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Life Cycle Cost Analysis

GoA 4.3

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List of abbreviations

BSR	Baltic Sea Region
EC	European Commission
EU	European Union
GoA	Group of Activity
DH	District heating
MO	Main output
LCC	Life-cycle cost
LCOE	Levelized costs of energy
LCCA	Life-cycle cost analysis
LTDH	Low-temperature district heating
NPV	Net present value
WP	Work package

List of symbols

a	annuity factor [w.d.]
A	annual costs for operating & maintaining the DH system at current prices [€]
CF_t	cash flow in year t [€]
I	Investment costs [€]
k	discount rate [%]
n	lifespan of the investment of the measure [years]
NPV	present value or net present value of the project [€]
Q_t	Heat output in year t [MWh]
Q_{useful}	useful heat [MWh]
t	time index number, a certain year of the investment [w.d.]

Abstract

This group of activity of the LowTEMP project analyzes how life-cycle costs of (low-temperature) district heating projects can be determined. The objective is to develop a calculation tool that is able to determine life-cycle costs including costs for contruction, operating, maintenance and a end-of-life scenario. Another aim is that it can be used by future stakeholders such as public authorities, heat suppliers, operators of DH networks, investors as well as planners and engineers. In addition to fundamental knowledge taken from desk research, knowledge from other groups of activities of the LowTEMP project is considered. In order to verify the comprehensibility, user-friendliness and functionality of the tool, it is tested on one pilot measure. As a result, an excel based tool is developed that is calculating life-cycle costs and levelized costs of energy based on the net present value of a project. Up to three different types of generating plants can be chosen out of a variety of different technologies. A manual provides the user with information on how to use the tool and what information is needed in order to do so. It includes a catalogue with possible cost parameters as a guidance. However, the results of the tool do not imply to be true values as it is mainly made for comparing different system alternatives and helping target groups in their decision making. All costs are considered over a period of max. 100 years.

Keywords: low-temperature district heating, life cycle cost analysis, planning tool

1 Introduction

1.1 Problem

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 (LTDH) system can be compared in its cost-effectiveness considering all occuring costs.

In view of the above, LCCA can be a tool to promote LTDH and environmental friendly solutions by comparing their life cycle costs with the ones of conventional district heating (DH) systems.

1.2 Aim of the work

The main output of this goal of activity (GoA) will consist of two parts: First, an excel based LCCA tool for LTDH systems will be developed. With this, users will be able to calculate life cycle costs of planned LTDH systems.

Second, a manual including a check list will be developed. It will give information on:

- How to calculate life cycle costs and where to get needed information.
- How to interpret the results of the LCCA.
- How to compare LTDH with non-LTDH or decentralized systems in terms of their life cycle costs in order to choose best longterm solution.

The outputs will be used by LowTEMP partners first, e.g. within the development of pilot energy strategies. Broader target groups are public authorities, heat suppliers, operators of DH networks, investors as well as planners and engineers as it shall show them, that there will be a payback for the implementation of LTDH systems in a long-term perspective. By this, their attitude towards LTDH shall be affected positively. They will use the output for planning, calculating, and operating LTDH systems.

1.3 Tasks

Different methods and research publications on how to carry out LCCA of technical systems already exist. Therefor, regulations and conventional calculating methods for life cycle costs will be researched and checked regarding their transferability to the project partners' regions. Suitable methods will be adjusted and further developed in order to create a LCCA method for LTDH.

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After that, a cost breakdown structure will be created including quantitative parameters and characteristic cost values from all Baltic Sea Region (BSR) partner countries. Regarding existing district heating systems, information on the following topics are necessary: investment costs, commissioning costs, costs for operating and maintaining, production downtime costs, costs for environment protection, and disposal costs. This cost breakdown strucuture will be integrated into the the LCCA method for LTDH.

The developed calculation method will be tested in one pilot project that is connected to the activities in work package (WP) 3: a feasibility study for one municipality (e.g. Gulbene, Latvia) will be developed to prove the method under realistic conditions.

2 Legal framework and guidelines for life cycle cost analysis

2.1 Legal framework for life cycle cost analysis

There is no obligatory legal framework available for determining life cycle costs and performing life cycle costs analysis specifically of DH systems on international level, that goes beyond EU level.

Therefore, the following deals with the legal framework on EU level.

On EU level, there is no obligatory legal framework for determining life cycle costs and performing life cycle costs analysis of DH systems specifically. However, *Directive 2014/24/EU on public procurement and repealing Directive 2004/18/EC* and *Directive 2014/25/EU on procurement by entities operating in the water, energy, transport and postal services sectors and repealing Directive 2004/17/EC* define costs that shall be included in LCCA and refer to cases where LCCA is mandatory during public procurement procedures (Directive 2014/24/EU, Art. 68; Directive 2014/25/EU, Art. 83). So far, LCCA is mandatory only during public procurement procedures for clean and energy-efficient road transport vehicles (Directive 2014/24/EU, Annex XIII; Directive 2014/25/EU, Annex XV).

The usage of LCCA in public procurement procedurs for (LT)DH projects is therefor voluntary. However, "Where contracting entities assess the costs using a life- cycle costing approach, they shall indicate in the procurement documents the data to be provided by the tenderers and the method which the contracting entity will use to determine the life-cycle costs on the basis of those data." (Directive 2014/25/EU, Art. 83 (2)).

2.2 Guidelines for life cycle cost analysis

The guideline *ISO 15686-5:2017 Buildings and constructed assets - Service life planning - Part 5: Life-cycle costing* "provides requirements and guidelines for performing life-cycle cost [...] analyses of buildings and constructed assets and their parts, whether new or existing" (ISO 15686-5, p. 1). It represents the current state of knowledge and technology for performing LCCA and is valid on international level, beyond EU level. However, the compliance with this guideline is not mandatory when performing LCCA.

In this main output, the guideline ISO 15686-5 is used in order to use the recommended nomenclature and to follow other standards that are defined in this guideline.

3 Current state of technology and knowledge

This chapter shows the current state of technology and knowledge on LCCA and the financial framework of DH and LTDH projects. It takes information into account that is gathered from literature during desk research and information that was already gathered in other work packages of the LowTEMP project in the form of questionnaires.

3.1 Definition of terms

There are various definitions of the keywords used in this work. To avoid any misunderstandings, these keywords are defined and described in this section. Their definitions apply to the studies which are done in section 3.4 Financial framework of District Heating systems in the Baltic Sea Region.

3.1.1 4th generation of district heat and low-temperature district heat

The aim of the LowTEMP project is to "promote the installation of so-called 4th generation district heating networks" (atene KOM GmbH and Thermopolis Ltd., 2018). According to Thorsen et al., 4th generation district heating networks have flow temperatures up to max. 70 °C and return flow temperatures around 25 °C, compare with figure 1.

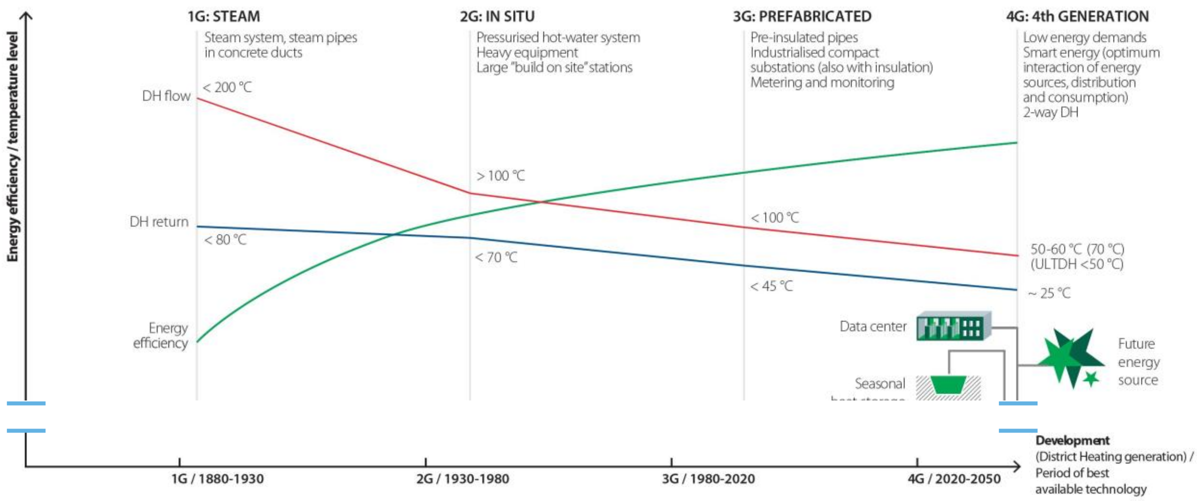

figure 1: definition of 4th generation DH networks depending on temperature level (section from Thorsen et al., 2018, p. 2)

Other definitions categorise 4th generation DH systems into temperature levels of 20 – 95 °C (ifeu, 2017, p. 21). The LowTEMP partnership and thus this work recognize a temperature level of 50 – 70 °C (atene KOM GmbH and Thermopolis Ltd., 2019) as low temperature which complies with the other definitions mentioned.

3.1.2 Life cycle

The guideline ISO 15686-5:2017 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).

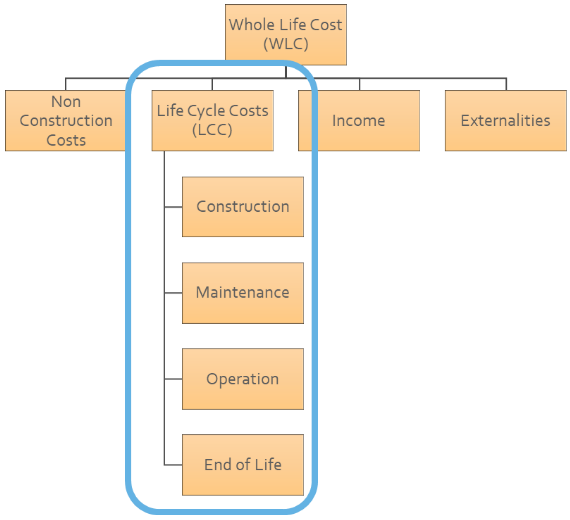

figure 2: stages of a life cycle (according to ISO 15686-5, p. 7)

3.1.3 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).

3.1.4 Life-cycle cost analysis

The "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) is called life-cycle costing. Sometimes, this is also called life-cycle cost analysis (LCCA) (National Institute of Building Sciences, 2020) and this MO will follow this description.

LCCA considers "all the costs that will be incurred during the lifetime of the product, work or service:

- Purchase price and all associated costs (delivery, installation, insurance, etc.)
- Operating costs, including energy, fuel and water use, spares, and maintenance
- End-of-life costs (such as decommissioning or disposal) or residual value (i.e. revenue from sale of product)

LCC[A] may also include the cost of externalities (such as greenhouse gas emissions) (…)" (European Commission).

3.2 Life-cycle cost analysis

This chapter covers the current state of knowledge and technology on LCCA concerning (LT)DH projects and in general.

3.2.1 Necessity of life-cycle cost analysis

In the energy sector, financial decisions are usually made based on the least cost approach. That means that investments with the lowest levelized costs of energy (LCOE) are realized that fulfil the project objective. (Konstantin and Konstantin, 2018a, p. 143)

LCOE represent the costs of capital and for operating per MWh net heat consumption. This shows that financial decisions do not include life-cycle stages such as an end-of-life scnearios. Financial impacts due to this last stage of a life cycle which lies far in the future remain unkown if not analysed. LCCA is a method that can include these kind of costs as well but this approach comes with the need for knowledge on not just costs for capital and operating, but also on maintaining and the end-of-life scenario.

3.2.2 Life cycle of district heating and low-temperature district heating systems

The life cycle of a (LT)DH system consists of four stages, as already seen in figure 2:

- The construction of the system
- The operation of the system
- The maintenance of the system
- The end of life-scenario of the system (post-use), including decommissioning, deconstruction, disposal or recycling of components

Therefor, the length of a life cycle is determined by how long a system is running. This is defined by the technical lifetime of the components involved in the system. A (LT)DH system consists of the following components (Konstantin and Konstantin, 2018a, p. 1):

- generating plant
- station for pumping & pressure maintenance
- grid
- house connection
- house substation
- in-house distribution system

However, not all of these components are suitable for consideration in LCCA due to the following: house substations (in some cases) and in-house distribution systems differ from the other main compnents by whom they are bought and owned namely house owners or DH consumers. The other compnents, generating plant, stations for pumping & pressure maintenance, grid, house connection and, in some cases, house substation, are commonly owned by those companies that invest in those components and own them. LCCA is a method for economic evaluation of life-cycle costs and therefor is mainly used by those target groups who rely on these results for future planning and are the target groups of this MO, e.g. public authorities, heat suppliers, operators of DH networks, investors as well as planners and engineers. This is why for this MO, accounting boundaries are necessary in order to define, which components are to be considered.

The accounting boundaries have to include everything that is needed to fullfill the project objective. figure 3 shows all the necessary components, including:

- generating plant
- station for pumping & pressure maintenance
- grid
- house connection
- house substation (if not owned by the DH consumer)

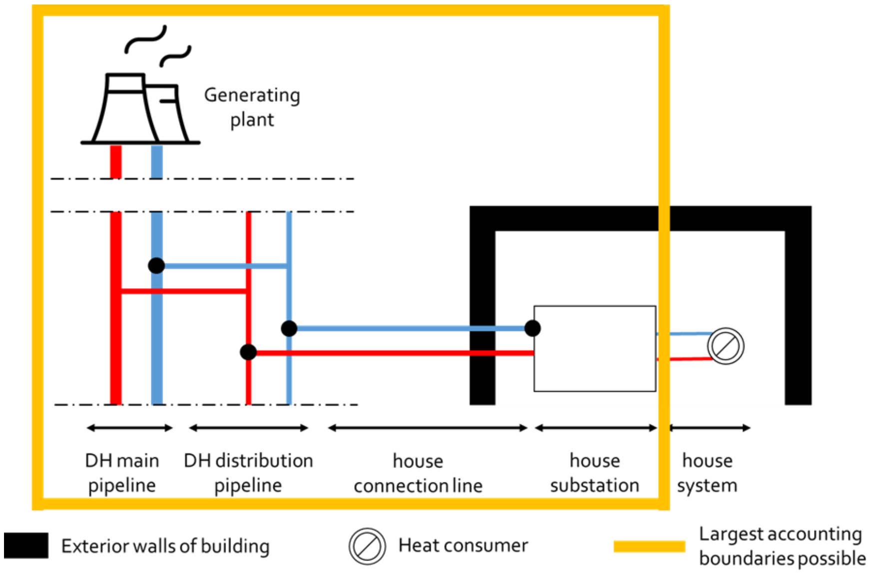

figure 3: largest accounting boundaries possible (own source following BAFA, 2017, p. 5 and Ostrovsky, 2019)

For these five main components, the following technical lifetimes can be defined, see table 1.

table 1: 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)

3.2.3 Calculation methods for life-cycle cost analysis

Net present value

When cash flows occur to different points in time, e.g. present and future cash flows, "discounting is the menchanism used to bring those costs to a common base date" (ISO 15686-5, p. 17). For LCCA, the guideline ISO 15686-5:2017 recommends using the discounting method net present value (NPV) for discounting the cash flows of an investment.

The net present value (NPV) "is the sum of all the cash flows (incomes and costs) discounted to the present using the time value of money. If the NPV is greater than zero, it is expected that value will be created for the investor. If it is less than zero, it is expected that value will be destroyed for the investor" (Crundwell, 2008, pp. 168–169). It is an absolute measure. Formula (1) shows how to determine the NPV of an investment where the following shall be (Crundwell, 2008, p. 169):

- NPV = net present value [€]
- n = lifespan of the investment of the measure [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 [€]
- k = discount rate [%]

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

Levelized costs of energy

Mean levelized costs of energy, or sometimes called Levelized energy costs (LEC) (Konstantin and Konstantin, 2018b, p. 143) represent the costs of capital and for operating per MWh net heat consumption. Simplifications can be made when determining the LCOE (Arbeitsgemeinschaft QM Fernwärme, 2018, p. 173):

- All investments occur at the beginning of the investment
- The time considered equals the length of the investment and therefore neither replacements are necessary during nor do any residual values remain after this time

Under these conditions, the LCOE is calculated according to formula (2) where the following shall be:

- LCOE = levelized costs of energy (heat) [€/MWh]
- I = investment costs [€]
- a = annuity factor [w.d.]
- A = annual costs for operating & maintaining the DH system at current prices [€]

- k = discount rate [%]
- Q_{useful} = useful heat [MWh]

$$LCOE = \frac{I \times a + A \times k \times a}{Q_{useful}} \tag{2}$$

The LCOE can be used to compare different DH systems with each other regarding their profitability[1]. In a German study on 4th generation district heating systems, the authors have calculated LCOE in order to compare several already existing but different types of LTDH systems[2] with each other (ifeu, 2017, p. 74).

However, when performing LCCA, it is clear that not all costs occur at the beginning of an investment. Therefor, this approach of calculating LCOE is not suitable for LCCA and has to be adapted. The following shows a possibility:

The costs per MWh net heat consumption can be expressed as the net present value of all LCC at the end of a life cycle divided by the total amount of heat output over the whole life cycle. Formula *(3)* 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.]
- Q_t = heat output in year t [MWh]

$$LCOE = \frac{NPV(LCC)}{\sum_{t=0}^{n} Q_t} \tag{3}$$

3.2.4 Exisiting tools for life-cycle cost analysis

There are many tools existing for calculating LCC and performing LCCA. However, there was no LCCA tool found that can be used to calculate LCC of (LT)DH systems. The European Commission (EC) has developed a few LCC tools as well, namely for the sectors vending machines, imaging equipment, computers and monitors, indoor lighting, and outdoor lighting (European Commission).

As (LT)DH is a part of technical infrastructure, the EC's LCC tool for outdoor lighting is analysed further.

The *Life Cycle Costing Tool for Green Public Procurement of Road lighting & Traffic signals* is maily designed to be used during tendering processes for road lighting and traffic lights but can also be used

[1] When comparing different systems by their LCOE, the same calculation method has to be used in order to ensure equivalence.
[2] Different types: LTDH systems based on solar energy with and without storage, surplus heat and solar energy with heat pump

before and after tendering processes. It has been developed for "procurement practitioners in public organisations in the European Union" (European Commission, 2019, p. 1). The excel based tool comes with a manual and is available online for free.

The tool and the manual are written in English. The tool does not have any password protection.

In order to determine LCC, the tool refers to a life-cycle length that is either equivalent to the component with the longest lifetime, or to a reference lifetime of 30 years (European Commission, 2019, excel tool).

Based on the NPV method, the tool calculates LCC. It gives recommendations on how to choose a suitable discount rate. However, the tool does not calculate or consider any costs occurring during an end-of-life scenario.

3.3 Financial framework of District Heating systems in the Baltic Sea Region

In order to get an overview of the current financial framework of the DH systems in the BSR, the work of GoA 3.1 *Analysis of institutional, organisational and technical framework for LTDH* of the LowTEMP project is analysed. In this GoA, the current situation of DH in the BSR partner countries was queried in the form of two questionnaires, A and B. This was done by PP 9 Thermopolis Ltd. The data collection of questionnaire A contains not just institutional, organisational and technical information but also information on the current financial framework in the respective partner countries. This section excerpts this kind of information, see appendix *I Financial framework of DH systems in the BSR.*

3.4 Cost catalogues from BSR partner countries

As one of the tasks of this GoA is the creation of a catalogue with characteristic cost parameters, desk research is done to find out whether such catalogues already exist in the BSR.

3.4.1 Cost catalogues from the Danish Energy Agency

The Danish Energy Agency has published several catalogues regarding energy generation and transport. These catalogues give information on "technology, economy and environment for a number of energy installations and are among other things used by the Danish Energy Agency for energy projections" (Danish Energy Agency, 2019). The catalogues *Technology Data for Generation of Electricity and District Heating* and *Technology Data for Energy Transport* include information on energy generation, transmission, and distribution in DH systems.

Regarding economics, the catalogues list cost parameters and values for typical DH system components including costs for investment, operating and maintenance of each component (Danish Energy Agency and Energinet, 2016, p. 7, 2017, p. 21).

The data on costs for distribution DH is differentiated between the following areas: rural, suburban, city, new development and new development with LTDH (Danish Energy Agency and Energinet, 2017, pp. 78–86). Some of the data were consolidated with the former Swedish district heating association Svensk Fjärrvärme (Danish Energy Agency and Energinet, 2017, pp. 77–87).

During the creation of these catalogues, "European data, with a particular focus on Danish sources, have been emphasized in developing this catalogue. This is done as generalizations of costs of energy technologies have been found to be impossible above the regional or local levels (...). For renewable energy technologies this effect is even stronger as the costs are widely determined by local conditions." (Danish Energy Agency and Energinet, 2017, p. 21).

The catalogues are available in English on the agency's website and there is no fee required.

3.4.2 District heating pipe cost catalogue from the Swedish district heating association

Svensk Fjärrvärme has published a district heating pipe cost catalogue in 2007. It gives information on construction costs for underground pipes in different areas: city, suburban, parks and natural areas, and areas where distribution infrastructure can be installed during road construction (Svensk Fjärrvärme AB, 2007, p. 10).

The catalogues are available in Sweden on Swedenergy's website and there is no fee required.

4 Methods

In this chapter, the methods for fulfilling the tasks mentioned in the introduction are described, see *1.3 Tasks*. The results are shown in chapter *5 Results.*

4.1 Determining minimum requirements for a life-cycle cost analysis tool

First, gathered information on the current state of technology and knowledge regarding LCCA for (LT)DH projects is analysed by answering the following questions:

- What parameters are needed at least to perform LCCA?
- What calculations methods should be used?
- What language should be used?
- Who is the user of such a tool and what needs do they have that must be met?
- How much effort should be needed at least to produce meaningful results?
- What expressions have to be used?
- How does the tool have to be made available for the user?

Thereof, the minimum requirements for such calculation tools are derived.

4.2 Creating a catalogue of cost parameters

One of the tasks of this GoA is to create a catalogue with characteristic cost parameters, for example, costs per meter district heating pipe and as seen in *3.4 Cost catalogues from BSR partner countries*. This is happening analogous to GoA 5.1.

The main idea of a catalogue is not only to name the types of parameters but also to quantify these in the form of values. In order to create a catalogue with such characteristic parameters that are deposited with financial data, the following has to be given:

- Parameters, i.e. their values need to be consistent nationwide or at least in one region of a country. As soon as parameters are too heterogeneous in one country or region, no universal value can be given for a parameter.
- There must be parameters and values for all BSR partner countries. As soon as one information is lacking at some point, the catalogue does not achieve its objective.

Based on the data gathered in chapter *3 Current state of technology and knowledge*, costs parameters can be derived from the following:

- parameters from questionnaires of LowTEMP's GoA 3.1, see 3.3 Financial framework of District Heating systems in the Baltic Sea Region
- parameters used in already existing cost catalogues

These two options are analyzed in order to find out whether it is possible to create a cost catalogue for this main output that follows the requirements mentioned above. If so, parameters and values, the latter if possible, are listed in the form of a catalogue.

4.2.1 Analysing parameters based on questionnaires for the analysis of institutional, organisational and technical framework

Based on the financial framework in appendix *I Financial framework of DH systems in the BSR* the following questions and their answers of each partner country are considered as important for the development of a catalogue with characteristic parameters. The reasons why are directly named afterwards.

- **VAT** [%]: direct impact on prices
- **Acknowledged DH losses** [%]: direct information on the operation of DH systems and indirect information on operating costs
- **Acknowledged supply and return temperatures in DH network** [°C]: indirect information on the efficiency of DH systems
- **Energy taxation and fuels under energy taxation** [€/MWh]: direct information on possible cost parameter
- **Taxation information available in English**: in case further information is needed
- **Other possible drivers of DH price**: indirect information on possible cost parameters
- **Method for calculating DH price for producers**: in case further information is needed

The parameters and their values are summarized in one table in order to get an overview and to see how consistent they are in one country or region and if there are values for each BSR partner country.

4.2.2 Analysing already existing cost catalogues and their parameters

Already existing cost catalogues are analysed whether it is possible to derive a catalogue based on the parameters given there. If they fulfill the requirements mentioned above, a list of cost and revenue parameters is given with corresponding values.

4.3 Developing a tool for life cycle cost analysis of low-temperature district heating systems

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Based on the results of the preceding steps, a tool that will be able to perform LCCA is created or further developed. Therefore, the minimum requirements are considered. If one requirement is not met, the tool will be adapted in order to do so.

4.4 Testing and further developing of the tool on one Low-TEMP pilot measure

In order to ensure that the developed calculation tool can be used by future stakeholders, it is tested on at least one partner municipality's pilot case of the LowTEMP project where a pilot energy strategy shall be developed. Therefor, the information from GoA's 5.1 testing and developing process is used. The information given in this test will be used for the developed LCCA tool. If there is any information missing that is needed for performing LCCA, further possible devlopments will be evaluated together with the respective project partners.

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5 Results

The results of the tasks performed with the methods mentioned in chapter *4 Methods* are shown in the following.

5.1 Minimum requirements for the calculation method

The answers to the following questions show the minimum requirements for a calculation method.

- What parameters are needed at least to determine economic efficiency?

  According to *3 Current state of technology and knowledge*, for determining LCC and performing LCCA all costs of all life-cycle stages need to be given. Besides that, the LCC of a project need to be considered over a certain life-cycle length as these kinds of investments are long-term decisions and spread over many years. That is why the life-cycle length of all components need to be given as well as a discount rate with which the time value of money and any uncertainty and risks are considered.

- What calculations methods should be used?

  As mentioned in to *3 Current state of technology and knowledge*, (LT)DH projects are longterm decisions. Only discounted cashflow techniques can be used when calculating LCC and performing LCCA. For (LT)DH projects, the method of net present value is recommended by ISO guideline. Besides that, LCOE will be calculated as well as this is a common value for comparing different (LT)DH systems with each other financially.

- What language should be used?

  As English is the main language used in the LowTEMP project, the tool and its appendices have to be available in English at least.

- Who is the user of such a tool and what needs do they have that must be met?

  As mentioned in *1.2 Aim of the work*, the target groups of this output are public authorities, heat suppliers, operators of DH networks, investors as well as planners and engineers.

- How much effort should be needed at least to produce meaningful results?

  The target groups have to be able to use the tool on their own, if necessary with the help of other stakeholders mentioned before. In some cases, further information from companies, such as companies specialized in the decommissioning, deconstruction, and disposal of (LT)DH systems and their components, may be consulted.

- What expressions have to be used?

  As there are various target groups with different backgrounds and knowledge concerning economic efficiency and funding gaps of (LT)DH systems, the target group who knows the least about this topic has to be able to understand the tool. That is why simple language is required and special terminology has to be explained in a manual that comes along with the tool.

- How does the tool have to be made available for the user?

  The tool and its annexes have to be available with no fee required and have to be downloadable from the internet.

5.2 Catalogue with characteristic cost and income parameters

5.2.1 Parameters and values based on questionnaires for the analysis of institutional, organisational and technical framework

By now, 8 out of 9 partner countries answered questionnaire A. Therefore, a catalogue with parameters and values based on these 8 questionnaires does not fulfill one of the requirements mentioned in *4.2 Creating a catalogue of cost parameters*, namely data from each of the nine BSR countries.

However, in the event that the last questionnaire might arrive after this work has ended but still during the LowTEMP project, the answers of the 8 filled out questionnaires are at least examined regarding their consistency which is the second requirement for such catalogues. All direct and indirect information is summarized in *table 2*.

table 2: direct and indirect information on parameters and their values from questionnaires (answered by project partners)

	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden
VAT [%]	20	24	19	21	21	23	18	25
Network losses [%]	10-20	5-15	14	12-30	15	n/a	12-20	8
T_{supply} & T_{return} [°C]	90-95 & 60-80	65-115 & 40-60	75-110 & 45-50	60-90 & 40-70	60-65	68-119	95-150 & 70	80-90 & 50-60
Taxes								
CO_2 tax	yes	yes	No	Yes	n/a	Yes	No	Yes
Energy content tax	No	Yes	Yes	Yes	n/a	No	No	Yes

Strategic stock pile fee	no	Yes	No	No	n/a	No	No	No
other	Natural gas excise	No	No	No	n/a	No	No	No
Fuels under energy taxation	yes	yes	yes	yes	yes	yes	no	Yes
Other possible drivers of DH price	yes	yes	yes	yes	yes	n/a	yes	Yes

As seen in *table 2*, some answers were not given (marked with "n/a"). Hence, the second requirement is not fulfilled as well as it cannot be assured that parameters and their values are consistent nation or regional wide.

5.2.2 Parameters and values used in already existing catalogues

Cost catalogues are found for Denmark and Sweden. During the desk research, no other cost catalogues were found. As only 2 out of 9 BSR countries provide such cost catalogues, the creation of a new catalogue based on this data is terminated as it does not fulfill the requirements mentioned in *4.2 Creating a catalogue of cost parameters* namely consistency within one nation or region and data from each of the nine BSR countries.

5.2.3 Choice of catalogue with characteristic cost and revenue parameters

As neither the answered questionnaires from GoA 3.1 fullfill the requirements for cost catalogues nor all BSR countries provide cost catalogues for DH projects, this task has to be changed. Instead of creating a catalogue with not just parameters but also values, a list of minimum parameters is created wherefore the user of the tool has to deliver suitable values. The list of these parameters is derived in the subsection before and goes with the calculation method chosen in *5.1 Minimum requirements for the calculation method.* A full list of parameters is given with the corresponding manual of the tool.

5.3 Development of calculation tool for life-cycle costs and performing life-cycle costs analysis

As there is no already existing calculation tool for determining LCC and performing LCCA of (LT)DH projects, a new tool has to be created. Therefor, the tool developed in LowTEMP's GoA 5.1 for determining economic efficiency and funding gaps is used and adapted. The reason for this is that this tool already calculates operating and maintaining costs of (LT)DH projects, two of four needed life-cycle stages of this output. The tool from GoA 5.1 is further adapted by spreadsheets for calculating costs occurring during construction and an end-of-life scenario and by an input cell for determining the life-cycle length (optional).

The tool is able to calculate the life-cycle costs of all four life-cycle stages, including an end-of-life scenario. This happens through calculating the NPV of all cash flows during the life-cycle length, either set by the user or automatically determined by the tool based on the information the user has given before. In addition, the tool calculates the LCOE of the analysed system alternative. This value can be used for further comparison with other system alternatives.

5.4 Testing of calculation tool with LowTEMP pilot measure Gulbene

The tool was tested on the pilot measure in Gulbene/Latvia. Based on the information already given in the development of GoA's 5.1 MO, it was possible to fill out the developed LCCA tool of this MO. Therefor, no further actions need to be done.

6 Discussion and outlook

6.1 A new developed tool for performing life-cycle costs anaysis and calculating life-cycle costs

The current state of knowledge shows that many tools exist for calculating LCC but there was no tool found that can be used for (LT)DH projects.

With the tool and the manual developed in this work, stakeholders are able to perform LCCA and calculate LCC of all four life-cycle stages: construction, operating, maintaining, and end-of-life. The results are calculated at once and directly without being limited to certain technologies or country-specific laws. Possible projects that can be considered with that are investments where all main components belong to the DH supplier. The user has to set own accounting boundaries, the manual provides assistance with that.

The tool is based on the tool from LowTEMP's GoA 5.1 *determining economic efficiency and funding gaps* and is further developed in order to meet all minimum requirements set in this work. It determines LCC by using the NPV method. Both and calculates LCOE for the analysed system alternative in order to make the results comparable. NPV is a discounted cash flow technique and a state of the art calculation method which is recommended for LCCA by ISO guideline.

The tool considers projects over a period of max. 100 years. The length of a life cycle is either determined by the technical lifetime of the component with the longest technical lifetime or is set by the user.

The user of this tool has the opportunity to either choose a discount rate on his or her own or to follow recommendations given in the manual. When using discounted cash flow techniques, the choice of the right discount rate is important as this has an impact of all cash flows and their present value. 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). That is why the user is responsible to consider an appropriate discount rate.

With the tool, users are able to perform LCCA, calculate LCC and to compare different system alternatives with each other. However, the results of the tool are not meant to be 100 % true as life cycle costs can occur in the far future and their forecast is difficult at this moment. This MO shall assist target groups in their decision making when comparing different system alternatives.

6.2 A catalogue with needed cost parameters without country-specific values

It is not possible to provide a catalogue with cost parameters that define country-specific values of

DH components and systems in all nine partner countries. Research shows that such catalogues already exist in only two countries, namely Denmark and Sweden. The analysis of the financial framework of DH in the nine BSR countries shows that values for cost parameters are not always consistent nation or regional wide.

This circumstance is confirmed by AGFW when they were asked to give information on any cost catalogues in Germany. No such catalogues as the ones shown from Denmark exist there (Bernhardt-Vautz, 2019). AGFW has a great overview of DH systems and their project development from institutions that are member of the association. The reason for this lack of cost catalogues is the following:

When an institution is planning a DH measure and is analysing its costs, values taken from experience or similar projects are used normally. These values can differ from one municipality to the next to such an extent that it is impossible to create a general catalogue which provides characteristic cost parameters and values. Besides that, institutions try to keep secret as much information as possible and therefore do not disclose information on cost parameters. (Bernhardt-Vautz, 2019)

Besides that, the Danish Energy Agency has mentioned that for generalizations on European data on cost parameters are impossible above regional or local level as local conditions have a strong effect on them (Danish Energy Agency and Energinet, 2017, p. 21).

Uncertainties in creating specific cost values exist as prices for LTDH components not only vary from country to country but also because of other reasons such as "contract value, the number of pieces ordered and the business relation of the network operator/planner and the provider of the components" (Köfinger et al., 2016, p. 102). Also, technically innovative and new components often do not have a mass-market price yet (Köfinger et al., 2016, p. 102).

Hence, a catalogue of possible cost parameters is given in the manual but without country or region related values. With this, the user knows what parameters can be considered when determining especially construction costs but also costs for operating and maintenance.

6.3 Outlook

As mentioned in the subsection before, there is a need for further development of the tool and the catalogue provided in the manual:

Integration of the catalogue with cost parameters in the tool: at this moment, the catalogue of cost parameters is provided as a checklist in the manual. The user has to go through the checklist and copy all the components by hand. The results have to be typed into the tool manually. This approach is not just effortful but also prone to errors. Hence, it is the goal to integrate the catalogue in the excel tool prior to the input mask. The user will have the choice to either fill out the catalogue with own values or to follow the approach that is used so far, namely typing in values manually.

It is planned to carry out these developments during the remaining project period of LowTEMP and to upload further developments onto the project consortium's database on LinA.

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Appendix

I Financial framework of DH systems in the BSR

Financial framework of DH systems – Estonia

- VAT (general)

  20 %
- Network losses (operation)

  Cities 10-15%; sparsely populated areas 15-20%
- Acknowledged supply and return temperature (operation & energy savings potential)

  Supply: 90-95 °C; return: 60-80 %
- Financial aids
  - Feed-in tariff (operation)

    0,0537 €/MWh
  - Feed-in premium (operation)

    if electricity is produced in a process of efficient cogeneration by biomass except condensation plants.
- Responsible institution for granting & subsidies

  Environmental Investment Centre
- Subsidy measure

  ERDF Measure "Effective production and transmission of thermal energy"
- Amount of money spent on development of DH networks and boiler rooms over the last 5 years

  202M€ investment of which 98 M€ subsidies
- Determination of investment subsidies for DH companies

  "Effective production and transmission of thermal energy". The purpose of the measure is reducing the final consumption of energy on the account of more efficient production and transmission of heat energy. The supported activities are:

  Renovation of district heating boilers and replacement of fuel;

  Renovation of amortised and inefficient heating piping;

  Preparation of the development plan for heating management;

  Construction of a local heating solution to replace district heating solutions.

- Tax aids for DH companies

  None
- Other possible aids

  Subsidies for reconstruction/renovation of grid

- Taxes
    - Carbon dioxide tax
    - Other: natural gas excise
- Fuels under energy taxation
    - Charge on use of natural resources - Environmental charges act: https://www.riigiteataja.ee/en/eli/ee/Riigikogu/act/521122017003/consolide
    - In addition there is excise on fossile fuels - Alcohol, Tobacco, Fuel and Electricity Excise Duty Act: https://www.riigiteataja.ee/en/eli/ee/Riigikogu/act/503072018010/consolide
    - unleaded petrol - 563 euros per one thousand litres
    - liquid petroleum gas - 68.94
    - motor liquid petroleum gas - 193 euros per one thousand kilograms
    - diesel fuel - 493 euros per one thousand litres
    - light heating oil - 493 euros per one thousand litres
    - heavy fuel oil - 559 euros per one thousand kilograms
    - shale-derived fuel oil - 548 euros per one thousand kilograms
    - natural gas - 50,65 euros per one thousand cubic metres
    - motor natural gas in liquefied form - 66 euros per one thousand kilograms
    - coal, lignite and coke - 0.93 euros per one gigajoule of the upper calorific value
    - oil shale - 0.93 euros per one gigajoule of the upper calorific value
    - electricity - 4.47 euros per one megawatt-hour
- taxation information in English available

  yes, see above
- other possible drivers of DH price

  According to District Heating Act (https://www.riigiteataja.ee/en/eli/520062017016/consolide):
    - § 8. Sale and pricing of heat
    - (3) The maximum price of heat shall be set such that:
    - 1) the necessary operating expenses, including the expenses incurred in relation to the production, distribution and sale of heat, are covered;
    - 2) any investments necessary in order to perform the operational and development obligations can be made;
    - 3) environmental requirements are met;
    - 4) quality and safety requirements are met;
    - 5) justified profitability is ensured.
    - § 9. Approval of price of heat
    - (1) A heating undertaking which:

    - must obtain, for each network area separately, the approval of the Competition Authority regarding the maximum price of the heat to be sold.

- Calculation method for determining DH price

  Covered by District Heating Act
- Customer prices for DH incl. VAT
    - Residential

      35-84 €/MWh
    - Industrial

      Same
    - Public sector

      Same
- Why are there differences?

  No differences
- Regulator of pricing

  Price is suggested by DH company and approved by Competition Authority
- Payment made on basis of heat meter (in majority)

  Yes

Financial framework of DH systems – Finland

- VAT (general)

  24 %
- Network losses (operation)
- 5-8 % in city center's, slightly higher 8-9 % in urban areas and 10-15 % (occasionally higher) in low density areas.
- Acknowledged supply and return temperature (operation & energy savings potential)

  Vary seasonally, Supply in winter: 115 °C; supply in summer: 65 °C, return: 40-60 %
- Financial aids
    - Feed-in tariff (operation)

      83,50 €/MWh

      Feed-in tariffs can be granted for CHP producers for the electricity production. The plant have to use either wood chips or other wood fuels, or it has to be a biogas plant. These plants are eligible only if they have not received any state aid. Beside feed-in tariff for electricity, eligible producers can apply also for increased feed-in tariff (including feed-in premium for heat) if they produce also heat. There are more restrictions whether the producer can join feed-in tariff or not: legislation in Finnish: https://www.finlex.fi/fi/laki/ajantasa/2010/20101396

      Producer can receive the grant for 12 years from the date when it has been accepted as a receiver of feed-in tariff. Maximum amount is 750,000 € / 4 tariff periods (3 periods in a year). Electricity is sold normally at the electricity markets. If the price is higher, the electricity price gets the

For wood chip power plants the budget was 54,000,000 € in 2018 (from the budget of Ministry of Finland). Biogas 10, 100,000 and wood fuel 1,500,000.

Heat premium is 20 €/MWh for wood fuel based plants where electricity is produced. Biogas power plants have 50 €/MWh.

- Green certificates

  volunteer in the field of electricity production. For heat production there are no specific certificates
- Investment subsidy

- Responsible institution for granting & subsidies

  Ministry of Economic Affairs and Employment in cooperation with Business Finland
- Subsidy measure

  N.N.
- Amount of money spent on development of DH networks and boiler rooms over the last 5 years

  N.N.
- Determination of investment subsidies for DH companies

Heat only boilers (biomass) 10-15 %, heat pumps 15%, solar heat 20%, solar electricity 25%, biogas 20-30%, subsidies of the investment price. Over 10 MW heat only boilers are not eligible to receive investment subsidies. Requirement for eligible heat only boilers is to achieve at least 70% usage of renewable energy. Investments have to be higher than 10 000 €. Flew gas scrubbers are not eligible

For new technology innovation projects 40 % subsidies.

Energy aid / investment subsidies can be found here in English: https://www.businessfinland.fi/en/for-finnish-customers/services/funding/sme/energy-aid/

40,000,000 € were allocated to investment subsidies for years 2016-2018 that are eligible due to the terms of subsidies.

- Tax aids for DH companies

In Finland fuels that are used in electricity production are tax free. However, for CHP production there are calculation tools how to measure the tax amount for the produced heat. Therefore, in district heat production companies have to pay fuel taxes but fuels in electricity production are tax free.

For CHP there are also lower carbon dioxide taxes, if the fuel is LFO, biofuel, HFO, coal, or natural gas. The amount of the tax is 50 % of the chart price. The tax aid is applied afterwards as tax returns, unless the company is authorized stock pile holder.

- Other possible aid

Electricity tax is added to the electricity price when distributed via distribution network to customers. Therefore, if district heating company has a CHP plant and use electricity for own process needs, it's tax free.

- Taxes
    - Carbon dioxide tax
    - Energy content tax
    - Strategic stock pile fee
- Fuels under energy taxation

  Coal is tax free if used in electricity production. For CHP and Heat only there are other regulations.

  Excise duty is paid of peat if used in heat production. Company is set free of the duty if peat is used less than 5,000 MWh/a.

  For coal, company have to pay excise duty and strategic stock pile fee (if deputy stock pile holder, or registered receiver). If coal is used only for electricity production, it's tax free..

  Coal: energy content tax 53.13 €/t, carbon dioxide tax 149.56€/t, strategic stock pile fee 1.18€/t. SUM: 203.87 €/t.

  Natural gas: 7.50€/MWh, 12.28€/MWh, 0.084 €/MWh, SUM: 19.864 €/MWh

  Peat: content tax: 1.90 €/MWh, SUM: 1.90 €/MWh

  Electricity: 2.24 c/kWh, 0.013 c/kWh, 2.253 c/kWh. Price class I (for normal customers, incl. housh-olds)
- Electricity: 0.69 c/kWh, 0.013 c/kWh, 0.703 c/kWh. Price class II (only for industrial customers, and some other high intensity energy users)
- taxation information in English available

  yes

  Data was not updated but here is the links: energy taxation guide: https://www.vero.fi/en/detailed-guidance/guidance/56206/energy_taxation/

  taxes for coal, peat etc.: https://www.vero.fi/en/businesses-and-corporations/about-corporate-taxes/excise_taxes/valmisteverolajit/sahko_ja_eraat_polttoaineet/s%C3%A4hk%C3%B6n-ja-er%C3%A4iden-polttoaineiden-verotaulukot/

  taxes for liquids: https://www.vero.fi/en/businesses-and-corporations/about-corporate-taxes/excise_taxes/valmisteverolajit/nestemaiset_polttoaineet/nestem%C3%A4isten-polttoaineiden-verotaulukko/
- other possible drivers of DH price

  One argument for price increases beside taxes are the availability of fuels. When the reliability of a specific fuel is insecure, fuel price will increase, which will lead to higher district heating prices. Other arguments for district heat price increases are e.g. the increase of general price levels.
- Calculation method for determining DH price

  District heating companies determine their district heat prices as cost correlated as possible.

  Energy fee covers the fuel costs, energy taxation, emission trading, electricity usage in production and distribution.

  Power fee (basic fee): Fixed costs of a district heating company are mainly covered with power fee.

Energy taxation - especially excise taxes of fuels have an important role in energy prices. Prices increase when taxes increase.

Connection fee: customer will pay district heating company a connection fee, which will cover the production and network investment capital costs. The price of connection fee is determined for customers so that it's feasible and reasonable for customers to join district heating and so that the connection prices won't change significantly in long term. Customers doesn't have to pay taxes of connection fee if the heating system can be used by the next user (resident) or it can be transfered.

- Customer prices for DH incl. VAT
  - Prices vary yearly. CHP is cheaper for customers than heat produced in heat only boilers, in general.

    https://energia.fi/ajankohtaista_ja_materiaalipankki/materiaalipankki/kaukolammon_hintatilasto.html#material-view
  - Residential

    Aritmetic average for 1 family house: 94.44 €/MWh, incl. energy and power fee.

    For 15 house detached house / apartment building: 84.62 €/MWh.

    80 house apartment building: 80.35 €/MWh
  - Industrial

    Industrial and public prices are in the same scale, depending on the power fee.
  - Public sector

    Industrial and public prices are in the same scale, depending on the power fee.
- Why are there differences?

In Finland the district heating pricing can be divided in two sectors: connection pricing and pricing during the use of district heat.

Pricing during the use of district heat:

Energy fee is a price for the measured heat consumption. The price varies but the significance in total heat bill is usually smaller among customers with low heat consumption. The used fuel and the variable costs of heat delivery for the district heating company determine the unit price of energy fee. In general the % share of energy fee is higher for apartment houses compared to single houses. Prices will include VAT, 24%. Some district heating companies use pricing that is based on seasonal changes. In this kind of pricing the prices are based on actual fuel usage in the production site (->cost correlated prices). The pricing is based on estimated shares of different fuels in different seasons.

Power fee (basic fee): is typically10...50 % of district heating bill. Fixed costs of a district heating company are mainly covered with power fee. The power fee can be based on actual heat power need/actual water flow need. Power fee can also be based on the same principles as in the connection fee (power/water flow). In general, the % share of power fee is higher for single house owners compared to apartment houses.

Finnish Energy has made national recommendations and guides for pricing of power and water flow contracts. There can also be other pricing methods that a district heating company can include to

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the price of district heat.

Each customer will make an individual heat power contract (hourly heat demand, kW) or an contract based on the water flow.

Power connection contract or water flow contract are typical basis of district heating pricing.

Connection pricing: Connection fee: customer will pay district heating company a connection fee, which will cover the production and network investment capital costs. District heating company will make the sizing of connection pipes, which is based on the HVAC desingner's (or other representative of the customer) district heating power requirement calculations. When connecting an apartment to a district heating system, a district heating enterprise will calculate and estimate heat consumption of the building. This will be the background for the selection of power connection contract or water flow contract.

- Regulator of pricing

  Supervising bodies for the prices are especially Finnish Competition and Consumer Authority and Energy Authority (more for electricity prices), both authorities are working under the Finnish government. Authorities can make an intervention if they see that customer has been mistreated. Authorities base their actions on legislation (consumer protection, competition legislation, energy efficiency legislation). This supervising is also the steering background for good and transparent pricing and customer service in the field of district heating.

  District heating is counted as determining market, as the investment costs are high and the investment is a long lasting investment. Once a building has been connected to district heating network, it's highly unlikely that the building will change it's heating system in next decades. Due to this, the requirements for reasonable pricing have been set and are supervised by supervising bodies.

  Competition act is the main legislation that regulates district heating prices. Competition act determines as for example that the prices have to be: 1) reasonable, 2) cost correlated 3) and similar customers must have similar prices.

- Payment made on basis of heat meter (in majority)

  Yes

Financial framework of DH systems – Germany

- VAT (general)

  19 %

- Network losses (operation)

  14 %

- Acknowledged supply and return temperature (operation & energy savings potential)

  Supply winter: 110 °C, supply summer: 80 °C; return winter: 75-80 °C, return summer: 45-50%

- Financial aids
  - Feed-in tariff (operation)

    depends strongly on the chosen technology and the date of first operation. The renewable energy act has been changed several times, but the tariff price has decreased everytime.

- Feed-in premium (operation)

  for non-coal fired CHP plants.

- Determination of feed in tariff and premium

  only biomass and biogas plants are eligible for the tariff to a capacity of 20 MWel. The tariff is paid for the fed-in electricity not the produced heat.

  In addition there is an investment subsidy for renewable energy sources like solarthermal, smaller heat pumps, biomass plants.

- Investment subsidy

- Responsible institution for granting & subsidies

  The subsidy for RES and for CHP are developed by the ministry for economics and energy. The money is paid by the corresponding authority.

- Subsidy measure

  N.N. (different)

- Amount of money spent on development of DH networks and boiler rooms over the last 5 years

  In the CHP act there is 150 million euro allocated for building new piping and thermal storages. Within the last 5 years subsidies of 175 Mio. Euro were spent for new grids

- Determination of investment subsidies for DH companies

  N.N. (but for example FW 703 but no general rule except of what is said in the GBER)

- Tax aids for DH companies

  There is a tax aid for CHP, where energy tax on gas has not to be paid while using high efficent CHP plants.

  In addition, small CHP plant operators up to 2 MWel can be exempted from electricity taxation for the electricity they distribute within the surrounding area around the plant (4.5 km radius)

- Other possible aids

  There is an CHP act, that defines subsidies for fed-in electricity from high efficient CHP. Additionally, there are subsidies for DHC grids and heat storages.

- Taxes

  - Energy content tax

- Fuels under energy taxation

  taxation for fuels is regulated by law "Energiesteuergesetz", in English: German Energy Tax Act, §2):

  the following fuels are under taxation: petrol, medium oils, gasoil, fuel oil, natural gas, other gaseous hydrocarbons, liquid gas, coal, petroleum coke, lubricating oil

  natural gas: till 31.12.2023: 13,90 €/MWh, from 01.01.2024 until 31.12.2026 taxation will rise annually up to 27,33 €/MWh. exceptions and lower taxation are possible, if natural gas is used in "benefiting installations" or plants coal: 0,33 €/GJ

ful oil: 130,00 €/t

- taxation information in English available
- no
- other possible drivers of DH price

  supply independent: investment costs, Inflation, labour costs

  supply dependent: fuel costs, taxes and surcharges (emission fees, energy taxes)
- Calculation method for determining DH price

  dh price consists of:

  - basic price, which covers all costs which are necessary for having a certain capacity available

  - commodity price, which covers output costs

  - transfer price, which covers costs for metering and invoicing
- If operator is not heat producer, how are costs and profits devided?

  This is content of the contract between the two parties and is usually not transparent or published.
- Customer prices for DH incl. VAT
  - Residential

    N.N.
  - Industrial

    N.N.
  - Public sector

    N.N.
  - Other differentiation

    prices do not include VAT, depending on output:

    <= 15 kW: 74,68 €/MWh

    <= 160 kW: 72,78 €/MWh

    <= 600 kW: 70,68 €/MWh
- Why are there differences?

  differences in prices for dh heat can occur because of differences in

  - type of generating plant (not an issue in same dh grid)

  - type of fuel / combustible (not an issue in same dh grid)

  - geological or urban conditions

  - overall connected load and dh consumption

  - depth of services which consumer is needing from producer
- Regulator of pricing

  The prices are unregulated: There is competition between all kinds of heating technologies and district heating and cooling has to offer an interesting price for delivering heat.

- Payment made on basis of heat meter (in majority)

  Yes, In addition to the heat meter, there is a demand rate for overhead costs.

Financial framework of DH systems – Latvia

- VAT (general)

  21 %
- Network losses (operation)

  Riga 12%; sparsely populated areas 20-30% if grid reconstruction has not been done
- Acknowledged supply and return temperature (operation & energy savings potential)

  Supply: 60-90 °C; return: 40-70 % (summer-winter)
- Financial aids
  - Feed-in tariff (operation)

    No, there is a feed-in tariff for electricity produced in CHP plants. Therefore, the feed-in tariff is not applicable on the produced heat.
  - Green certificates

    But not yet introduced in Latvia
- Responsible institution for granting & subsidies
- Ministry of Economic affairs and Central Finance and Contracting Agency coordinates the grants from European Structural and Investment funds
- Subsidy measure

  N.N.
- Amount of money spent on development of DH networks and boiler rooms over the last 5 years

  Allocated 60 million Euro for DH companies
- Determination of investment subsidies for DH companies

  Support is provided to promote energy efficiency and the use of local RES in district heating. Within this measure, the following is supported:

  - heat energy conversion to increase energy efficiency and switch to the use of RES in central heating, incl. purchase and installation of technological equipment;

  - increase of energy efficiency of the heat energy transmission and distribution system;

  - conversion of a cogeneration plant to a heat source

  The investment subsidies can cover 40% of total project costs.

- Tax aids for DH companies

  None
- Other possible aids

  When using the alternative energy sources, DH company does not pays the natural resource tax
- Taxes

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  - Carbon dioxide tax
  - Energy content tax (called: natural resource tax)
- Fuels under energy taxation

  Energy tax (In Latvia: natural resource tax) for natural gas is 1,83 EUR/MWh; Coal 8,54 EUR/MWh; Oils Shale (5,79 EUR/MWh);

  Therefore there is tax on particular emissions.

  - CO_2 emission tax 3,5 Euro/t .
  - Nitrogen oxides and other anorganic nitrogen compounds, normalised to NO_2 quantities (0,08537 Eiro/kg);
  - Sulphur-tax (0,08537 Eiro/kg); CO (0,0077 Eiro/kg);
  - PM excluding heavy metals and heavy metal compounds 0,075 Eiro/kg;
  - Heavy metals and heavy metal compounds (1,1383 Eiro/kg))
- taxation information in English available

  yes and no, Natural resource law: https://likumi.lv/ta/en/en/id/124707-natural-resources-tax-law Law on Pollution: https://likumi.lv/ta/en/en/id/6075-on-pollution
- other possible drivers of DH price

  As the main component in heat tariff is production costs, the energy source is main driver for heat price. Therefore, the heat price is strongly impacted by local conditions (number of inhabitants, heat density, availability of energy sources etc.)
- Calculation method for determining DH price

  The tariff is calculated for each heat supply stage separately in accordance with the decision of the Council of the Public Utilities Commission No. 1/7. The tariff calculation consists of the sum of the three heat supply stages : production tariff, EUR/MWh; transmission tariff, EUR/MWh; realization tariff, EUR/MWh.

  In production tariff maintenance and running costs are included which consists of both labor and administration salaries, as well as repairs and other additional expenses. One of the most important controllable costs is investment, and repayment of the associated credit.

  In the transmission tariff the same as in the production tariff. In the transmission section, the costs of heat loss, as well as the electricity consumption for running the pump, which is directly related to the transmission of heat, appears on the variable costs.

  Realization tariff is made from cost attributed to heat transferred to the users. The realization tariff retains part of the other elements in the tariffs, but the share of electricity and heat losses is eliminated.
- Customer prices for DH incl. VAT
  - Residential

    42-70 €/MWh
  - Industrial

    Same

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  - Public sector

    Same

- Why are there differences?

  No differences. The regulation in country does not allow different tariffs for different consumer groups. Therefore, most of large industrial companies has own heat plants and mainly does not buys the heat from DH.

- Regulator of pricing

  The heat tariffs are regulated and confirmed by the Council of the Public Utilities Commission. There have not be major changes in tariff regulation during last years

- Payment made on basis of heat meter (in majority)

  Yes

Financial framework of DH systems – Lithuania

- VAT (general)

  21 %

- Network losses (operation)

  15 %

- Acknowledged supply and return temperature (operation & energy savings potential)

  Minimum temperature is given by Ministry of Economy

  1. in a case of closed heat supply system, at least 65 degrees C;

  2. in the case of an open-source heat supply system, at least 60 degrees temp. C;

- Financial aids

  - Investment subsidies (though not ticked)

- Responsible institution for granting & subsidies

  N.N.

- Subsidy measure

  See down below

- Amount of money spent on development of DH networks and boiler rooms over the last 5 years

  1. During the years 2007-2013 EU structural assistance period about 12% of total DHT pipelines in length were modernized;

  2. During 2014-2020 funding period it is planned to allocate funding for:

  2.1. Measure "Modernization and development of heat supply networks", 69.5 mln. Eur;

  2.2. Measure "Promotion of high-efficiency cogeneration in Vilnius city" (share of biofuels: 154 MWh and 70 MWe) - 96.6 million;

  2.3. Measure "Changing of heating plants that use biomass", 10 mln. Eur;

  2.4. Measure "Development of municipal waste incineration capacities" (Vilnius CHP power plant (53 MW and 18 MWe), 67.4 million EUR; Kaunas Cogeneration Plant (measure not approved yet) Planned: (71 MWh and 24 MWe); 69 million Eur;

2.5. Measure "Modernization of fossil fuel boilers" 15.0 mln. Eur.

- Determination of investment subsidies for DH companies

  N.N.

- Tax aids for DH companies

  N.N.

- Other possible aids

  N.N.

- Taxes

  N.N.

- Fuels under energy taxation

  The heat supplier, which sells at least 10 GWh of heat per year, in accordance with the methodology for the determination of heat prices and, having regard to the comments of the municipal authority and the National Control Commission for Prices and Energy, develops and submits a heat base price project to the National Control Commission for Prices and Energy and the municipal authority.

  The municipality authority submits to the National Control Commission for Prices and Energy the basic documents for harmonization of the price and / or substantiated comments. The National Control Commission for Prices and Energy sets the price for the heat base. The National Control Commission for Prices and Energy determines the price of the basic heating price on its website for each heat supplyer: http://www.regula.lt/siluma/Puslapiai/silumos-zemelapis/silumos-zemelapis.aspx;

- taxation information in English available

  no

- other possible drivers of DH price

  The base price for heat consists of two parts: constant and variable. The constant and the variable are recalculated once a year, and the monthly price for consumers is adjusted for the price of the purchased fuel. Fixed costs include wages, depreciation, profits, repairs, material and other costs. The constant costs incurred by companies are independent of the amount of heat produced and supplied to consumers. These costs are monitored and monitored by the National Control Commission for Prices and Energy to avoid unreasonable and unreasonably high costs incurred in the heat price. Variable costs include the production of fuel for heat production, the purchase of heat from independent heat producers, electricity generation and preparation of heating water. Costs vary depending on the amount of heat needed to produce and supply to the heat transfer networks. Fuel consumption is 40 to 80 percent of the heat price. Fuel prices are not regulated by the Commission.

- Calculation method for determining DH price

  N.N.

- Customer prices for DH incl. VAT
    - Residential

      N.N.
    - Industrial

      N.N.
    - Public sector

      N.N.
- Why are there differences?

  N.N.
- Regulator of pricing

  In the heat energy sector, the Commission regulates heat energy prices for those heat suppliers whose sales of heat exceed 10 GWh / year (smaller heat suppliers) the prices of heat supplied are regulated by the municipal authorities.

  Map of the heat prices:

  http://www.vkekk.lt/siluma/Puslapiai/silumos-zemelapis/silumos-zemelapis.aspx
- Payment made on basis of heat meter (in majority)

  N.N.

Financial framework of DH systems – Poland

- VAT (general)

  23 %
- Network losses (operation)

  N.N.
- Acknowledged supply and return temperature (operation & energy savings potential)

  According to ENGIE (owner of Pomeranian heating company ENGIE EC Slupsk) the maximum temperature of the heating medium during the heating season is 119 °C, minimum – 68 °C, and in summer – 68 °C.
- Financial aids
    - Green certificates

      9,12 €/MWh, supervised by Energy Regulatory Office (URE)

      The green certificate system was introduced in Poland on October 1, 2005 on the basis of the amended Energy Law (replaced in 2015 by the auction system), but they act as an element of the support system only for electricity from RES, they do not concern the production of thermal energy. The price of green certificates given above is the weighted average price for the entire 2017, however in June 2018 it was 16.93 EUR/MWh and in July 2018, when the possibility of buying certificates to fulfill the obligation of renewable energy sources for 2017 disappeared, the price of certificates continued to increase to the average level of 21.01 EUR/MWh. However, there are

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Property rights to Certificates of Origin confirming the production of electricity and heat in high-efficiency cogeneration.

- Tax aid
    - Other

      There are Property rights to Certificates of Origin (violet certificates) confirming the production of electricity and heat in high-efficiency cogeneration in sources referred to Energy Law (e.g. fired with gas obtained from biomass processing).
- Responsible institution for granting & subsidies

  N.N.
- Subsidy measure

  N.N.
- Amount of money spent on development of DH networks and boiler rooms over the last 5 years

  N.N.
- Determination of investment subsidies for DH companies

  N.N.
- Tax aids for DH companies

  N.N.
- Other possible aids

  N.N.
- Taxes
    - Carbon dioxide tax
- Fuels under energy taxation

  Every fuels and electricity are under taxation in Poland – excise duty:

  - natural gas 1.28 PLN/GJ i.e. 1.074 EUR/MWh,

  - coal 1.28 PLN/GJ i.e. 1.074 EUR/MWh,

  - light fuel oil 0.232 PLN/l i.e. 5.438 EUR/MWh,

  - electricity 20 PLN/MWh i.e. 4.662 EUR/MWh
- taxation information in English available

  no
- other possible drivers of DH price

  N.N.
- Calculation method for determining DH price

  N.N.
- Customer prices for DH incl. VAT
    - Residential

66.18 €/MWh

- Industrial

  N.N.

- Public sector

  66.18 €/MWh

- Why are there differences?

  N.N.

- Regulator of pricing

  Energy Regulatory Office (URE) is the regulator of the pricing of energy, including heat.

- Payment made on basis of heat meter (in majority)

  Yes

Financial framework of DH systems – Russia

- VAT (general)

  18 %

- Network losses (operation)

  20% on average, 12-16% in larger cities

- Acknowledged supply and return temperature (operation & energy savings potential)

  Quality control plans: 150/70, 120/70, 95/70 with the temperature of a heating medium of 70 degrees for hot water supply

- Financial aids

  none

- Responsible institution for granting & subsidies

  none

- Subsidy measure

  none

- Amount of money spent on development of DH networks and boiler rooms over the last 5 years

  none

- Determination of investment subsidies for DH companies

  none

- Tax aids for DH companies

  None

- Other possible aids

  none

- Taxes

  None, just VAT

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- Fuels under energy taxation

  All types of fuel are subject to VAT
- taxation information in English available

  no
- other possible drivers of DH price

  Electricity tariffs, cost of natural gas, materials and equipment, etc
- Calculation method for determining DH price

  The price is calculated based on the basic principles for pricing. The tariff is approved by the State committee for rates and prices of the Republic of Karelia based on the tariff application and proofs of costs in previous periods.
- Customer prices for DH incl. VAT
  - Residential

    35 €/MWh
  - Industrial

    35 €/MWh
  - Public sector

    n/a
- Why are there differences?

  The pricing for all consumer groups is the same.

  Fuel - 40%, electricity - 10 %, salary fund -20 %, investment+ production company– 10 %, other - 20%. [author's note: this answer partially answers the question for calculation method for determining DH price, see above]
- Regulator of pricing

  The State committee for rates and prices of the Republic of Karelia
- Payment made on basis of heat meter (in majority)

  No, about 50% of customers have metering skids

Financial framework of DH systems – Sweden

- VAT (general)

  25 %
- Network losses (operation)

  8 % overall
- Acknowledged supply and return temperature (operation & energy savings potential)

  Supply: 80-90 °C; return: 50-60 %
- Financial aids
  - Feed-in premium (operation)

    if electricity is produced in a process of efficient cogeneration by biomass except condensation plants.

- Green certificates: 16 €/MWh, no organization named which is the supervisor of these certificates

- Description green certificates for DH companies

  Electricity certificates are distributed to producers of renewable electricity for a maximum of 15 years. This means that CHP plants fed by bio energy and younger than 15 years are eligable to recieve the certificates.

  The prices have been varying extremely in the last few years and have been much lower than expected. In early 2017 they dipped to 4 euro/MWh. During the summer 2018 they have again risen to reasonable levels. In 2018, the average has been 16 EUR.

- Responsible institution for granting & subsidies

  The national authority Swedish Environmental Protection Agency distributes an investment support called Klimatklivet (The climate leap), which is a support fpr the most climate friendly investments per invested SEK. It is not possible to apply for techniques that have seperate support schemes (like PV installations).

  There are four calls a year and each time the submitted applications are weighed against eachother based on how much CO_2 emissions are reduced per invested sum. This fund is open for district heating and LTDH, even though large investments in pipes in trenches can make the investment to large to compete. LTDH with cheaper pipe infrastructure should have a good chance though.

- Subsidy measure

  Klimatklivet

- Amount of money spent on development of DH networks and boiler rooms over the last 5 years

  n/a

- Determination of investment subsidies for DH companies

  The entire cost for the system can included in the application and the the competition is decided on reduced CO_2 emission/cost unit (Swedish krona)

- Tax aids for DH companies

  None

- Other possible aids

  No directed aids.

- Taxes
  - Carbon dioxide tax (only if fossil fuels are used)
  - Energy content tax
- Fuels under energy taxation
- Fossile fuels have CO_2 tax and energy tax. 1 EUR = 10 SEK (to make it easy)
  - Coal: energy tax 661 SEK (~ 66.1 €) per 1000 kg and CO_2 tax 2865 SEK (~ 286.5 €) per 1000 kg = 3 526 SEK (~ 352.6 € per 1000 kg)

  - Natural gas has different tax dependign if it is used for vehicles or in biolers. For boilers: 3 425 SEK/ 1000 m³ (~ 342.5 €/1000 m³)
  - Oil for heating: 4161 SEK/m3 (~416.1 €/m³)

- taxation information in English available

  no, but: Energy taxes: https://www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/energiskatter/skattesatserochvax-elkurser.4.77dbcb041438070e0395e96.html It is in Swedish, but a table that is quite easy to read

- other possible drivers of DH price

  After a big storm in Sweden in 2005 when electricty distribution was severely effected, a new law came that all electric cables should eb dug down and thereby climate protected. This has meant big costs for the utilities distributing electricity. When it comes to DH, the pipes are already dug down, but with risk for flooding and earth slides following heavy rains, it could theorectically mean the DH companies will have to evaluate their distribution.

  Looking at a more current issue, DH is under heavy pressure from other heat sources like heat pumps, which has the benefit of a low electricity price that has lasted for a few years. This also means the CHP plants receive less income from their old cash cow, the electricity production, which affects the overall balance.

- Calculation method for determining DH price

  Difficult to answer, business secret

- If the grid is owned by a different operator than the heat producer, how are the costs/profits devided?

  No fixed model. It is negotiated seperatly in every single case.

- Customer prices for DH incl. VAT

  - Residential

    85 €/MWh

  - Industrial

    Not public

  - Public sector

    ?

- Why are there differences?

  The production industry have discount on the energy tax.

  Big consumers can extra for peak load, which households do not pay.

  There is often a monthly fee, which is more significant for households who uses less kWh.

  Public sector can lift all VAT on everything they purchase within the country.

- Regulator of pricing

  Every district heating company decide their own prices, but there is a national authority, Ener-

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gimarknadsinspektionen, overseeing the pricing to make sure they are not increased unrealistically.

- Payment made on basis of heat meter (in majority)

  Yes

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Annex

The following annexes belong to this work:

- Excel based calculation tool *LowTEMP_life-cycle cost analysis LTDH_V0-9*
- Manual *LowTEMP_ Performing Life Cycle Cost Analysis on (LT)DH systems*

Both of them are uploaded together with this work on the projects internal document library LinA.

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