Low-temperature heating and cooling grids based on shallow geothermal methods for urban areas

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ABSTRACT

Low temperature heating and cooling (LTHC) grids are innovative approaches to meet the heating and cooling demand especially in urban areas. In October 2018 the authors started the interdisciplinary applied research project "Smart Anergy Quarter Baden" (SANBA), with the aim of developing a LTHC grid for the former military camp "Martinek-Kaserne" in the City of Baden south of Vienna, which was abandoned in 2014 and for which there are plans to develop a new urban mixed-use quarter. The main challenge for this project is the condition of the buildings which date back to the 1930s and which are protected by cultural heritage. The need for refurbishment of the buildings is given regardless of their future use. The refurbishment of the buildings that they are suitable for a low-temperature heating and cooling distribution system is a new aspect for the owner, the Austrian Federal Ministry of Defence. Key elements for the LTHC grid are the use of industrial low-temperature waste heat from processes in the neighbouring NÖM dairy plant as well as the development of refurbishment and conversion concepts for the protected buildings. The approach and the first results will be presented at the conference.

1. INTRODUCTION

LTHC grids were installed first in Switzerland around 10 years ago. In Austria, some research projects have dealt with the feasibility of those grids and in Vienna, there are two small LTHC grids in operation. The topic of LTHC grids gains increasing attention particularly in urban areas in Austria, due to (I) the increasingly lower temperature demand of heating distribution systems in new buildings which often have a high building standard (passive house or similar); (II) energy efficiency measures in old buildings (thermal insulation, new windows etc.); and (III) the trend to decentralised heating and cooling grids with an increased share of renewables, supporting local or national climate and energy goals. The number of so-called local energy communities, especially in urban and sub-urban areas, where high-temperature district heating is not available or where the building and usage structure allows for low-temperature heating and cooling, is expected to increase substantially over the next years.

In general, the knowledge of the main components of LTHC grids is well developed. The actual challenge is not the design of the single components but rather the hydraulic and thermal interaction of all components with its high degrees of freedom. Standard procedures for the technical design of common district heating networks and geothermal installations are therefore not appropriate. For that reason, a fully dynamic simulation tool with coupled thermo-hydraulic processes is important for dimensioning the components and their interaction with the grid. In comparison to common district heating networks the flow direction is bidirectional. Hence, heat can be carried to and from the consumer, depending on the season and heating/cooling demand. The geothermal energy storage must balance the residuum of the actual energy demand of all users and should be designed with balanced annual heat load and discharge. Finally, a complex network with the interaction of many users and different load functions and constraints have to be considered in the system design. Additionally, the possible change of users or power loads must be taken into account and concepts for reliability have to be elaborated. In addition to the seasonal geothermal storage also technical thermal storages may play an important role, when a short time balance of heating and cooling is required or to optimize the heat pump operation time. Furthermore, it is of advantage to use photovoltaic (PV) systems for the operation of the heat pumps and their impact will therefore be under investigation in this project.

LTHC grids are, technically speaking, networks of pipes, distributing water with temperatures in the range of 4 and 22 °C at most times (min. 2 and max. 30 °C) between individual buildings and/or groups of buildings. The water can be used for free cooling as well as cooling or heating with the help of heat pumps. Usually, the networks are connected to seasonal storage units for thermal energy (Figure 1).

LTHC grids have the following main characteristics (Figure 1):

- Low grid temperatures (4 - 30 °C) for supplying heat pumps (heating and cooling) as well as provision of free cooling capability, if the temperature level is suitable.
- Include seasonal underground storage of thermal energy, with balanced annual heat load and discharge.
- Implementation of available local low exergy heat sources (e.g.: waste heat, solar heat, geothermal resources, waste water heat).
- Low carbon emission and low environmental footprint.

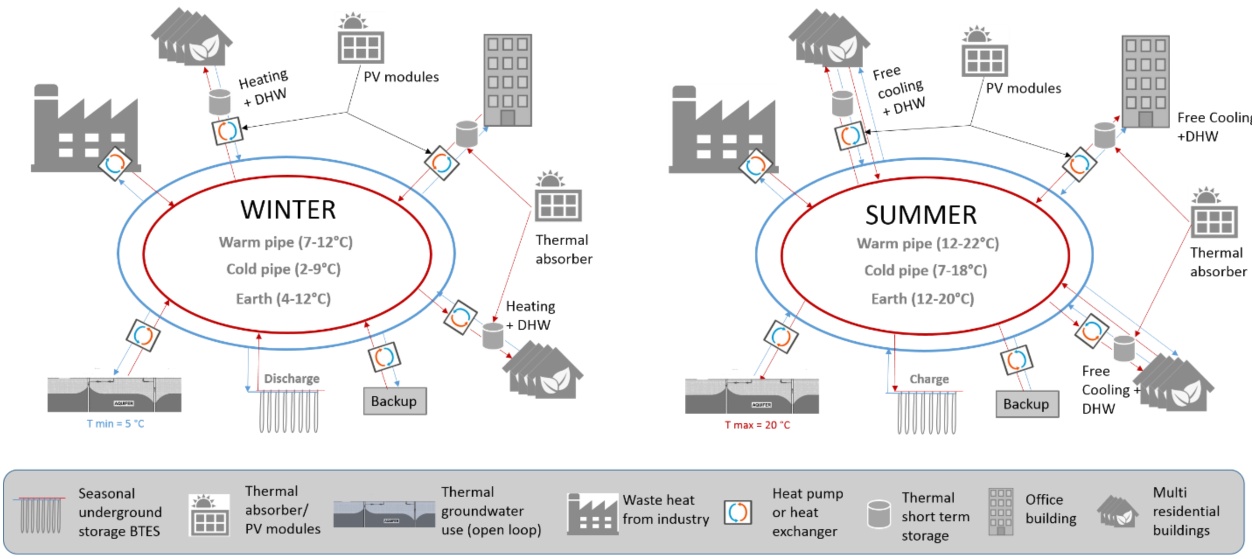

Figure 1: Illustration of the general concept of a low-temperature heating and cooling grid, its components, and the operating conditions in winter (left) and in summer (right).

2. PROJECT SMART ANERGY QUARTER BADEN (SANBA)

In October 2018 the authors started an interdisciplinary applied research project, with the aim of developing a LTHC grid for the former military camp "Martinek-Kaserne" in the City of Baden south of Vienna, for which there are plans to develop a new urban mixed-use quarter. Key elements are the use of industrial low-temperature waste heat from processes in the neighbouring NÖM dairy plant as well as the development of refurbishment and conversion concepts for the protected buildings.

2.1 Investigation area former military camp "Martinek-Kaserne" in Baden south of Vienna

The former military camp "Martinek-Kaserne" was constructed by architect Leo Splett of the construction management of the German Luftwaffe during the war years 1938 to 1943 as antiaircraft defence base. After the Second World War, the camp was used by the Soviet Army and then by the Austrian Military until 2014, when the Military Camp was abandoned. The property owner is the Austrian Armed Forces with the Austrian Federal Ministry of Defence as superordinate institution.

Figure 2: Satellite view of the NÖM plant (right) and the "Martinek Kaserne" (left) (Google Earth)

The vast property with an area of 40 hectares with buildings protected by cultural heritage has been subject of several development plans over the years. Plans to sell the property to an investor were unsuccessful up to now, since the conditions of the buildings and the sheer size of the project has proven a challenge too big even for the most ambitious investors. Over the last years the main stakeholders, i.e. the Federal Ministry of Defence as property owner, the City of Baden, the Federal Monument Protection Agency, and the neighbouring municipality Sooß, which owns a small part of the "Martinek-Kaserne" property, have discussed several options for the future use of the area. Some areas of the former camp can potentially be developed with new buildings, whereas these developments have to be elaborated with the main stakeholders, mentioned before.

One of the biggest challenges of the project is the status of some of the buildings of the "Martinek-Kaserne". Since the abandonment in 2014, the condition of the buildings deteriorates very rapidly (Figure 3). In a meeting with the Federal Monument Protection Agency in April 2018, the representative of the Agency made a statement which summarizes the need for refurbishment measures concerning the buildings: *"One year of abandonment of the buildings has the same implications for the buildings as ten years of use".* This statement emphasizes the need for action, because every year of non-use deteriorates the buildings at an exorbitant rate. Independent of the future use of the buildings, there has to be a concept for refurbishment soon.

Buildings under cultural protection are subject to certain limitations in terms of thermal renovation and energy efficiency. From the provisions of monument preservation external insulation is usually not permitted, as they affect the appearance of the building massively. The focus is on measures that can increase energy efficiency without endangering their appearance or substance. Despite energy efficiency measures, buildings under protection usually have a higher heat load. Higher heat loads are provided by high flow temperatures of the heat distribution system. A LTHC grid works with low supply temperatures and usually requires customers to get accustomed to low supply temperatures to maximize the performance of the heat pumps.

2.2 Scenarios for a future use of the "Martinek-Kaserne" and resulting research questions

Over the past years after the abandonment, the "Martinek-Kaserne" has been subject to many development plans. The need for refurbishment of the buildings is given regardless of their future use. The refurbishment of the buildings that they are suitable for a low-temperature heating and cooling distribution system is a new aspect for the owner, the Federal Ministry of Defence. The Ministry itself carried out or ordered studies for a possible future use of the buildings. Three possible scenarios for planning and simulation of the LTHC grid for the "Martinek-Kaserne" will be developed.

- Use of only the existing building stock with protected buildings ("Mini")
- Use of the existing buildings stock + 50 % of free area with new buildings ("Midi")
- Use of the existing building stock + 80 % of free area with new buildings ("Maxi")

The subsequent work for the design of the LTHC grid will be carried out in close coordination with the stakeholders. The design and simulation of the grid will be independent of the future use, whereas a future use of the "Martinek-Kaserne" again merely as a military camp is excluded after talks with the stakeholders. The user and therefore load profiles of the buildings are assumed as mixed, with housing, commercial and office buildings, education etc., whereas we can work with preliminary studies of architects and developers as a guideline for the development of the scenarios.

Figure 3: Pictures of the interior of the buildings and the outside area. The central staff building with the main entrance and the round tower is well-preserved. The upper two pictures show the dining hall and the main meeting room in the round tower. In some pictures, the poor condition of the buildings – partially due to damage by water - even after only four years of abandonment and signs of vandalism can be seen.

3. DESIGN OF THE LTHC GRID

In a first step, all essential data from the site will be gathered, whereas the available data can be classified as follows:

a. *Geoscientific data:* (hydro-)geological data, e.g. maps, data of boreholes, existing water rights; construction of test borehole, enhanced thermal response test (eTRT) measurements, soil and water examinations, geoelectric measurements;
b. *Technical data:* Possible components in the LTHC grid, technical and energetic specifications and boundary condition;
c. *Building data:* Assessment of the existing building stock, load profiles etc.;
d. *Economic data:* Definition of essential cost components, price research etc.

ad a.: After the geoscientific data collection and the measurements at the borehole, a hydrogeological model will be established out, which will feed into a process model based on the software FEFLOW™ to assess the thermal interaction of thee subsurface (solid soil and possible groundwater layers) with the seasonal heat storage.

ad b.: Following the three scenarios, the distinct energetic boundary conditions will be developed for each scenario. Furthermore, the energy system of the NÖM dairy plant will be analysed to determine the energy potentials for the LTHC grid.

For the simulation of the LTHC grid new and communicating simulation tools will be developed to cope with the complex situation of the area, consisting of different heat sources, protected and potential new buildings, different temperature levels and times of energy demand, different uses of the buildings, etc. The tool will comprise

(I) the heat recovery from the wastewater, cooling units and compressed air of the neighbouring NÖM dairy plant,

(II) integration of locally available renewable energy sources,
(III) energy storage aspects,
(IV) the special challenge of different building standards of the old protected buildings vs. newly built buildings with different usages (living, commercial, education), and therefore different supply temperatures and demand characteristics, and
(V) moderate cooling via Free Cooling.

ad c.: The existing building stock will be assessed with regard to the renovation needs and the thermal requirement for refurbishment, in accordance with the monument protection standards. Subsequently, the free areas will be assessed for potential new buildings and usage, in order to generate realistic load profiles. For each scenario, the HVAC systems will be designed, including the energy transfer to the LTHC grid and the energy distribution within the buildings.

ad d.: On the basis of the available cost data, a method for a comprehensive economic assessment of the LTHC grid, considering environmental costs and benefits will be developed. The calculations support the assessment of the competitiveness of LTHC grids with industrial waste heat and geothermal heat supply compared to fossil-fuel based grids and district heating.

4. OUTLOOK

The project results will support the stakeholders in the decision, whether the concept of an anergy grid at the area of the “Martinek-Kaserne” is technically and economically feasible and whether this concept should be pursued further.

The project’s results will be an important first step contributing to the wider implementation of LTHC grids in Austria. It will allow for the screening of sites as well as for the planning of grid designs. The consortium is aiming to support potential developers with the realisation of the LTHC grid at the “Martinek-Kaserne” military camp in the near future.

Furthermore, a positive demonstration of the feasibility of LTHC grids for protected buildings and/or buildings which are subject to refurbishment, can lead to further application of these concepts at other military camps. The Federal Ministry of Defence is one of the biggest land owners in Austria and owns many other military camps in Austria, for which LTHC grids could be an interesting option for a future sustainable energy supply.

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