CONCEPT DEVELOPMENT OF AN INDUSTRIAL WASTE HEAT BASED MICRO DH NETWORK

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ABSTRACT

District heating (DH) systems are an effective and efficient way to address the challenges of urban areas in terms of energy efficiency, use of renewables and CO_2 emissions reductions [1]. The design and operation strategy of such systems is not always trivial and several questions appear, especially when integrating a significant share of fluctuating, small scale and distributed low temperature heat sources: How to optimize a network design, how to operate a network in an energy and cost efficient way? How to integrate different technologies? How to satisfy customers ‘needs when they have different profiles?

This paper briefly presents the CITYOPT project, which aims at creating a web application with guidelines to support efficient planning and detailed design and operation of energy systems in urban districts. A demonstration case for testing the CITYOPT application is then presented: A concept/feasibility analyses for a micro DH network in Vienna, based on industrial waste heat at different temperature levels rejected from a nearby industrial facility. The study includes the consideration of one standard office building, two energy efficient office buildings, existing renewable energy supply (solar thermal heat and heat pumps) and thermal storages (long and short term), to balance the heat production and demand. In the future, different configurations of the district network will be modelled and tested through APROS, a multifunctional dynamic simulation tool and linked to the CITYOPT application, in order to determine the optimal design solution.

Keywords: micro-DH network, industrial waste heat; energy systems, smart cities

INTRODUCTION

The green transition of the District Heating and Cooling sector can be achieved through large-scale replication of best practice by 2020: better valorization of local resources, such as renewable (including secondary biomass and waste) and surplus energy [2]. Systems must evolve to provide more flexible solutions for instance low temperature networks and the integration of innovative thermal storage. These solutions must fit customers’ profiles and be applicable to different scales from small neighborhood solutions to city wide networks. The efficient utilization of local waste heat (excess heat from industrial processes, waste incineration and power stations) together with other renewable energy (geothermal energy, large-scale solar thermal energy or large-scale heat pumps) in district heating networks becomes essential in future sustainable cities [3-5]. The integration of various sources is difficult to handle, since standard tools and operation strategies don’t consider low-temperature and fluctuating sources with a significant share. These issues are addressed in the CITYOPT project and in particular in the Vienna demonstration case.

The CITYOPT project is a collaborative European project [2] whose main objective is to create applications that bring together information and guidelines for designing scenarios of energy systems and help prioritizing alternative energy solution scenarios based on social, economic and environmental criteria. The “CITYOPT Tool” will provide support for decision makers through a platform which can be used to combine diverse input information in order to perform simulations (interactions with any simulation software will be possible) and optimizations based on the input information and mathematical models. This information can be used to build indicators which allow the performance analysis of an energy system under different conditions. In particular, the CITYOPT tool will be tested with APROS simulation software (a simulation energy software allows to model complex urban energy system in a flexible way [6]) on the Vienna case study which consists of an industrial fed micro-DH network including existing and new buildings together with short and long term storages and renewable energy supply.

This paper is structured as follows. First the method used within the project to identify the challenges of the case study is explained. Then the Vienna case study of is described. The network concept development and the challenges are presented afterwards.

METHOD

Initially, the Vienna case was selected to be studied within the CITYOPT Tool because it embodies the main challenges of future DH systems as mentioned above (various industrial waste heat, renewable and fossil heat sources, low-energy consumers and standard consumers, storages).

Several steps were necessary to develop the DH network options that will be evaluated. First of all, the supply heat sources characteristics were either manufacturer information (solar panels, heat pumps, gas boilers) together with literature or monitoring data (temperatures and fluctuations of the industrial waste heat source). The energy demand characteristics were obtained from TRNSYS simulations of the buildings, where monitoring data of the energy consumption were used to calibrate the simulation. The second step was the identification of the specific challenges from the case study, through preliminary design studies and workshops with different stakeholders and thematic experts:

- Technical challenges: hydraulic and multi-temperature level constraints, integration of various sources and consumers with low-energy demand
- Social challenges: behaviors and comfort requirements from the end-users
- Economic challenges: current and possible future business models

CASE STUDY AND CHALLENGES

The Vienna study case is based on three office buildings, TECHbase (Tb), ENERGYbase (Eb) and FUTUREbase (Fb), located in the 21st district of Vienna. Fb is under planning but not built yet. They lie in close proximity to Rail Tec Arsenal GmbH (RTA), a facility using one of European largest climatic wind tunnels. During these tests a huge amount of waste heat is rejected from the chillers to the air [7].

This case study of Vienna is a particular case of interest for the investigation in the CITYOPT Tool, since it can bring a lot of knowledge and concepts for future developments of smart and micro district heating networks (DHN). Indeed, it gathers many current and future challenges regarding DHN, such as how to integrate in a hydraulically connected system: renewable sources, industrial waste heat (fluctuating heat source, with different temperature levels), thermal storages (short term and long term) in order to satisfy the heat demand of low energy buildings and standard buildings, with respect to environmental, energetic and economic objectives. This case study is not trivial since the optimum dimensioning and design of the system components (topology of the distribution network according to multi-temperature levels and pressure levels, hydraulics of the network and control strategy) require particular attention and the use specific tools. The different temperature levels that have to be included in the network are illustrated in Figure 1.

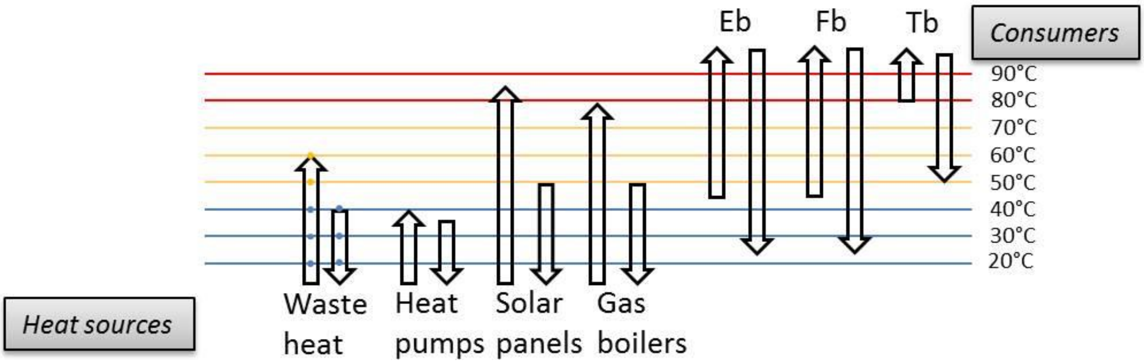

Figure 1: Supply and return temperatures of the heat sources and the consumers

Apart from the network design, the control strategy has also to be well defined in order to allow an optimum operation of the network, addressing issues such as, which situation is more profitable to store heat for long or short term, the number of prosumers who can feed the grid at the same time or how much heat can be store, considering the renewable and waste heat available. Additionally, the complexity of this system brings the need for the development of new business models which consider local price regulations, customers' needs, the prosumers integration, network operators and industrial profitability.

Moreover, this micro-DH can be used as an example that could be scaled up or adjusted to many cases of networks that have to be refurbished or extended. These are some questions that arise with this specific study case that can help for similar case studies [3-5, 8-10].

The current situation the different components is illustrated in Figure 2. A gas boiler provides heat to Tb. Fb will have a solar thermal array and potentially an additional ground source heat pump (not shown on Figure 1 for drawing reasons). Two ground source heat pumps and solar thermal panels provide heat to Eb. Fb and Eb are designed for a maximal use of the internal gains from occupants and equipment in order to almost eliminate heating demand. The average daily heat demand profile for Eb and Tb are shown on Figure 3 [11]. The test case is to connect all the components by a micro-DHN. Several scenarios are designed for the study case and will be simulated through APROS. More detailed information about this study case in [11].

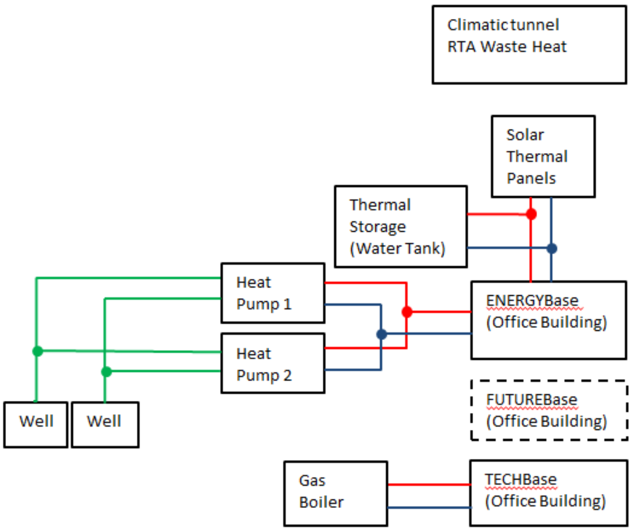

Figure 2: Base scenario –3 independent buildings and an industry are located in the same area.

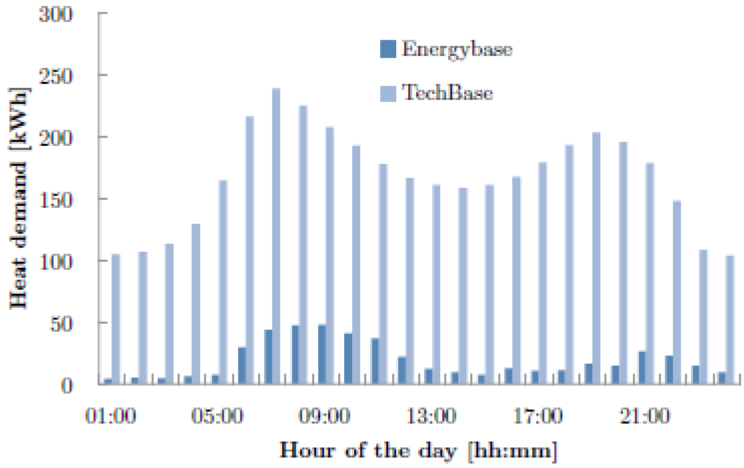

Figure 3:Average daily heat demand profile for 2010, (mathematical models [12]).

Moreover two possible storage solutions are envisaged, a water tank as mid-term storage and boreholes heat exchangers as seasonal storage, to allow the storage of excess energy from the solar thermal panels and from the RTA chiller. Depending on the experiments performed in the RTA´s climatic tunnel the temperature levels and total heat loads of the waste heat able to be supplied to thermal energy network will vary significantly, as illustrated in Figure 4. In addition to this, the periods of the facility when no experiments are taking place have to be considered. Therefore mid-term thermal storage is expected to be an important feature of the balancing system, making it a key component of the thermal energy network performance in the Vienna study case. Using the mid-term storage, the surplus heat could be stored for a few days to enable the network to balance heat generation with demand.

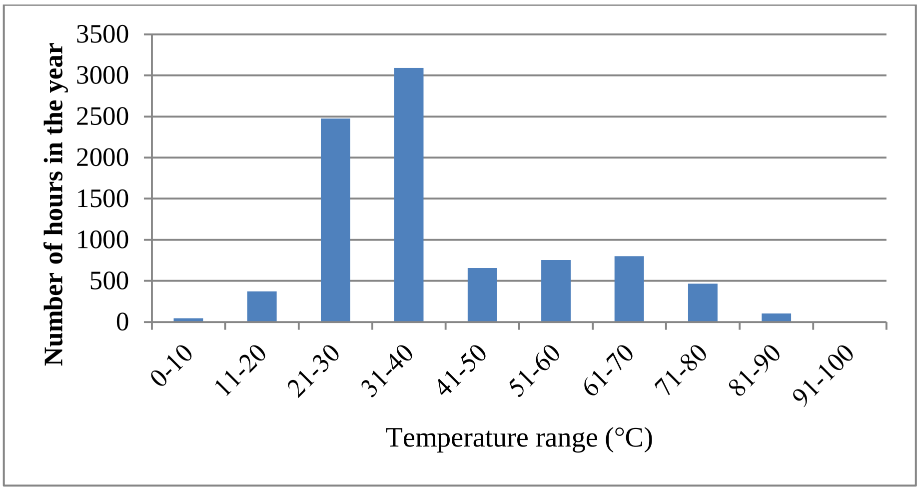

Figure 4: Frequency of temperatures that can be supplied by the industrial waste heat source. (based on a study of the heat rejection system of RTA [12]).

To produce usable information, the CITYOPT tool will perform optimizations on different scenarios which have different options in terms of the design of the water tank, ground heat exchanger, the topology of the district heating networks together with operation of the system according to the variation on the defined constraints. The best design of the district heating network will be determined according to specific criteria (optimization variables) to maximize the rejected heat to the ground, to maximize the energy efficiency of the chillers of the RTA´s climatic tunnel, to minimize the CO_2 emissions of the overall system according with the technical and economic constraints, to minimize the import of energy (gas and electricity) to the system or to minimize the energy bill of the office buildings. The optimization process should be run under several type of constraints such as: the maximum size of the water tank, the maximum area were the boreholes of the heat exchanger can be allocated, the maximum temperature of the ground which can be reached by the rejected heat, the minimum and maximum temperature levels of the warm water needed to cover the heat demand of the office buildings, economical constraints based on the investment and operational cost of the system, fluctuations on the production of the waste heat from RTA´s climatic tunnel due to its use, influence of the weather conditions in the heat production from the solar thermal panels.

DISCUSSION/ OUTLOOK

The Vienna case of micro DH-network is a challenging study case, insofar as it is a small scale network, it consists of several components, with specific characteristics, that can be connected in different ways. The four network configurations which will be designed in more detail and the Base scenario that will be later simulated in the CITYOPT tool are presented in Table 1. Various thermal, dimensioning and hydraulic issues arise for each possible design scenario, such as:

- the pipes configuration/ network topology which is more efficient (less expensive, more controllable): choosing between bi-directional use of pipes and the use of several pipes in parallel.
- how to connect the buildings to supply the grid and to take energy from the grid (a direct connection or heat exchangers),
- the number of network pumps that should be used, especially considering bi-directional flow from and to the buildings/storages (some buildings can receive and supply energy to the network)
- the possible need for (micro-)booster heat pumps to deal with the different temperature levels of supply and demand,
- the optimal size for the storages in order to optimize the balance between heat generation and demand, maximize the utilization of waste energy, to minimize the losses, costs …

Simulations and optimizations through the CITYOPT tool will address these issues and determine the optimal network design according to the key performance indicators defined (e.g. total costs, CO2 emissions, share of renewables, waste heat supplied, primary energy consumed, storages contribution …).

	Base Sc.	Sc. 1	Sc. 2	Sc. 3	Sc. 4
Micro-net	No	Yes	Yes	Yes	Yes
Water tank	No	Yes	No	No	Yes
Ground storage	No	No	Yes	No	Yes
Waste heat source	No	No	Yes	No	Yes

Table 1: Different network configurations which will be simulated.

CONCLUSION

To address the challenges of future DH systems, a small scale case study in Vienna has been selected as role model. This case study is including existing and new buildings, waste heat from an industrial climatic chamber, renewables (heat pumps, solar panels), fossil heat source (gas boiler), and storages. The design and operation of such systems, with a high share of alternative heat sources and different customer characteristics, is complex and its optimization faces many challenges. A suitable decision environment (CITYOPT tool) will be applied in the future to the specific case study to handle the aspects mentioned above.

At the time of the writing, the CITYOPT project is still in its running phase. So far it has been decided to evaluate four configurations of networks and the Base scenario. Each of these configurations will be optimized (system design parameter, temperatures, size and power of pumps, size of storages, control strategy) and various indicators will be calculated out of the simulation results, in order to determine the best design scenario that will allow satisfying consumers' needs at the least costs and environmental impacts. The results given by the CITYOPT tool will allow decision makers and planners to design networks based on the analysis of a large panel of possibilities.

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