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D.T2.2. COUNTRY SPECIFIC PLANNING GUIDELINES FOR SMALL DH

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Content

1. Introduction

The planning guidelines for biomass and renewable district heating aim at providing an overview of the planning procedure from the project initiation to the plant commissioning phase. They are based on the planning guidelines of QM Holzheizwerke, the experience of the Austrian and German project partners and other EU projects focusing on RES DH. The target group of this guidelines are potential operators and investors of biomass district heating systems.

High quality planning strongly affects the efficiency and economic success of the plant. After the erection of a plant possible planning mistakes can only be corrected at high financial costs or cannot be corrected at all. Hence, the planning and commissioning procedure is essential for the long-term success of the project. It is strongly recommended to involve experienced planning experts at an early stage of the project as their know-how is valuable and absolutely necessary.

The planning guidelines of QM Holzheizwerke are a more comprehensive version of the planning procedure for biomass district heating and can be downloaded via www.qmholzheizwerke.ch.

The ENTRAIN project aims at improving the capacities of public authorities to develop and implement local strategies and action plans for enhancing the use of endogenous renewable energy sources in small district heating grids, whether it is solar, biomass, waste heat, heat pumps or geothermal energy. Implementation of these action plans will lead to a CO2 emission reduction, to an improvement of local air quality and to socio-economic benefits for local communities through the growths of technical expertise, the start-up of in-vestments and innovative financial tools. The project is funded by INTERREG CENTRAL EUROPE.

1.1. Renewable district heating systems

District heating systems distribute heat produced from a variety of sources to residential, public and commercial buildings using insulated underground pipes. Instead of individual heat supply units in each building (e.g. a gas boiler), the district heating network provide the required heat for each building (consumer) from hot water flowing through the district heating network.

District heating systems typically comprise:

- Central or distributed heat productions plants (each can have multiple production units) where heat is generated using either just one fuel or source (monovalent plants) or different fuels or heat sources (bivalent/multivalent plants). Each feed in point into the district heating network has network circulation pumps, a heat meter and a temperature control. Optionally, the heat production units can be equipped with thermal storages.
- Insulated underground pipes (steal or plastic) carrying hot water around the network in a closed circuit. The pipework typically consists of a flow (supply) line transporting heated water to the consumers and a return line (parallel to flow line) to transport the cooled water back to the heating units for reheating. Two pipe systems and water as heat transfer medium is the most common setup, while there are only a few steam systems remaining and 3- or 4-pipe systems are usually just applied for special applications.
- Heat transfer stations (heat exchanger, control and measuring equipment, valves, etc.) to transfer the heat from the pipe network to each consumer connected to the system. The heat transfer station separates the district heating system from the consumer side and allows a safe heat supply, measuring/billing and control. Depending on size, technical standards and special requirements there are various designs of heat transfer stations applicable. A direct supply is possible but not very common.

The utilisation of biomass (wood chips, bark, various wood residues, straw, etc.) and the therefore required heating plants are a frequently used heat source and initial driver for renewable district heating. They typically consist of one or multiple biomass furnace and boiler units with heat recovery (e.g. economizer, flue gas condensation), a fuel storage and fuel transport system, a flue gas cleaning system (incl. flue gas fan, ducts and chimney) and an ash handling and storage system as well as an hydraulic, electrical, measurement and control systems.

Besides biomass as a main fuel of current renewable district heating, various other renewable heat sources are increasingly becoming important and are combined with biomass heating plants or integrated into other district heating systems to increase their share of renewables such as:

- Solar thermal collectors
- Directly usable waste heat (if temperature level is sufficient) or heat pump driven utilisation of low temperature waste heat from various industrial or other sources
- Heat pump driven utilisation of ambient heat (air, lakes, rivers, shallow geothermal energy) heat from waste water/waste water treatment plants, …
- Geothermal energy

Even though these alternative heat production technologies significantly differ from biomass heating plants, the general planning and construction procedure, basic quality criteria and basic considerations regarding dimensioning based on consumer heat demand is similar or likewise respectively. The ENTRAIN project provides guidelines for a simplified evaluation of the potential for renewable heat, see www.interreg-central.eu/ENTRAIN

Even renewable district heating systems may have natural gas or oil boiler units as back-up and/or for peak load coverage. Depending on the situation this can be technically and economically meaningful, if the share of fossil fuel remains negligible.

1.2. Project procedure

The project procedure for planning and realisation of a renewable district heating system contains various tasks that should take place in a specific chronological order. For each of these steps specific stakeholders are involved and responsible:

Tasks	Responsible stakeholder
Map/image of supply area	Operator/Investor, Support of Energy Agency, local stakeholders, planner
Heat demand assesment	Operator/Investor, Support of Energy Agency, local stakeholders, planner
Assessment of potental heat sources and fuel asortments	Operator/Investor Support of Energy Agency, local stakeholders, planner
Drafting of the heating network	Operator/Investor Support of Energy Agency,planner
Legal Requirements	Operator/Investor, Planner, Support of Energy Agency, Public Authorities
Technical/Economical Pre-Feasibility	Professional planner, Operator/Investor
Detailed Feasibility Study	Professional planner, Operator/Investor
Detailed Planning, Tendering and Constrution	Professional planner, Operator/Investor, manufacturer
Commissioning and Optimisation	Professsional planner, Operator/Investor, manufacturer

1.3. Aspects affected by legal issues and national constraints

The planning, construction and operation of biomass or renewable district heating plants concerns various laws, provisions and standards and requires building and operation permits. Besides general regulations and standards for civil, mechanical, electrical and heating engineering and general legal aspects for founding and managing a heat supply company the following aspects have to be especially considered within planning and obtaining building, operation and environmental permits:

- Biomass fuel standards, special fuel assortments and fuel qualities and utilisation allowances

- Availability of biomass fuels, fuel logistics and therewith related spatial requirements for transport and unloading as well as potential noise disturbances
- Emissions (solid, liquid and gaseous, noise, odour), emission limits and therewith related requirements regarding flue gas cleaning and emission prevention, emission measurement points in flue gas duct or chimney, …
- Ash handling, utilisation (e.g. as fertilizer, additive, ...) and disposal
- General safety regulations, special safety devices for heating plants
- occupational health and safety, including fall protection, protection against accidental contact (hot surfaces, conveyors, …), danger of suffocation (e.g. in fuel storages)
- General Fire protection including explosion prevention (gas, dust, …) and lightning protection, structural fire protection, special devices for fire detection and protection of biomass furnaces
- All technical and legal regulations regarding building and operation of district heating networks including easements for pipe network and water quality requirements
- Regulations regarding metering, billing and heat price regulations (if existing), protection of data privacy
- Funding schemes and therewith related legal, economic issues and technical criteria and constraints
- Potential disturbances of neighbouring residents (emissions, noise, odour, traffic, plume, ...)
- Requirements of land use e.g. for large solar fields and storages and therewith related issues;
- Further potential issues: special environmental requirements/permits (e.g. specially protected areas, compensating areas, relocation of animals, special protecting measures, ...), flood protection, conservation of architectural heritage, solar glare assessment, …
- Implementing other heat sources such as waste heat, heat pumps, geothermal energy may cause additional legal issues, permits or constraints which have to be checked and considered individually

As regulations and standards may differ from country to country, they cannot be implemented in these planning guidelines. It is the responsibility of experts/planners to know and apply the corresponding regulations and standards used for the specific country, to support the application of building and operation permits and to ensure that the planning and the construction of the plant is according to the state of the art.

Furthermore, we strongly advice to evaluate if there are any other special national constraints which may influence the technical concept of a biomass or renewable district heating plants and which may have to be especially considered.

The terms used in these guidelines may vary from country to country. Please refer to the authors, literature or your planning expert in case of ambiguity.

1.4. Quality management

Biomass and renewable district heating plants are infrastructure projects with high initial investments, and long lifetimes and payback periods. The complexity of the planning and investment entails numerous risks. Quality Management for Biomass District Heating Plants (QM Holzheizwerke®) is a project-related quality management (QM) system helping plant owners to actually receive the quality they ordered and to reduce these risks. Hence, quality management pay off.

QM for Biomass DH plants is the result of a cross-border cooperation. The team of developers of the QM for Biomass DH plants (ARGE QM Holzheizwerke) consists of experts from Germany, Austria and Switzerland who are continuously involved in the improvement of the system.

The most important quality objectives of QM for Biomass DH plants are

- reliable, low-maintenance operation
- high utilisation ratios and low distribution losses
- low emissions in all operating conditions
- precise and stable control systems
- ecological and economic sustainability

2. Feasibility analysis

2.1. Pre-Feasibility

Person in charge: Planner, energy agency/consultant, investor

Pre-feasibility analyses are an early strategic planning stage to identify or evaluate potential supply areas and potential heat sources and to roughly check if a district heating project could be feasible.

The result is a basis of information do decide, if further steps should be undertaken such as performing/ordering a detailed feasibility. A pre-feasibility study is not sufficient to decide regarding the realization of a plant!

The first step of the preliminary analysis is an indicative determination and mapping of the heat demand of all consumers (space heating, domestic hot water, process heat) within a potential supply area.

The accurate estimation of heat demands is a time-consuming task, especially for large numbers of consumers. Hence, the effort therefore should be limited at that stage in order to find the most promising areas with high heat demands and focused on larger consumers. The proposed approach is the use already available tools (often free of charge) and easy accessible data (e.g. Energy Performance Certificates - EPC). A description of free available GIS-tools and different simple heat demand calculation methods can be found in the document Heat demand calculation, Annex: Collection of tools. A detailed determination of heat demands including visiting all consumers to evaluate their data is scope of the detailed feasibility study, but contacting some of the most important main consumers, to check their heat demand requirements and their interest in renewable DH is advisable.

Knowing the heat demand of individual consumers, heat demand density areas can be determined as a first criteria to evaluate the area regarding suitability for district heating. The heat demand density in kWh/(a.m^2) is defined as the ratio between the annual heat demand of the consumers in the potential supply area and the total land area in m^2.

A first assessment of the region and the identification of focus areas can be done by comparing the determined heat demand densities of an area with the reference values of the following table.

Reference heat demand density values to evaluation opportunity areas for district heating (Good et al., 2008)

Suitability of the district heating system	Heat demand density in kWh/(a.m^2)
Low	< 50
Conditioned	50 - 70
High	> 70

Besides determining heat demands, an inquiry on possible heat sources within or near the potential supply area need to be done. A biomass heating plant could serve as an initial point as long as there are suitable biomass resources available within a certain distance (e.g. 50 km but depending on plant size and fuel quality). However, it is strongly recommended to start evaluating the potentials of waste heat, thermal solar and heat pump applications. Determining potential heat sources strongly influence first economic considerations and the determination of potential plant locations.

The next step is to draft a potential routing of the pipe network considering the main production sites and potential consumers using focusing on areas with high heat densities and large consumers. Based on that, the linear heat demand density can be calculated. It is defined as the ratio between the annual heat demand of the connected consumers and the total necessary route length of the district heating grid in m.

District heating systems with a linear heat demand density over > 1,2 MWh/(a.m) are promising and should be further evaluated. However, it depends on the specific boundary conditions and expansion phase. Favorable boundary conditions allowing lower linear heat densities e.g. means low construction costs for pipe construction or low fuel prices.

Guiding values for the minimum required linear heat density of district heating system (Good et al., 2008).

Degree of connections	Minimal acceptable heat demand linear density in MWh/(a.m)	
	Favourable boundary conditions	Unfavourable boundary conditions
First expansion phase	0,7	1,4
Final expansion phase	1,2	2,0

Based on these basic results an experienced expert is able to determine a rough draft concept of a possible heating plant configuration considering potential heat sources and plant size. Using specific investment costs for heat production units, construction works and pipe network a first indicative economic assessment can be done. However, due to the early stage of planning and the therewith related required assumptions and uncertainties, the technical and economic evaluation at that stage is only indicative, unprecise and does not allow making a final investment decision. If the results of the pre-feasibility study are promising, it is strongly recommended to carry out a detailed feasibility study of the district heating system according to chapter 2.2.

2.2. Detailed feasibility study

Person in charge: Experienced planner (technical consultant)

The detailed feasibility study aims at developing feasible technical concepts based on a reliable heat demand inquiry and defined frame conditions and provides comprehensive an economic evaluation of these concepts.

The results of the feasibility study allow investors to decide whether the DH project should be realised or not.

The starting point is the data and results already identified in the pre-feasibility, which are further evaluated and validated and turned into detailed technical concepts. It is recommended to develop several different concepts (e.g. heat sources, technical setups and dimensioning of plant and network, plant locations, network routing, …) and then evaluate and compare them to find the best option.

It is of great importance to invest time and money into a detailed feasibility study in order to find the best technical and economical solution, minimize investment risks and obtain a reliable basis for further decisions which have significant influence on the success of a project. Therefore, it is strongly recommended to assign professional and experienced planners for this task.

Improvement of the available dataset

The first step is the revision and validation of the heat requirements (annual heat demand, heating installed capacity and operating temperatures) to reduce the uncertainty of the results. Therefore, a detailed heat demand inquiry for the supply areas determined in the pre-feasibility study is necessary. It is strongly recommended to visit potential customers and gather the required data directly from them (e.g. fuel/energy bills). For that purpose, a questionnaire on consumer data can be used (e.g. the one from QM Heizwerke see Annex: Collection of tools). In the case of new constructed buildings, the yearly heat demand can be calculated following standardized methods, e.g. EN ISO 13790. Only missing information should be added using other methods and well-founded assumptions based on available information, e.g. building type, year of construction, number of residents, known information (e.g. heating capacity) of similar objects (see Annex: Collection of tools). Furthermore, the potential interest of each consumer to connect to the district heating network must be assessed. Latest before making a final investment decision at least 75% of the expected heat sale must be secured by heat supply contracts or preliminary agreements.

Design of the District Heating System

In this phase of planning, the probable location of heating plants and other heat sources must be determined. The required plots of land should be secured by means of preliminary agreement if necessary and possible. Knowing the position and heat requirements of the consumers and the position of heating plants or heat sources a preliminary design of the district heating network (routing, dimensioning of pipes) can be done. General considerations therefore are:

- The pipe network should be as short as possible to reduce investments, heat losses and pumping costs.
- Heating plant and heat sources should be as close as possible to the consumers (especially large ones). However, there are several other aspects to be considered, among them; the price of land, fuel logistics (e.g. truck access restrictions), access to basic infrastructure (power grid, water supply, sewage system, etc.), minimum distance to neighbouring residents, environmental limitations and others (see chapter 1.3).
- The basic dimensioning of the pipes is based on the required heat transport capacity of each pipe or section of the network (related to capacity and location of consumers and producers), the system temperatures (temperature difference) and recommended maximum flow velocities or a specific pressure drop (in Pa/m) which can be derived from literature or technical standards. In the end it is a complex technical/economical optimization problem balancing investments versus costs for heat losses and pumping while several other influencing factors need to be considered as well (e.g. future development of the heat demand and the supply area). For the feasibility study a basic design and dimensioning to determine investment and operating costs are sufficient. However, for the detailed planning phase comprehensive calculation and optimisation of the network using therefore developed software is strongly recommended.
- Pre-insulated district heating pipes are state-of-the-art. If steel or plastic pipes are used depends on the indented system temperature and pressure and other influencing factors and

need to be decided individually. The same applies for choosing the insulation standard of the pipes, but nowadays built networks or network enlargements usually take very high insulation standards.

- Manufactures offer standard designs for heat transfer stations up to 200 kW or even lager which can be adjusted to special requirements (e.g. metering) For larger consumers or consumers with special requirements individual designs are applied (scope of the detailed planning phase).

Notice that the investment costs of the district heating network are a main part of the overall investment costs. Thus, an optimal design is of great importance and will highly influence the economic feasibility of the project.

Design of the heat production

The main decision on what heat sources to be used depends on availability, costs and many other influencing factors (e.g. distance to network, supply profile, temperature level). This requires an individual evaluation by experts considering the local situation. It is strongly recommended to take all renewable options into account. There is a clear trend to the utilisation of all locally available heat sources. Hence, no option should be excluded without detailed evaluation. The development of detailed technical configurations of the production units is a complex task to be done by experts but general considerations therefore are:

- Main requirements of the heat production are high efficiency, minimum use of resources, minimised emissions, high reliability and supply security and minimised heat generation costs.
- The dimensioning of boilers and other production units strongly depends on the load profile of the district heating network (cumulated profile of all consumers). In interaction of all production units (e.g. biomass & solar thermal) and storages the required heat load profile must be covered at any time. However, every production unit has constraints regarding supply profile, min/max load, partial load behaviour and load change gradients, required start-up and shut down times and many more which must be considered.
- Operating states outside the defined limits of each individual production unit (e.g. below minimum load rate, frequent starts and stops) and interactions between production units causing such operating states or other negative effects must be avoided at all costs.
- The configuration and dimensioning should allow high operational flexibility (e.g. a multi-boiler plant is much more flexible than a single boiler plant) and should allow future enlargements.
- Oversized plants lead to low full load operation hours, high investment costs and low utilisation of the capital respectively as well as to low efficiency and various other operational problems.
- Biomass heating plants should have a pre-defined fuel supply concept to ensure later availability of fuel and to define the fuel quality in order to obtain a suitable storage, handling and combustion technology and fuel costs.

Economic evaluation and sensitivity analysis

Once the district heating network and the heat production units are designed, all relevant investment and operation costs can be determined in detail and it is possible to perform an economic evaluation of the different plant concepts. Even though there are various simplified calculation methods we strongly recommend to use a dynamic cash-flow model to calculate the payback period of investments. Additionally, the heat generation costs can be calculated using an annuity method. By any means, a serious and proven definition of investment and operation costs is required considering all aspects as well as future re-investments. Costs for planning, continuous maintenance, sufficient staff costs, vehicles (if required), cost of financing and other costs must not be forgotten. The excel tool “Economic profitability calculation” listed in Annex: Collection of tools can be used to carry out such detailed economic calculation.

Notice that the reliability of the obtained results greatly depends on the input data. Therefore, it is important that an experienced planner is responsible for this calculation and that all input data are critically checked and validated by the investor. To consider heat sales revenues a tariff model for the heat sale needs to be defined. An analysis of the local heating prices will help the determine of a competitive heat sales price. The excel tool "cost comparison" listed in Annex: Collection of tools can be used to carry out this analysis. A sensibility analysis will help to understand which the most relevant influencing parameters are and to evaluate best/worst case scenarios, to determine minimum required revenues (heat sales price) or a maximum fuel price.

The consideration of local boundary conditions such as possible subsidies and synergies with other projects (e.g. shared costs for network construction, if other construction works for roads/infrastructure are ongoing).

Final evaluation and investment decisions

The different technical designs (scenarios) and the economic evaluation are the basis for the decision-making process. Any relevant aspect of the project that has not been taken into account so far or couldn't be clarified (e.g. pending agreements on pipe laying on private land, signing of heat sale contracts, secure of needed land via provisional agreements) needs to be taken care of before a final decision is taken. Once an investment decision is made and the heat delivery has been contractually guaranteed with the majority of customers the detailed planning and realisation of the project can start.

3. Detailed planning, tendering and cunstruction

Person in charge: Experienced planner, manufacturer

Aims: Development of the final technical concept and preparation of all required technical documents for the application of permits and the construction of the plant; tendering of all required manufacturers and companies for the construction of the plant and network; supervising the construction;

Results: All required permits for building and operating the plant are approved. The plant and network are completed and ready for commissioning.

First of all, the technical concept of the feasibility study must be revised and validated. This is the basis for the preparation of documents for the application of permits which depend on the respective national legislation (see chapter 1.3 for details) and for the tendering. Concerning tendering firstly it has to be decided whether a general contractor is to be commissioned to build the entire plant, or if individual parts of the work are put out for tendering. Both options have advantages and disadvantages and must be carefully weighed up. Assigning a general contractor reduces coordination work and the investment costs are not necessarily higher but it has to be ensured, that a careful and serious planning is applied and that the general contractor is an experienced expert with proven references. In case of individual tendering the overall scope of work is divided into useful sections such as construction work, piping and heat transfer stations for the district heating network and e.g. construction works, furnace/boiler unit including fuel transport, ash disposal and flue gas systems, hydraulic installations and electrical installations. Individual tendering enables more flexibility and more participation in decision making (e.g. choosing manufacturers and technological options). Besides general terms and conditions either option of tendering must precisely define the total scope of delivery including a comprehensive documentation of the plant (manuals, maintenance instructions, technical data sheets, technical drawings, list of wear and spare parts) and mutual responsibilities. It is strongly recommended to include provable quality and performance criteria, define the performance test procedure and include therewith related guarantees (e.g. for heat output, emissions, etc.). The tender must include contractual penalties based on milestones in the timeline (e.g. if delivery to construction site is delayed) and if main quality/performance parameters are not fulfilled. The contract should include a financial retention valid during the whole warranty period, but allowing to disburse this retention if a bank guarantee is provided. Details and open questions should be negotiated and added to the final contract.

If all main parts are ordered, the main planner together with the manufacturers completes the detailed planning and prepares all layout and construction plans and documents required for construction. The coordination of interfaces/connection points and the individual requirements of each part of the plant (especially if manufactured and delivered by different parties) including dimensions is crucial and should be done with great care. The main planner is usually responsible for the construction supervision and coordinates a general timeline, all involved parties and the entire construction works. A strict construction supervision helps to ensure that the plant is built as planned and helps to achieve a correct implementation and a high technical quality. The main planner or a special dedicated safety coordinator is responsible to comply all safety regulations and measures on the construction site. The construction supervisor must keep records of the whole construction phase and report any delays, deviations or other noticeable incidents and has to take care of any ambiguity or inconsistency. In case of deficiencies in the execution of the installations, immediate action must be taken to correct them. The completion of individual plant sections must be reported immediately in order to be able to start the preparation and coordination of commissioning.

4. Comissioning and optimisation

Commissioning is the process of assuring that all systems and components of a plant are designed, installed, tested, operated, and maintained according to the operational requirements of the final client and has to be applied for new plants and existing plants after expansion or revamping. Operational optimisation is the evaluation of the early operating phase and the optimisation of operating parameters and control strategy to ensure high efficiency and plant durability and low emissions.

Person in charge: Manufacturer, experienced planner and operator

Pre-Commissioning and system check

The first phase of commissioning takes place after mechanical and electrical completion of the plant and includes a required task to prepare the system start-up including a final check if main plant components are built as planned (especially piping), safety devices are installed and operational as well as cleaning, filling/deaeration of systems, leakage tests. The start-up of biomass furnaces usually requires rather dry fuel. Fuel storage silos must only be filled up to 30% in case it has to be re-emptied due to malfunctions. It is strongly recommended that the later plant operators are present during the whole commissioning due to training reasons. After pre-commissioning the plant comprehensive system checks must be made to test the functionality of each component, all electric drives and actuators (incl. rotating direction), the whole measurement equipment and control routines.

Start-Up

The general start-up of a district heating system must be coordinated with heat consumer and during start-up, sufficient heat output to the consumer must be guaranteed. Since the start-up of biomass furnaces or other heat production units need time, the peak load/emergency boiler (if existing) or a rented mobile heating unit could support the procedure.

While the start-up of small biomass boiler units is rather easy, large scale industrial biomass furnaces with refractory liner need a special start-up procedure. They have to be heated up slow and carefully according to the manufacturers time-temperature profile while using high quality and dry biomass fuel to dry the refractory liner and check all systems. At the same time all other systems (fuel transport, ash disposal, flue gas system, hydraulic/electrical system) must be put into operation. After sufficient drying of the refractory liner the heat output can be increased stepwise. Depending on the plant size and the number of production units 1-4 days should be considered and a commissioning team (plant operator, control engineer, planner and experienced technicians from all main plant components) should be present or available in short time.

The commissioning is finished and the plant is ready for trial run if all emerged malfunctions are fixed, and the plant is in stable and automatic operation mode. Moreover, all safety tests and the training of the later plant operators have to be completed.

Trial run and approval

It is strongly recommended to include detailed terms and conditions regarding a trial run into the delivery contracts of main plant components for a period of a few days to a couple of weeks depending on size and complexity of the plant. The trial run period is within the responsibility of the manufacturers while the later plant operators support it and use it for additional training. During the trial run all performance tests and emission measurements are done according terms and conditions in the contract and it is used to proof the functionality of the plant and an undisturbed automatic operation. Relevant shortcomings and malfunctions must be resolved immediately. After a successful trial run the scope of delivery, the documentation (incl. manuals, certificates, test and measurement protocols, etc.), the completion of work (detailed plant inspection) and the fulfilment of contracts is checked finally and documented in an approval protocol. After approval (acceptance) the plant ownership and responsibility are handed over to the final client.

Operational optimisation

Even if plants are planned and constructed correctly, experiences show that the actual operation of a plant may differ from what was planned due to various reasons. Within the first 1-2 years of operation a continuous monitoring and operational optimisation shall reveal shortcomings of the control strategy, setpoint values and unintended operating conditions (instabilities, load/temperature fluctuations, high emissions, low efficiency, insufficient load and storage management, etc.). Many of these issues can be resolved with low effort by adjusting the plant control (setpoints/parameters, general strategy).

Basis for the evaluation, is a functional description of different operating modes, predefined benchmarks and quality criteria and adequate measurement and data acquisition system for a comprehensive monitoring of all relevant operating parameters. For further information please take a look at the Info Sheet Measuring Equipment. All of these must be planned and defined during the planning phase of a project as stated in the Q-Guidelines. To foster a successful optimisation together with the responsible manufacturers and the main planner, it is strongly recommended to consider financial retentions during the warranty period in the delivery contracts of main plant components and include monitoring and optimisation services in the assignment of the planner.

5. Annex: Collection of tools

Overview of free available tools and documents that support the planning of renewable district heating

ScenoCalc Fernwärme (SCFW)	SCFW is a calculation tool for the integration of solar installations in district heating systems. It does use hourly weather data to calculate the solar gain. The district heating system is defined by a load profile with hourly values for load, supply and return temperatures. The tool allows a technical evaluation with some flexibility but lack of economic evaluation. https://www.scfw.de/
Sunstore 4	This excel-based feasibility tool can be used to carry out feasibility studies for five different hybrid concepts with 100 % RES such as solar collector, seasonal water pit storage, heat pump and biomass CHP (ORC) or solar collector, short-term water tank storage and biomass boiler. The Sunstore 4 tool is based on the district heating grid in Marstal (Denmark) and includes data (default values) from that project. The tool can be used with other boundary conditions by selecting a different country/region. https://www.solar-district-heating.eu/en/tools/
Sophena	Sophena is an open source software for the planning of heating plants and local heating networks. It offers the possibility to carry out the technical and economic planning of a heat supply project. Further results include a greenhouse gas balance and the heat occupancy density of the network. https://www.carmen-ev.de/infothek/downloads/sophena
Situationserfassung V35 (QM Heizwerke)	This excel-based tool can be used to obtain a load duration curve and size different standard technical solutions with biomass and fossil fuel boilers for a set of predefined boundary conditions (locations). https://www.qmholzheizwerke.at/de/situationserfassung.html
B4B BioHeat Profitability Assessment Tool v66	The B4B BioHeat Profitability Calculator can be used for a comparison of the economic efficiency (pre-feasibility level) of mid-scale, solid biomass and fossil fuel fired (district & in-house) heat-only plants. The application range is for biomass heating plants with and without district heating networks, in a capacity range from 0.1 to 20 MW. https://www.energyagency.at/fakten-service/register.html
Netzverlustberechnung (QM Heizwerke)	With this tool an assessment of heat losses of the district heating network can be done. Introducing total pipe length per diameter and other relevant data such as network temperatures. www.qmholzheizwerke.ch
Berechnungstool Fernwärme	This excel-based tool does a technical and economic evaluation for a specific pipe-length and operational conditions for different pipe diameters. Thus, it gives a good overview of the influence the pipe diameter on the yearly costs. http://www.verenum.ch/Dokumente/FW_Tool_DN-Sensi_V1.0_Web.xlsx
TABULA / EPISCOPE	During TABULA and its follow-up project EPISCOPE residential building typologies have been developed for 13 European countries. Following the seasonal method described in EN ISO 13790 the energy need for space heating

	and domestic hot water preparation has been calculated for each of this building typology. Values for the specific heat demand can be obtained directly from the webtool or using the excel workbook "TABULA.xls". http://episcope.eu/welcome/
Cost comparison	This tool calculates the annual heating costs of different supply concepts (e.g. gas boilers, heat pump) of private consumers in a simplified way. It gives an overview of the local heating prices ("competition") where a district heating system is under consideration/planning. www.qmholzheizwerke.ch
Economic Profitability Calculation (QM Heizwerke)	The "Wirtschaflichkeitsrechnung" tool from QM Heizwerke have been translated into English within the ENTRAIN Project. The tool can be used to carry out a dynamic economic evaluation of biomass district heating system projects. www.qmholzheizwerke.ch
Heat demand estimation – Annex to planning guidelines	This document summarizes some relevant data sources (tools, databases) and simple methods on the estimation of yearly heat demands of buildings. It gives a short description on GIS tools which data can be easily retrieved, a data base which values of the yearly heat demand are mainly based on building typologies and year of construction, simple calculation methods based on Heating Degree Day (HDD) measurements and a summary on proposed values for the heat demand for domestic hot water from different data sources. https://www.interreg-central.eu/Content.Node/ENTRAIN.html
Heat customer data questionnaire (QM Heizwerke)	This questionnaire is a translation of "Fragebogen Anschlußdaten eines Wärmeabnehmers" from QM Heizwerke. It includes most of the necessary information of potential heat consumers for the planning of a district heating system in a structured way. www.qmholzheizwerke.ch

Table 1: Overview of free available GIS-tools that can be of help during the performance of a prefeasibility study

Pan-European Thermal Atlas 4 (Peta4)	The Peta4 is an online map carried out within the Heat Roadmap Europe 4 (HRE4) which main aim is the mapping of relevant information for the heat and cold market. It includes information about heating and cooling demands as well as potential of excess and renewable heat sources. https://heatroadmap.eu/peta4/
THERMOS	The THERMOS is a free, open-source software that aims to offer local authorities address-level data for the optimal design of new or expansions of a district heating system. The software includes data regarding the heat demand at a building level which can be used to identify high density areas. Based on the defined ecological, economic and technical boundary conditions the tool can calculate an optimal district heating system for the selected area. https://www.thermos-project.eu/home/
Hotmaps	The main goal of the Hotmaps project is the development of an open source heating/cooling mapping and planning toolbox and to provide default data for EU28 at

	national and local level. The Hotmaps toolbox is already available and contain data at different scales resolution, being 1 hectare the finest grid element and national the coarsest. A useful option of the tool is the possibility to select specific areas, e.g. hectare cells or regions, and obtain a results summary for it. https://www.hotmaps.hevs.ch/map
Energieholz Kenndaten-kalkulation	The calculation tool allows quick conversion between common volume-related or weight-related biomass fuel prices. The essential characteristic data for different energy wood assortments can be quickly determined and the assortments compared with each other. The economic evaluation is limited to the determination of fuel costs. Verson 1.9 only available in german, version 1.8 available in 10 different languages. https://www.klimaaktiv.at/erneuerbare/energieholz/werkzeuge-und-hilfsmittel/kenndatenkalkulation.html
PLANHEAT	This simulation tool is created to support local authorities in selecting, simulating and comparing alternative low carbon and economically sustainable scenarios for heating and cooling. http://planheat.eu/tool-download https://www.publenef-toolbox.eu/tools/planheat-simulation-tool

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