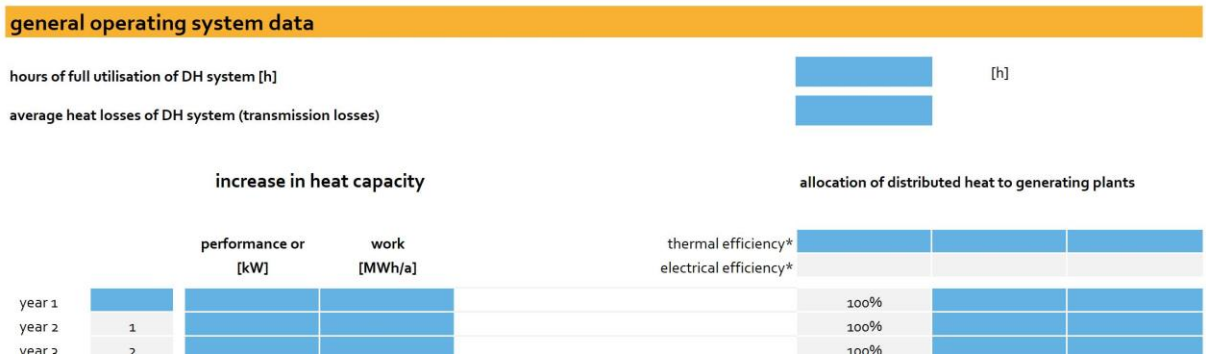

figure 5: input 4 - heat distribution and other system data (own source, 2020)

1.3.4 Input 3_end-of-life scenario

In this input, the user has the choice to either define the end-of life scenario by him-/herself or to let the tool calculate the residiual value of the whole system that remains after the end of the life cycle.

If the user wants to define the costs of the end-of-life scenario by him-/herself, the following informationfor each component from input 1 is needed:

- Costs for decommissioning
- Information whether component will be deconstructed or left on site and related costs
- If deconstruction will be happening, information on whether the component will be diposed of or recycled and related costs

figure 6 shows these inputs.

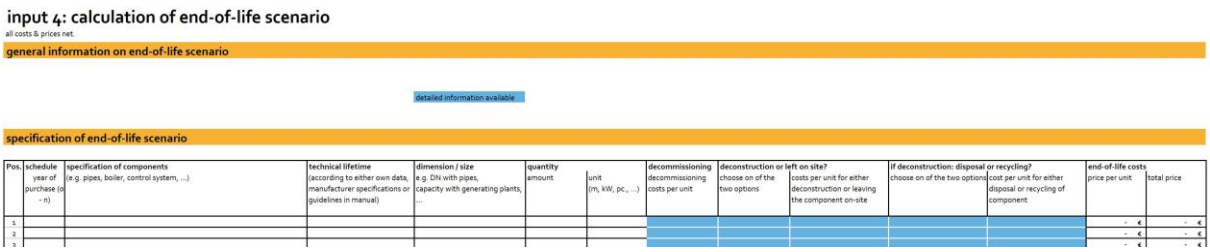

figure 6: input 4 - calculation of end-of-life scenario (own sources, 2020)

1.3.5 Additional calculations 1 and 2

In these two spreadsheets, no input is required. In "add. calc. 1", the tool will create an overview of reinvestments of all components over the whole life cycle. In "add. calc. 2", the costs for fuel, maintenance and general operating for the whole life cycle are calculated. All cells are visible so that the user is able to understand the calculation. As the spreadsheet is protected, no changes can be made here. Even if the protection of the workbook and of this spreadsheet is deactivated, it is recommended not to change any cells or references to ensure the proper functioning of the tool.

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1.3.6 Results

In this spreadsheet the following results are calculated:

- The costs of each life-cycle stage: construction, operation, maintenance, end-of-life (or residual value)
- Total life-cycle costs at the end of the life cycle
- Levelized costs of energy (LCOE)

These main results are shown in a yellow box, see figure 7.

construction costs (initial investment)	169.717 €
operation costs	891.206 €
maintenance costs	25.799 €
residual value	-128.971 €
total life cycle costs after 80 years	**957.751 €**
levelized costs of energy, i.e. heat (LCOE) per MWh	**14 €**

figure 7: main results, example (own resource, 2020)

Below, all costs / expenses over the entire life cycle are calculated and discounted to their present value.

1.3.7 Background data

In this spreadsheet, dropdown menues, references, and text blocks are listed which are used in the spreadsheets before. In here, the user is able to define his or her own types of generating plant, the corresponding fuel and its ratio of superior to inferior calorific value in blue cells, see figure 8.

dropdown menue	*reference*	*reference*	
type of generating plant	**corresponding fuel**	**conversion factor to inferior calorific value (Hi) according to DIN 18599-1 AH B**	
please select		fuel	HS/Hi
boiler_natural gas	natural gas	natural gas	1,11
boiler_biogas	biogas	biogas	1,11
boiler_biomethane	biomethane	biomethane	1,11
boiler_oil	oil	oil	1,06
boiler_wood/pellets/straw	wood	wood	1,08
boiler_brown coal	brown coal	electricity	1,00
boiler_black coal	black coal	solar energy	1,00
cogeneration unit_natural gas	natural gas	brown coal	1,07
cogeneration unit_biogas	biogas	black coal	1,04
cogeneration unit_biomethane	biomethane	-	1,00
cogeneration unit_oil	oil		
cogeneration unit_brown coal			
cogeneration unit_black coal			
cogeneration unit_peat			
heat pump_brine	electricity		
heat pump_air	electricity		
heat pump_natural gas	natural gas		
heat pump_biogas	biogas		
heat pump_biomethane	biomethane		
solar_collector	solar energy		
P2H_electricity	electricity		
external heat	-		

figure 8: possibilities of own setups in background data (own resource, 2020)

Although a wide range of different generating plants and fuels are already given, it is possible that new inventions may be used in future case studies. Therefore, the tool offers the option to set up new components. When defining new types of generating plants, a corresponding fuel and a conversion factor have to be given always.

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Otherwise, all non-blue cells are protected.

1.3.8 Version

This spreadsheet shows the current version of the tool. Although tested on one pilot measure, it is still possible that the tool might be adjusted in the future. The author may upload future versions of the tool without notice but will keep the change log up to date. Besides that, author and system requirements are given.

1.3.9 Deactivating and activating the workbook protection

There is no password needed to deactivate the protection of the workbook. To do so, the user has to carry out the following steps:

1. In Excel, go to the tab „File"
2. In "File", go to "Info", see figure 1. If protection is activated, it will be highlighted yellow. In this case, the option "protect workbook structure" and "protect current sheet" is activated, see figure 9. The latter will sum up all protected spread sheets.

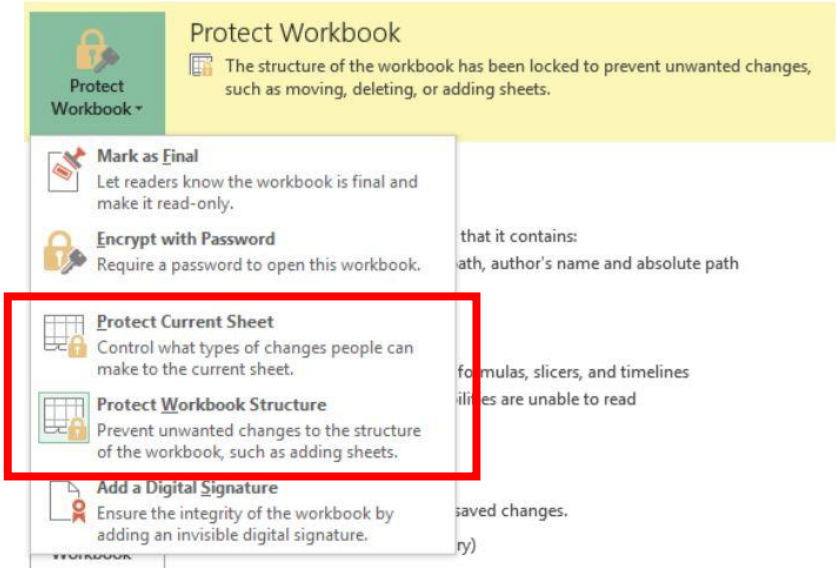

figure 9: activated protection in the tool (own source, 2020)

3. In order to deactivate the protection of a single spread sheet, click on "unprotect" behind each spread sheet.
4. In order to deactivate the protection of the whole file, click on "unprotect workbook structure".
5. After deleting protection, in order to protect either the workbook structure or a single spread sheet, click on either "protect workbook structure" or "protect current sheet".

However, it is recommended to keep it protected in order to guarantee the proper functioning of the tool. If the user deactivates the protection, the tool is used at the user's own risk.

2 Methodology

The tool is able to determine LCC and LCOE of a (LT)DH project.

The tool and its result can be used by the target groups mentioned in *1.2 Target groups* while planning (LT)DH measures. Also, it is supposed to support planning institutions in their decision making and collaboration with other stakeholders by analysing different system alternatives by means of their LCC and LCOE.

2.1 Calculation of life-cycle costs

Life-cycle costs (LCC) are the costs "of an asset or its part throughout its life cycle, while fulfilling the performance requirements" (ISO 15686-5, p. 2). defines life cycle as "consecutive and interlinked stages of the object under consideration [and] (...) it comprises all stages from construction, operation and maintenance to end-of-life, including decommissioning, deconstruction and disposal" (ISO 15686-5, p. 4).

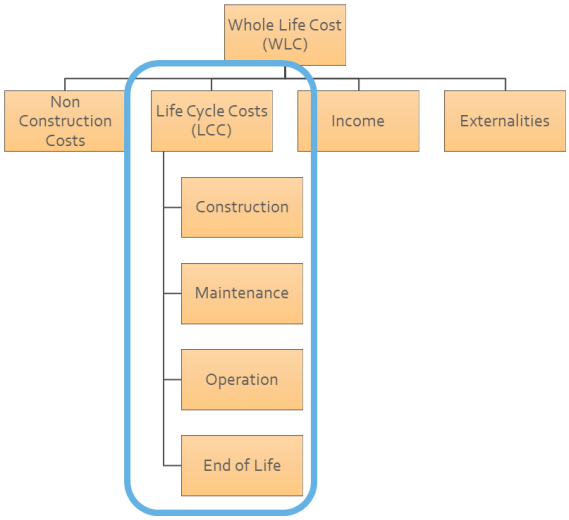

figure 10: stages of a life cycle (according to ISO 15686-5, p. 7)

Mathematically speaking, LCC are the net present value of the whole investment over the entire life cycle. Formula (1) shows how to determine this where the following shall be (Crundwell, 2008, p. 169):

- NPV (LCC) = net present value of life-cycle costs [€]
- n = life-cycle length [years]
- t = time index number, a certain year of the investment [w.d.]
- CF_t = cash flow in year t or in other words the difference between costs and incomes in year t [€]. Costs for construction, operating, maintenance and for decommissioning, deconstruction and disposal count in this MO as positive cash flows whereas the residual value counts as a negative cash flow.

- k = discount rate [%]

$$NPV(LCC) = \sum_{t=0}^{n} \frac{CF_t}{(1+k)^t} \quad (1)$$

2.2 Calculating levelized costs of energy

Mean levelized costs of energy (LCOE), or sometimes called Levelized energy costs (LEC) (Konstantin and Konstantin, 2018, p. 143) represent the costs per MWh net heat consumption. Therefor, the net present value of all LCC at the end of a life cycle are divided by the total amount of heat output over the whole life cycle. Formula *(2)* shows how to determine this where the following shall be:

- LCOE = levelized costs of energy [€/MWh]
- NPV (LCC) = net present value of life-cycle costs [€], see formula *(1)*
- n = life-cycle length [years]
- t = time index number, a certain year of the investment [w.d.]

$$LCOE = \frac{NPV(LCC)}{\sum_{t=0}^{n} Q_t} \quad (2)$$

2.3 Comparing different scenarios

If different scenarios shall be compared with each other, the tool has to be filled out and saved for each one of them. This can be the case if non-LTDH projects shall be compared with LTDH projects, or different system alternatives are considered, just to name a few.

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3 Prerequisites

In order to use the tool properly and to guarantee correct results, the following prerequsites have to be known to the user prior to using the tool.

3.1 Object of consideration and construction

First, the project objective has to be clear to the user in order to define the object of consideration.

3.1.1 Accounting boundaries

The accounting boundaries have to include everything that is needed to fullfill the project objective. However, this tool only considers investments in whole systems which consist of components that are commonly owned by those companies that invest in those components and own them. figure 11 shows the largest accounting boundaries possible with this tool.

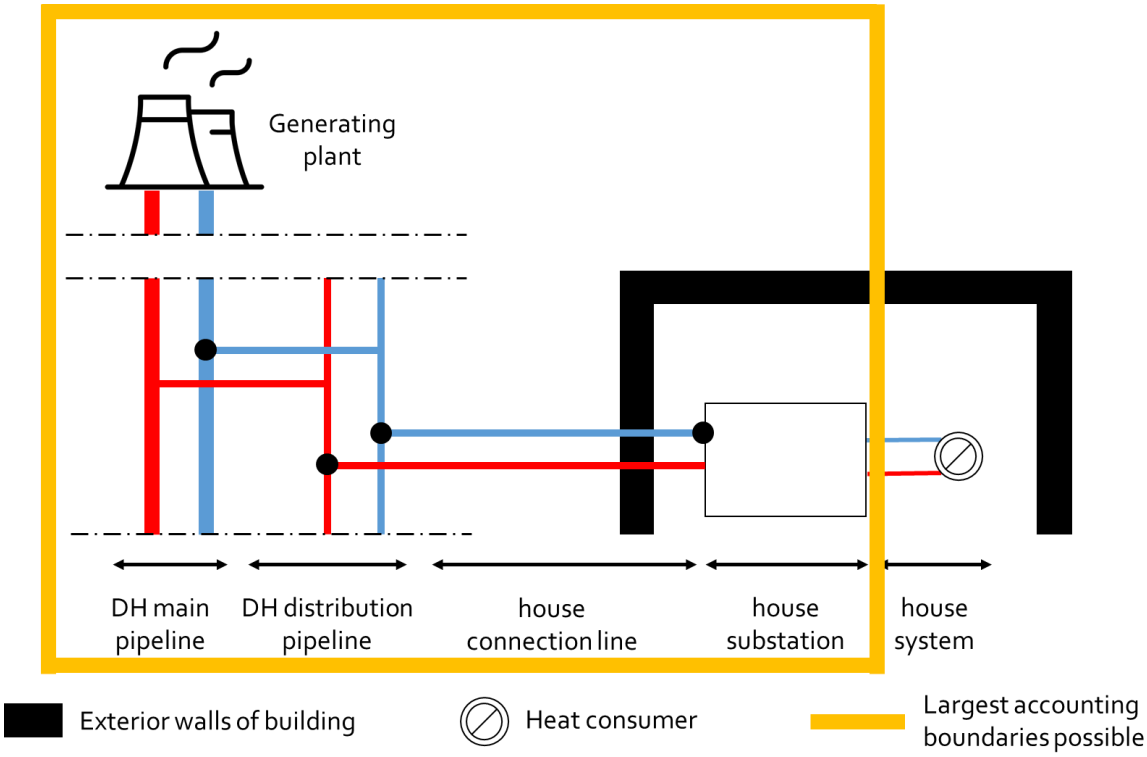

figure 11: largest accounting boundaries possible for the tool (own source following BAFA, 2017, p. 5 and The noun project, 2019)

Everything from generating plant to house substation can be considered with the tool, as long as it is part of the investment and not owned by the house owner. The house substation is seen as a part of the grid if they are owned by the DH-supplier. If they are not owned by the DH supplier, the accounting boundaries go up to the customer's property line.

3.1.2 Discount rate

The discount rate is used for calculating the NPV of all cash flows. It discounts the cash flow of each

year to its present value (year 0 of the project). The choice of the right discount rate is important as this has an impact of all cash flows, the NPV and, in the end, on the amount of a funding gap. In general, the following can be said: the higher the risks of a project, the higher the discount rate should be but this demands higher returns as higher discount rates reduce future cash flows more (Frederiksen and Werner, 2014, p. 504). For public investment operations co-financed by European Structural- and Investments Funds (ESI), a discount rate of 4 % is given but exceptions may be made (((EU) No 480/2014), Art. 19). Also, the longer the life cycle of a project, the higher the discount rate can be because risks may be harder to be foreseen.

The user is responsible to consider an appropriate discount rate. On the basis of the information mentioned above, the following recommendation for a discount rate x is given

- 0 % < x > 4 %: for small projects with low costs, low revenues and low risks. The value 0 will not work.
- x = 4 %: for projects that are co-financed by European Structural- and Investments Funds (ESI) or where risks cannot be foreseen.
- x > 4 %: for projects with high costs and revenues and high risks.

3.1.3 Life-cycle length

In some cases, different alternatives may be compared with each other by a certain life-cycle length. In LCCA, this is a legitimate way of analysing more than one alternative. However, life-cycle length might not be known to the user in all cases. In this case, the tool will automatically consider the technical lifetime of the component with the longest technical lifetime as the life cycle length. When comparing different alternatives with each other, this life cycle length has to be used in all other alternatives as well.

3.1.4 Additional costs

In some cases, additional costs may occur for the construction stage. In this case, they have to be typed in by the user. This input is optional though.

3.1.5 Construction costs

Construction costs are the costs that are necessary to build the project objective. A detailed list of all costs parameters is given in *6.2 Although partially fictional, the numbers* used in this example of calculation are based on own experience values and do not differ from real values that much. Having that said, this comparison shows that LCCA is an important method and tool when planning big infrastructure projects such as (LT)DH projects.

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Catalogue of cost parameters. The user can either use this catalogue as a guideline or, if further planning has already been done, use a quote. Construction costs have to be given in € and without VAT.

3.1.6 Technical lifetime

For each component, the technical, not the economical, lifetime has to be known by the user. This can be either taken from manufacturer's specifications or from appendix 6.3 where typical technical lifetimes for major (LT)DH components are listed.

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3.2 Costs for operating and maintaining

3.2.1 Operating costs

The following information on operating the planned system and the incurring costs needs to be known by the user:

- Type of generating plant and corresponding fuel
- Fuel costs in €/MWh and their reference to either superior (H_S) or inferior (H_i) calorific value[1], without VAT
- Expected cost increase for fuel costs in %/a
- General operating costs (no fuel costs included), either as a lump sum in €/a or as percentage of the expected revenues in %, without VAT

3.2.2 Costs for maintenance

The following information on maintaining the planned system and the incurring costs needs to be known by the user:

- Costs for maintenance, either as a lump sum in €/a or as percentage of the investment in %, without VAT
- Expected cost increase in %/a

3.2.3 Heat distribution

The following input concerning the heat disitrbution system of the project is needed:

- Hours of full utilization of the DH system in h/a
- Average heat losses of the DH system (transmission losses) in %

3.2.4 Heat capacity

The tool allows the economical considertation of the project over a period of 20 years. During this time, it is possible to some projects to undergo either an increase or a decrease in installed heat capacity. For example, in year 1, a boiler with 200 kW is installed. Two years later, in year 3, another boiler with 150 kW is installed. This generates an increase in the heat capacity which has a direct influence on the operating costs. Therefor, the user has to know and define any in- or decrease in installed heat capacity per year:

- Year of installation or deinstallation of a generating plant or heat source
- Performance in kW or amount of generated heat as work in MWh/a

If performance as well as work is given by the user, the tool will automatically give priority to work.

[1] Fuel costs in €/Mwh relate to the calorific value of the fuel which describes the amount of energy that is released during its complete combustion. The costs can relate to either inferior or superior calorific value. The latter considers latent heat from condensing water vapour in the flue gas as well. Normally, the specification of fuel costs gives information on which calorific value the costs relate to.

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3.2.5 Allocation of distributed heat to generating plants

The share in work for each generating plant or heat source of the planned system needs to be defined by giving the follwing information:

- Thermal efficiency in %, e.g. $\eta_{thermal}$ (CHP) = 60 %. If heat pumps are used, the COP[2] or SPF[3] has to be given in %, e.g. if the COP = 4, the input in the tool will be 400 % (same procedure with SPF).
- If CHP technology is used, the electrical efficiency of the plant has to be given as well (same procedure as with thermal efficiency).
- If more than one generating plant is planned, the share in work for each generating plant or heat source has to be defined. In total, all shares sum up to 100 % (the total amount of work produced).

3.3 Costs occurring during end-of-life scenario

If the end-of-life scenario is not defined by the residual value of the analysed system, the tool will calculate costs that will occur for:

- Decommissioning
- Deconstruction or leaving on site
- If deconstructed: disposal or recycling

Of all components. The user has to type in the costs for these end-of-life steps. However, this life-cycle stage lies far in the future and it may be hard to foresee these costs. There are no general values given for these cost parameters as they might vary from district to district in each country (LEGEP Software GmbH, 2020). In this case, information from special companies working in the field of de-commissioning, deconstruction, disposal, or recycling of technical infrastructure might know cost values for the considered components.

[2] COP = coefficient of performance, given by manufacturer.
[3] SPF = seasonal performance factor. Ratio of amount of generated heat to the total amount of electrical energy needed for running the heat pump.

4 Results

At the top of the spreadsheet "results", an info box gives information on:

- The costs of each life-cycle stage: construction, operation, maintenance, end-of-life (or residual value)
- Total life-cycle costs at the end of the life cycle
- Levelized costs of energy (LCOE)

Intermediate results on costs as well as their present values are calculated below the infobox, see figure 12.

calculation of life cycle costs

construction costs (initial investment)	169.717 €
operation costs	891.206 €
maintenance costs	25.799 €
end of life costs	0 €
total life cycle costs after 80 years	**1.086.722 €**
levelized costs of energy, i.e. heat (LCOE) per MWh	**16 €**

	construction		maintenance		operating				end of life		result	present value
year	non-discounted construction costs	discounted construction costs	non-discounted maintenance costs	discounted maintenance costs	operating costs: general	operating costs: fuel costs	non-discounted operating costs	discounted operating costs	non-discounted detailed end-of-life costs	discounted detailed end-of-life costs	sum	present value of sum
	€	€	€	€	€	€	€	€	€		€	€
0 2020	162.000	162.000									162.000	162.000
1 2021	8.257	7.717	500	467	3.905	42.712	46.617	43.567	0	0	55.374	51.752
2 2022	0	0	1.010	882	3.905	43.566	47.471	41.463	0	0	48.481	42.346
3 2023	0	0	1.010	824	3.905	44.438	48.343	39.462	0	0	49.353	40.287

figure 12:example of info box in spreadsheet "results" (own source, 201)

The results in the infobox represent the main results of the LCCA performed in the spreadsheets before and can be compared with the results of other comparable system alternatives.

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5 Glossary

Discount rate: interest rate used in discounted cash flow techniques to calculate the present value of future cash flows.

Net present value: sum of all cash flows (negative and positive) discounted to their present value

Levelized Costs of Energy: costs per MWh net heat consumption

Life-cycle costs: costs "of an asset or its part throughout its life cycle, while fulfilling the performance requirements" (ISO 15686-5, p. 2).

Life-cycle cost analysis: "methodology for systematic economic evaluation of life-cycle costs over a period of analysis, as defined in the agreed scope. (...) [it] can address a period of analysis that covers the entire life cycle or (a) selected stage(s) or periods of interest thereof" (ISO 15686-5, p. 2).

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6 Appendix

6.1 Example of calculation: Gulbene pilot measure

As a guidance, the tool is used on a pilot measure from the LowTEMP project and shown in this section. Information is taken from a questionnaire that Gulbene municipality has answered during the testing phase of the tool from GoA 5.1 of the LowTEMP project. Unless specified differently, the following information is gathered from this questionnaire (Kalmane and Kalniņš, 2019).

6.1.1 Description of the pilot measure

In Gulbene, Latvia, a local heating system was installed in 2019. It provides heat for three municipal buildings, generated by a biomass boiler and distributed in a small local heat grid. Besides that, a smart metering system within the three existing buildings has been installed in order to allow the residents to analyse their heat consumption. (atene KOM GmbH and Thermopolis Ltd., 2019)

6.1.2 Input 0: general input

Accounting boundaries

First, accounting boundaries are defined. According to the description of the pilot measure above, the installation of a local heating system is the goal of the project. Therefore, the following components can be considered as necessary for achieving this goal:

- Biomass boiler
- Small local heat grid
- Control system

The smart metering system is not considered as necessary for achieving the goal of the project, namely the installation of a local heating system, as it would run without the smart metering system as well. Besides that, this component falls outside the accounting boundaries according to figure 11.

Discount rate

The discount rate is set to 7 % as it is not possible to foresee any future risks at this moment.

Life-cycle length

The length of the life-cycle for this project is unknow and therefor not defined manually.

6.1.3 Input 1: construction costs

For this, the project partner from Gulbene provided a compilation of all components and services that were necessary to achieve the project objective, see table 1. However, some additional information was made up for this example of calculation as well.

Additional costs

Additional costs were made up because costs for designing und supervision exist and amount to 8 %.

table 1: construction costs overview for the example of calculation from Gulbene

Component	Year of commissioning	Technical lifetime (see appendix 6.3)	quantity	Price excl. VAT [€] (partially according to Kalmane, 2019)
boiler	0	25	1 pc	50,000.00
pipes	0	80	500 m	100,000.00
Control system	1	50	1 pc	7,645.51

6.1.4 Input 2: costs for operating and maintaining

Operating costs

In this pilot measure, the biomass boiler is fired with wood pellets which cost 40.00 €/MWh[4]. Their price is expected to rise by 2 % per year.

Besides that, general operating costs are set to 3 905.05 € per year.

Costs for maintenance

Costs for maintaining are set to 500 € per year and should start in 2019. They are expected to rise by 2 % per year.

Heat distribution and other system data

The local DH system is expected to run 4 258.60 h per year in full utilisation mode. The average heat losses of the system are estimated at 5 %.

The boiler is installed and put into operation at once at right at the beginning. Therefore, the increase in heat capacity starts with 199 $kW_{thermal}$ in year 1. Its thermal efficiency amounts to 90 %.

6.1.5 End-of-life scenario

In this calculation of example, the residual value of the system at the end of the life cycle shall be considered due to unkown costs for decommissioning, deconstruction and disposal / recycling of each component.

[4] This price refers tot he superior calorific value of the wood pellets.

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6.1.6 Results

The following results are calculated.

construction costs (initial investment)	169.717 €
operation costs	891.206 €
maintenance costs	25.799 €
residual value	-128.971 €
total life cycle costs after 80 years	**957.751 €**
levelized costs of energy, i.e. heat (LCOE) per MWh	**14 €**

figure 13: results for Gulbene's pilot measure (own source, 2020)

According to figure 13, the life cycle of this example of calculation is 80 years long. During this time, the life-cycle costs amount to 957,751 €. The LCOE amount to 14 €/MWh.

6.1.7 Non-LTDH system alternative

For purposes of illustration only, a fictious non-LTDH system alternative is made up and compared with the example of calculation from Gulbene. The system alternative is defined as follows:

Accounting boundaries

- Brown coal boiler
- Small local heat grid
- Control system

Discount rate

The discount rate is set to 7 % as it is not possible to foresee any future risks at this moment.

Life-cycle length

The length of the life cycle for this project is 80 years due to the results of the Gulbene pilot case.

Additional and construction costs

Additional costs were made up because costs for designing und supervision exist and amount to 8 %.

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table 2: construction costs overview of the system alternative

Component	Year of commissioning	Technical lifetime (see appendix ...)	quantity	Price excl. VAT [€]
boiler	0	25	1 pc	30,000.00
pipes	0	50	500 m	100,000.00
Control system	1	50	1 pc	7,645.51

Operating costs

In this pilot measure, the brown coal boiler is fired with wood pellets which cost 70.00 €/MWh. Their price is expected to rise by 2 % per year.

Besides that, general operating costs are set to 3 905.05 € per year.

Costs for maintenance

Costs for maintaining are set to 500 € per year and should start in 2019. They are expected to rise by 2 % per year.

Heat distribution and other system data

The local DH system is expected to run 4 258.60 h per year in full utilisation mode. The average heat losses of the system are estimated at 5 %.

The boiler is installed and put into operation at once at right at the beginning. Therefore, the increase in heat capacity starts with 199 $kW_{thermal}$ in year 1. Its thermal efficiency amounts to 90 %.

End-of-life scenario

In this calculation of example, the residual value of the system at the end of the life cycle shall be considered due to unkown costs for decommissioning, deconstruction and disposal / recycling of each component.

Results

The following results are calculated.

construction costs (initial investment)	148.117 €
operation costs	1.504.416 €
maintenance costs	24.258 €
residual value	-22.818 €
total life cycle costs after 80 years	**1.653.973 €**
levelized costs of energy, i.e. heat (LCOE) per MWh	**24 €**

figure 14: results for the non-LTDH system alternative (own source, 2020)

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According tofigure 14, the life cycle of this example of calculation is 80 years long. During this time, the life-cycle costs amount to 1,653,973 €. The LCOE amount to 24 €/MWh.

This comparison shows that lower initial costs, i.e. construction costs, do not imply lower LCC, as the operation costs have a bigger impact on the results in this case. Although partially fictional, the numbers used in this example of calculation are based on own experience values and do not differ from real values that much. Having that said, this comparison shows that LCCA is an important method and tool when planning big infrastructure projects such as (LT)DH projects.

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6.2 Catalogue of cost parameters

The following catalogue gives information on what kind of costs the user can consider with this tool. The parameters are given in form of a list and without any specific values as these vary from country to country or sometimes even from region to region.

The catalogue works as a guideline. However, the author of this manual does not give any guarantee for completenes. The user of the tool has to check relevant standards and the state of the art in his or her country as well.

In general, all costs that are necessary to achieve the project objective and lie inside the accounting boundaries shown in figure 11 can be considered here. The following cost categories exist:

- Additional and construction costs (input 1)
- Costs for operating and maintaining (input 2)

Additional and construction costs

table 3 shows cost parameters that are based on groups of cost types defined in the German norm DIN 276: building costs, unless specified differently. Although used in structural engineering, some values of this norm can be taken as a guideline for planning DH projects.

table 3: investment costs parameters according to DIN 276, table 1

parameter	explanation
Building plot	Costs incurring for the plot provided for the object of consideration.
Plot price (value)	This parameter needs separate consideration as a plot usually does not diminish in value over a period of 20 years. Hence, this parameter needs to be considered in year 20. However, the tool is not able to consider investments in different years as it sums up the whole investment in year 0 and takes the time value of money into account. At this stage of development, the user needs to add the plot price manually in year 20 in a separate calculation.
Incidental costs of ownership	Costs that are associated with the purchase and ownership of the plot
Third party rights	Costs incurring for repealing third-party rights in order to dispose freely over the plot
Preparatory measures	Preparatory measures in order to carry out construction work on the plot
Preparation	Preparation of the plot

Provision of public services	Costs for buying the public service area Costs for establishing or adapting technical facilities of collective use Costs for establishing or developing areas for public traffic, green spaces, and other open spaces for public use
Provision of non-public services	Costs for traffic areas and technical facilities for non-public use
Compensation measures and compensatory levies	Measures and levies that arise one time and additionaly to provision costs due to public law regulation and by reason of the planned project
Temporary meausres	Temporary measures of structural or organisational nature maintaining utilisation and operation of the object of consideration during construction period
Building - construction	Construction work and supply needed for the completion of the building without technical installations. If conversion or modernization of the building is done, costs for partially demolishing, repairing, safety work, and dismantling are also included.
Pit / earthmoving	Work on soil and topsoil, earthmoving, pits, dams, cuttings, ramparts, slope stabilization
Foundation, base	Measures for foundation and base of the project of consideration
Exterior walls, vertical exterior construction	Bearing and non-load bearing vertical constructions that are located on the exterior face of the building
Interior walls, vertical interior construction	Bearing and non-load bearing vertical construc-tions that are located inside the building
Ceilings & floors, horizontal constructions	Bearing and non-load bearing constructions for ceilings, stairs, ramps, and other horizontal constructions
roofs	Bearing and non-load bearing constructions for flat and inclined roofs and other horizontal constructions that close the building to the top
Infrastructural installations	Independent constructions for infrastructural installations for traffic, energy supply and waste disposal
Structural installations	Installations that are directly attached to the building but

	without use-specific installations and process-related systems (see below)
Other measures related to construction	Constructions and overarching measures that cannot be allocated to one of the parameters named under "building - construction" or "building - technical installations", e.g. site set-up, scaffold, disposal of materials.
Building - technical installations	Construction work and supply needed for the completion of technical installations of the building. If conversion or modernization is done, costs for partially demolishing, repairing, safety work, and dismantling are also included.
Waste water, water, and gas installations	Primarily sanitary installations
Heat supply installations	Generating plants, distribution grids, room heating, and heating systems for traffic spaces
Ventilation and air conditioning installations	Installations with and without ventilation function
Electrical installations	Electrical installations for power current including fire resistant grommets
Installtions for telecommunication, safety-related installations, and information technology systems	Including necessary terminal blocks, cables, circuits, and fire resistant grommets
Installations for transportation	Elevators, escalators, transport and crane systems, façade lifts, and hydraulic systems
Use-specific installations and process-related systems	Installations that are directly attached to the building and fulfil a specific use, e.g. for kitchens, laundries, laboratories
Building and plant automation	monitoring, controlling, and optimising installations to automatically execute technical processes
Other measures for technical installations	Technical installations and overarching measures that cannot be allocated to one of the parameters named under "building - technical installations", e.g. site set-up, scaffold, disposal of materials.
Additional costs / expenses	Services besides construction works and supplies that are necessary for the project. If additional costs are not known to this level of detail, a fixed percentage of 12 % of costs for materials and construction

	can be used instead (AGFW, 2015, p. 10).
Principal's tasks	Duties that are performed by the owner or assigned to someone else
Preparation of building planning	Examinations, valuation, services for urban development or landscaping, and competitions
Building planning	Planning and construction supervision
Specialist planning	Planning and construction supervision
General additional building costs	Costs for expert opinions, permits, inspections, operating costs, sampling, provisionally operating, and insurances
Other additional building costs	As-built documentation

Costs for operating and maintaining

table 4 shows parameters for costs incurred during operating and maintaining the object of consideration.

table 4: parameters for operating and maintainance costs

Parameter	explanation
Operating costs	
Fuel costs	Costs for fuel [€/MWh]. Referring to either superior (gross) or inferior (net) calorific value of the considered fuel.
General operating expenses	Costs for operating the object of consideration, including costs for electricity (not to be understood as fuel), insurance, taxes, and staff costs. Can be given as a lump sum or as percentage of annual revenues.
Costs for maintainance	
Maintenance	Costs for keeping the object of consideration running. Can be given as a lump sum or as percentage of the investment.

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6.3 Technical lifetimes of main district heating components

table 5: technical lifetimes of main DH components

Component	Technical lifetime	Source
Generating plant	10-30 years, depending on technology	(Danish Energy Agency and Energinet, 2016)
Station for pumping & pressure maintenance	No values found	
Grid	> 30 years, depending on material	(AGFW, 2018)
House connection	No values found	
House substation	~ 30 years	(VDI 2067, p. 23)
Whole systems in general	40-50 years	(Danish Energy Agency, 2017, p. 10)

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