FLEXIBLE DISTRICT HEATING SOLUTIONS – INTEGRATION AND INTERACTION OF VARIOUS TECHNOLOGIES

Annex to D.T2.2. Planning Guidelines for Small District Heating

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Content

1. Introduction

This document is an annex to the Planning Guidelines for Small District Heating (deliverable D.T2.2. of the ENTRAIN project) and comprises information regarding modern flexible district heating (DH) solutions. Systems using various heat sources and technologies are complex plants and require a careful project developing, design and construction by experienced experts. This annex aims at providing a general overview about the integration of various heat sources and their interactions as well as an overview of new district heating technologies basic things to be considered. It is a guideline for decision makers (e.g. mayors), planning engineers and operators of district heating plants to foster the development of flexible and renewable district heating solutions and the utilisation of alternative heat sources.

More detailed information about the integration of waste heat, heat pumps and solar thermal plants are given in the additional annexes “WASTE HEAT AND HEAT PUMPS FOR DISTRICT HEATING” and “SOLAR THERMAL PLANTS FOR DISTRICT HEATING”.

2. Renewable and flexible district heating

The thermal utilisation of biomass (wood chips, wood pellets, bark, straw and many others) in biomass district heating plants was one of the main drivers to establish small scale district heating systems as a state-of-the-art heat supply technology besides the well-known large urban district heating systems in big cities. Hence, small scale renewable district heating is so far dominated by biomass as the main heat source and biomass is seen as one of the key technologies to decarbonise district heating. This is mainly due to the energy content, the storage capacity and the flexible and regional availability of biomass. From today's perspective, it seems unlikely that biomass will be able to completely cover the world's energy needs without conflicting goals in terms of biodiversity, land, water and food requirements. Nevertheless, biomass will be a supporting pillar of our future energy supply but great attention must be given to a highly efficient, resource-conserving and sustainable use of biomass as an energy source.

To achieve a fully renewable heat supply, it will also be essential to use other regional and renewable heat sources (see chapter 3). Wood heating plants and local heating networks are an ideal starting point for integrating these heat sources and making them usable. Since this in any case leads to more complex plant configurations and interactions between different heat sources, it is even more important to pay great attention to comprehensive and detailed planning with special consideration of the requirements of the individual heat sources, as well as their efficient and low-emission interaction.

Due to the increased integration of different renewable heat sources, the change of boundary conditions (e.g. reduced heat demand of buildings, increased cooling demands) and a continuing technological development many new district heating concepts and technologies appeared on the market within the last decade. There is a clear requirement and trend to

- reduced or flexible system temperatures
- decentral integration of heat production units
- prosumer solutions (heat customers who also feed excess heat back into the DH network)
- intelligent sector coupling with other energy infrastructure (e.g. power and gas grid)
- combined solutions for heating and cooling
- higher system flexibility and increased short and long term (seasonal) storage capacities
- smart metering, intelligent control and monitoring strategies

The basic objective of these developments and concepts is to make district heating renewable, regionally supplied, efficient, low emission, flexible, resilient and thus sustainable, affordable, secure and future proof. Flexible and resilient in this context means to design systems which allow the integration of various existing and future renewable heat sources and the ability to adopt to continuously changing boundary conditions. For example, the general plant and network concept should be open for future enlargements and central or decentral integration of alternative renewable heat sources and storages.

3. Alternative renewable heat sources for district heating

3.1. Basic assessment

Continuously decreasing DH system temperatures (see chapter 4) and the ability of heat pumps to lift temperatures of heat sources, nowadays turn almost everything (even ambient heat) into a potential heat source for DH. For example, it is theoretically possible to use an air source heat pump to convert ambient heat into usable heat for district heating, but with rather low efficiency and high electricity demand. The basic idea is to find the most efficient, ecologic (regarding emissions, CO_2, primary energy demand, ...) and simultaneously economically viable local renewable heat sources and technical solutions. Therefore, highest priority should be on direct waste heat utilisation or thermal solar plants, followed by heat pumps for heat sources with higher temperatures than ambient. Already during this initial analysis, the local boundary conditions, the available potential (power, energy quantity) as well as the respective special technical/non-technical characteristics of the heat sources (temporal availability/load profile, controllability, temperature level, etc.) must be assessed.

Potentially interesting sources should be investigated in more detail regarding technical and economic feasibility. This leads to a profound basis for the planning of a new district heating project as well as for enlarging or refurbishing existing DH systems where these locally available renewable heat sources should be taken into account best possible. Besides own assessments, research of all available information and data sources should be considered, such as:

- Public potential analysis/studies
- Databases and geographic information systems
- Local/regional authorities and municipalities
- Local energy agencies

It is important to be open minded and positive thinking at that stage of a project and no potential heat source should be excluded without having a closer look. Even if heat sources may not be suitable or accessible at the moment, they might be interesting for future plant and network enlargements. Thus, a comprehensive knowledge of the local situation is valuable and should be integrated into design considerations and the development of current and future scenarios.

3.2. Potential heat sources

The following heat sources are commonly known for the integration into DH systems and should be taken into account:

- **Waste or excess heat**
  Waste or excess heat is unused heat produced as a by-product by any kind of man-made processes, hence not only industry. If not used, waste heat is emitted to the ambient directly or using cooling units. Depending on the temperature level of the waste heat source and the required temperature level of the DH network (see chapter 4), it can be used directly or using

heat pumps.
→ see annex "WASTE HEAT AND HEAT PUMPS FOR DISTRICT HEATING" for further information

- **Heat pumps**
  Heat pumps are no heat source themself but they are able to lift the temperature of a low temperature heat source to a suitable level for its utilisation and thus, make all kinds of low temperature heat sources available for DH (e.g. low temperature waste heat, ambient heat from air, lakes or rivers, waste water, shallow geothermal energy, …)
  → see annex "WASTE HEAT AND HEAT PUMPS FOR DISTRICT HEATING" for further information

- **Thermal solar plants**
  → see annex "SOLAR THERMAL PLANTS FOR DISTRICT HEATING" for further information

- **Geothermal energy**
  Geothermal energy is the naturally generated and stored heat in the Earth and origins from the formation of the planet. In contrast to that shallow geothermal sources based on horizontal ground collectors or vertical borehole heat exchangers (typically used for heat pump applications for detached houses) require some kind of regeneration. In case of boreholes regeneration can be provided by deep geothermal energy. For horizontal collectors by natural solar radiation/ambient heat or an active regeneration using other heat sources. The use of geothermal energy for heat and power production is a well-known state-of-the-art-technology. In 2010 already 28 GW of direct geothermal heating capacity were installed for district heating, space heating, spas, industrial processes, desalination and agricultural applications [1]. Its availability strongly depends on the local geological conditions and thus the utilisation of geothermal energy for district heating is so far frequently used in areas where it is well known or easily accessible. But examples of Vienna (project "GeoTief"), Munich and other cities show, that geothermal energy gains more attention as an additional local heat source for district heating. Geothermal energy is usually constantly available but limited in its mass flow, temperature and thermal capacity respectively. Lower district heating temperatures increase the yield of a geothermal source. The utilisation of geothermal energy usually requires special permits which may include specific constraints. Geothermal energy requires large initial investments for identifying potential areas and drilling costs to access it, both related to a certain risk not to find an exploitable source.

3.3. Selection of heat sources (portfolio)

Evaluating and selecting the best portfolio of heat sources is not an easy task and many different parameters must be taken into account. The portfolio of heat sources significantly influences the overall plant design and the economic performance. Hence, considerations about heat sources must be included at an early stage of pre-feasibility studies and into the planning procedure in general.

The most important decision-making criteria are

- administrative and technical feasibility and availability
- heat generation costs

This means, at some point a detailed technical and economic feasibility study need to be carried out to provide a profound basis for selecting the most promising heat sources and finalize the overall plant concept. This includes the designing of detailed technical concepts and is usually part of the overall design procedure as descripted in the planning guidelines. To reduce costs and efforts, a basic assessment of potential sources (see chapter 3.1) and pre-selection (pre-feasibility) should be performed. The following general considerations may help to pre-select sources. However, the relevance of the points in the following depends on the type of heat source and some of them might be contradictive:

- Higher prioritization of location-bound sources (e.g. waste heat or ambient heat) than mobile sources (e.g. local biomass)
- Higher prioritization of non-resource consuming and non-emissive sources
- Higher prioritization of sources with higher (direct usable) temperature levels
- Does the location of the source allow for technically and economically effective integration?
- Does thermal capacity, load profile and seasonal availability fit to the heat demand requirements and possible other heat sources?
- How do other characteristics such as controllability, transport and/or storage ability fit to the overall concept?
- Are there possible positive/negative interactions with other heat sources?
- Are there insurmountable obstacles or is there a reasonable probability that the heat source is utilizable from a technical and an administrative perspective?
  - Talk to stakeholders and assess the situation best possible
  - Are any pre-agreements (e.g. letter of intent) possible?
  - What are the results of roughly technical and economic estimations (e.g. energy balance, basic cost calculation)?
- How about supply security and long-term perspective?
- Are there any comparable reference projects proving the feasibility?

The chosen heat source portfolio should lead to a system with low CO_2- and other emissions, low input of primary energy and resources in combination with low heat generation costs and high reliability at the same time.

4. District heating system temperatures

Small scale district heating systems are mostly operated at supply temperatures between 80 and 95°C which is also referred to as the 3rd generation of district heating. Steam DH systems (1st generation of DH) are almost vanished nowadays and temperatures above 100°C (2nd generation of DH) are usually only used in large urban DH networks. Since many years DH technology shows a clear trend to reduced supply and return temperatures in order to allow an easier and more efficient integration of renewable heat sources and to reduce heat losses of the pipe network. Related to that, Lund et. al. [2] introduced the concept of the 4th generation of district heating with renewables as the main heat source and system temperatures below 70°C. The guidebook "Implementation of Low-Temperature District Heating Systems" of the IEA DHC TS2 (IEA technology collaboration programme concerning district heating and cooling) provides comprehensive information about the potentials and benefits of low-temperature-DH and transition strategies to implement it. Furthermore, it provides a collection of various already realized low-temperature-DH projects and proves the feasibility and success of this technology.

Figure 1 shows an overview of the system temperatures of these newest generation of DH systems and the limitations related to the supply temperature. So-called warm DH systems above about 60°C are able to provide space heating and domestic hot water directly and conventional DH technology with heat transfer stations can be applied. Regulations regarding hygienic domestic hot water preparation typically require a minimum temperature. Hence, DH systems below 60°C (often referred to as cold DH) usually do not comply with that any more. This requires a change in technology and the application of alternative solutions for domestic hot water preparation (e.g. a heat pump booster). The limit of providing space heating directly is at about 30°C but that already requires low temperature heating systems in buildings. DH systems operated at temperatures below that use individual heat pumps in order to lift the temperature to the required level. Rather than providing heat directly such DH networks serve as a shared source for individual heat pumps. If the system temperatures are below 20°C the DH network can provide heating and cooling at the same time.

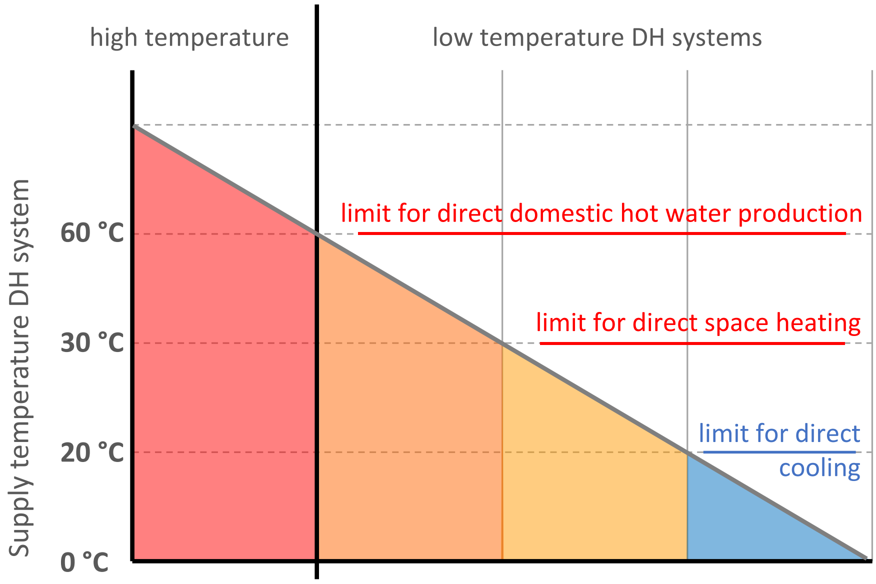

Figure 1: Range of supply temperatures in DH systems and related limitations (image based on [3])

It strongly depends on the specific situation of each project, which system temperature and the therewith related DH concept should be applied. A low temperature or even cold DH system is not necessarily better. Which system temperature to be chosen strongly depends on the applied hat sources (see Chapter 3.3) since some heat sources are temperature sensitive such as solar thermal and heat pumps and others are not.

A biomass boiler, for example, can easily provide higher temperatures and its efficiency does not depend on supply and return temperature of the DH network. Thus, if biomass is the main heat source, there is no need for a cold network with supply temperatures lower than 60°C. This also applies if waste heat with a sufficient temperature level for a direct supply of space heating and domestic hot water preparation is available.

However, the network temperatures should be kept as low as possible to reduce heat losses and also allow a better integration of additional renewables at a later stage. If a flue gas condensation unit is applied for heat recovery, low return temperature levels significantly influence the efficiency of the heat recovery. If only low temperature waste heat sources or ambient heat is available, either a central large scale heat pump and a warm DH network or a cold DH network and distributed (decentral) heat pumps can be applied.

5. New DH concepts

Conventional district heating technology usually follows clear and well-known technical concepts and system configurations. Due to many new options regarding heat sources, temperature levels and DH technologies various new and often very specific system configurations appear. The basic requirements of being renewable, flexible and resilient lead to more complex system setups and control strategies for many new systems.

Creativity and open-minded thinking at the beginning of a project helps to create innovative ideas and concepts. But then these concepts must prove themselves by assessing their technical and economic feasibility. For new systems additional administrative or legal barriers may arise and need to be especially considered (see chapter 6 for further information).

The following gives a short overview of general considerations and some technical options. However, due to the high planning demands by the increasing complexity of such new systems beyond the state-of-the-art this cannot replace a detailed planning procedure with the support of highly skilled and well experienced engineers. A good guideline for the approach to develop a comprehensive and appropriate overall concept is given in [4] (see chapter "9.2.1 Holistic heat supply strategies").

5.1. System and plant configuration and dimensioning

In connection with the increasing requirements for future flexible DH solutions a comprehensive and detailed planning is even more important. Thereby, the following issues should be considered and investigated:

- Choosing a suitable mix of heat sources (het source portfolio – see chapter 3.3)
- Choosing a suitable overall system configuration of the DH network to connect all heat sources, storages and heat/cold customers
    - central/decentral positioning of plant components and integration into the overall system
    - choosing a suitable temperature level for the DH network
    - choosing a suitable general operation strategy for the DH supply with the selected heat sources (interaction of heat sources)
- Dimensioning, prioritisation (unit commitment to heat production) and load management of the selected heat sources as heat producers
- Heat storage dimensioning and management
- Designing and applying a comprehensive and intelligent control and monitoring system

Each heat source has its own characteristics and boundary conditions that have to be considered for the integration into DH systems. Further information regarding waste heat utilisation and the integration of solar thermal plants can be found in the additional annexes "WASTE HEAT AND HEAT PUMPS FOR DISTRICT HEATING" and "SOLAR THERMAL PLANTS FOR DISTRICT HEATING".

A central point is the selection of a suitable system and plant configuration, matching the selected portfolio of heat sources. The good coordination of the dimensioning of the individual heat generators with each other (temporal availability/load profiles of the selected heat sources) is particularly important. Furthermore, there are high requirements for the dimensioning and management of heat storage systems, which are partly a prerequisite for the sensible use of alternative renewable heat sources.

5.2. Central or decentral integration and prosumers

While it is common (state-of-the-art technology) for large urban DH systems to be supplied by multiple production units at different locations, this is less common for small scale DH systems which mainly have one central heat production plant. However, if it is required due to the individual framework conditions given, or if it is beneficial, this is also implemented in small scale systems. Typical examples are the decentral integration of an existing boiler for peak load or summer operation, the integration of a biogas plant, a waste heat source or a solar thermal plant into small scale biomass DH networks.

The decentralised integration of additional heat sources results in increased requirements for the monitoring and control of the entire system. Previously simple heat customers can also become heat suppliers, so-called prosumers. A prosumer is both, heat consumer and heat supplier at the same time. This new customer category is emerging in connection with the decentralised integration of alternative renewable energy sources at heat consumers, similar to the electricity feed-in of smaller private photovoltaic systems into the public power grid.

5.3. Intelligent control and monitoring strategies

In order to cope with the increasing complexity of the systems for successful plant operation, comprehensive and intelligent process control and monitoring concepts are necessary. In this context and also with regard to the evaluation of system performance, comprehensive data collection, recording and (long-term) storage is necessary as well. The data collection should include all heat producers and consumers (smart metering) in order to obtain a holistic picture.

For the successful later implementation of a developed control strategy it is important, to take the requirements related to control issues (e.g. controllability of the different heat sources) into account at the design of the overall system concept from the very beginning. The following points are relevant for the design of an intelligent and easy to handle control system:

- If possible, integration of all data and control surface in a single (superordinate) process control system
- Well-coordinated control of all heat production units (heat sources)
- Definition of clear responsibilities and unambiguous delivery boundaries and interfaces
- Remote access to de-centralised heat production units (heat sources)

6. Administrative issues to be considered

General administrative issues emerging for new DH systems with various heat sources are briefly described in the following. The following topics are relevant in this context (without claiming to be exhaustive):

- **Additional administrative or legal barriers** may arise for new DH systems and need to be especially considered. For example the effort for negotiations with authorities (to obtain permits) can be considerably increased. In a first step it must be checked which laws and regulations must be complied with and which authorities are responsible depending on the heat source and technology to be integrated.
- **Business models**
  Both, the heat production units as well as the DH network of small DH systems are usually in public or private ownership of a single institution (e.g. municipality or cooperative) or company, which results in a monopoly position for the district heating supply. For the production units this situation can potentially change with the introduction of new (alternative) heat sources and additional producers ([5]).
  There are four main ownership models for district energy systems: consumer, public, private (commercial) and public-private partnerships (PPPs). […] *The motives of publicly and privately owned DHC projects are often fundamentally different in terms of initiation, development and financing. For example, a publicly owned DHC project is more likely to pursue lower heat prices and environmental and socio-economic benefits than a privately-owned project, which*

will largely focus on maximising company profits. Consumer-owned DHC projects often seek the lowest heat prices. [5]
Each of the four ownership models has certain benefits and challenges (see [5] for further information).

- **Innovative heat tariff models**
  The introduction of motivational tariffs can be advantageous for promoting suitable framework conditions for the integration of alternative heat sources into new (possibly low temperature) DH systems. E.g. incentive systems for customers to adapt their heating systems for low return temperatures or flexible tariff models with the objective to redistribute peak loads (additional charging during peak load periods) can be implemented (see chapter 9.3 in [4] for further information). However, suitable smart meters have to be available at the heat customers in order to be able to implement such tariff models.

Which business model is most suitable and if innovative tariff models should be applied, has to be decided on a case-by-case basis. The overarching objective should always be to create win-win situations for all stakeholders.

References

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