IPN DSTG – Development of Smart Thermal Grids
Results report

Hanne Kauko
SINTEF Energi AS

31.01.2018

1 Objectives and background

Approximately half of buildings' energy demand is related to heating and cooling. At the same time, the amount of industrial waste heat available in Europe is estimated to be in the same order of magnitude as the total heating demand. District heating (DH) is a significant technology in that it enables efficient and economical utilization of surplus heat sources to cover the buildings heating demands. Today's DH networks in Norway have supply temperatures ranging from 80-120 °C; however, modern building stock with low heating demands does not need heat at such high temperatures. Lowering the supply temperatures provides several significant advantages, including reduction in distribution heat losses; possibility to utilize low-temperature surplus heat, available for instance from data centers and food retail stores; and increased production capacity and improved efficiency of renewable heat sources, such as solar thermal and heat pumps.

It is impossible to lower the supply temperature in the entire DH network due to existing customers with high temperature demands. Transition to low-temperature DH must therefore start from new building areas consisting mainly of modern buildings. Due to the complexity and high investment costs related to DH systems, there is a great interest in simulation and planning software to find the most optimal solutions regarding production and distribution of heat.

Hence, the primary objective of the project DSTG was to develop a tool for evaluation of energetic, economic and environmental benefits of utilizing a local smart thermal grid for a building area. This encompasses the evaluation of different smart thermal grid solutions, including low-temperature heat distribution, innovative thermal storage solutions and utilization of available surplus heat and renewable energy sources, as well as interaction with the district heating network.

The secondary objectives leading to the accomplishment of the primary goal were:

- Mapping the heating demand and load profiles for the most typical building types in Trondheim through analysis of existing energy use data and/or simulations.
- Mapping the applicable renewable and surplus heat sources, as well as solutions for seasonal and diurnal thermal storage, and evaluating their costs and environmental impact.
- Modeling and simulating a smart thermal grid for a building area consisting of different building types to consider the thermodynamic limitations of the above-mentioned smart thermal grid solutions.

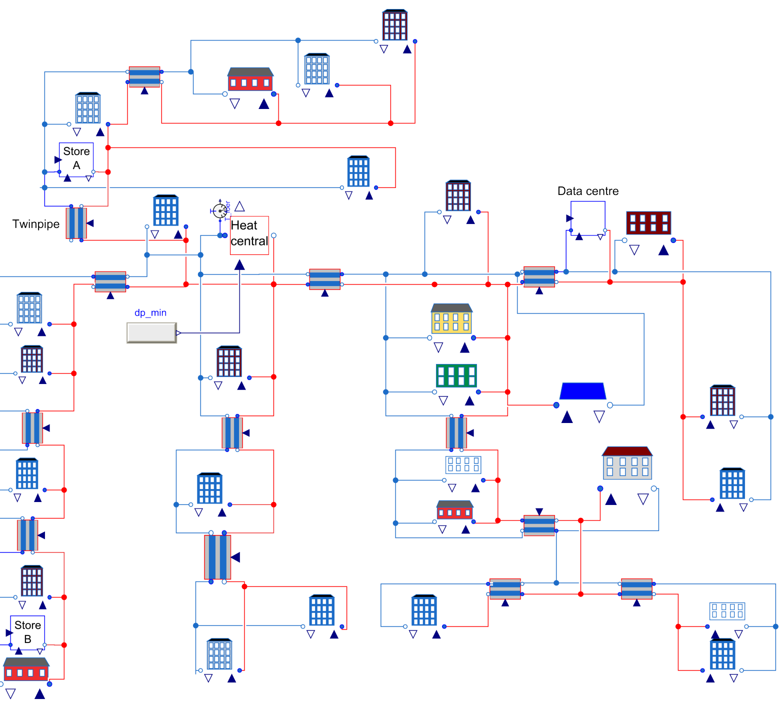

Figure 1: The modeled building area in Dymola, including different building types, piping, surplus heat suppliers (a data center and two food retail stores) and a heat supply plant. The supply lines are denoted with red, and the return lines with blue.

2 Account of the achieved results

The main objective

In the project, a tool for modeling a local thermal grid for a building area has been developed in the dynamic modeling software Dymola. The system model included component models for different types of buildings, piping network, a heat central and surplus heat suppliers, as shown in Figure 1. The tool allows the user to model and simulate a local thermal grid with different types of buildings in detail, and to dimension and design the system based on real DH use data. The tool has been applied to study the benefits and potential drawbacks of low-temperature heat distribution; as well as to study the utilization of waste heat from sources often present in urban areas, such as food retail stores and data centers, in the local thermal grid.

With the model, different scenarios were simulated for Brøset, a building area planned to be built in Trondheim. The simulated scenarios include e.g. high-temperature reference scenario, with supply temperatures corresponding to today's level (75-115 °C), low-temperature scenarios, with supply temperature levels of 65 and 55 °C, and a low-temperature system with surplus heat providers (data center and food retail stores). In addition, the effect of peak shaving in the buildings was studied for the high-temperature scenario.

The simulation results demonstrated the benefits of low-temperature heat distribution in terms of drastically lowered heat losses (by up to 30 %), as well as the drawbacks related to increased energy demand for pumping. The results were further applied to calculate the environmental benefits of the low-temperature systems, with and without waste heat supply, with respect to the conventional high-temperature system. After discussion with the partners, economical evaluation was not carried out; mainly because the main research efforts were focused on developing the thermodynamic thermal grid model, and partly due to the lack of appropriate input data for the investment costs. A methodology for cost analysis of local energy systems will however be developed in FME ZEN.

Diurnal thermal storage was studied in the form of peak shaving, which assumed local thermal storage to be present at the buildings. In addition, initial studies on connecting the local thermal grid to a borehole thermal energy storage (BTES) system were carried out with the model. To fully account the benefits of seasonal storage in BTES however, a rigorous parameter study of the different designing parameters (e.g. depth of the boreholes, mass flow rate and set-point temperatures), and an advanced control system is needed. These aspects were not covered in the project, but will be studied further in two spin-off projects: KPN LTTG+ and KPN RockStore.

Secondary objectives

- *Mapping the heating demand and load profiles for the most typical building types in Trondheim through analysis of existing energy use data and/or simulations*:

  This was carried out during the first year of the project. The gathered data was used as an input in the simulation model.

- *Mapping the applicable renewable and surplus heat sources, as well as solutions for seasonal and diurnal thermal storage, and evaluating their costs and environmental impact*:

  - Surplus heat suppliers were included in the model and their environmental impact for the system was evaluated. The costs of surplus heat were not considered.
  - Solar thermal and heat pumps were regarded as the relevant renewable heat sources for local thermal grids. An initial model of a network utilizing solar thermal collectors and a BTES was built, however this model needs further refinement to obtain reliable results. The main output from the simulations performed with the initial model was that the solar thermal area required to cover a reasonable share of the heat demand of the area is so huge that the system would not be feasible.
  - Diurnal thermal storage was implemented through peak shaving, which assumes thermal storage to be present in the buildings. Initial studies of a system incorporating seasonal storage in the form of BTES were carried out, as mentioned above.

- *Modeling and simulating a smart thermal grid for a building area consisting of different building types to consider the thermodynamic limitations of the above-mentioned smart thermal grid solutions:*

  This objective was fulfilled to the highest degree, and the main results were published in two journal publications (the second one is under review) [1, 2].

3 R&D tasks and project roles

The most important R&D tasks carried out in the project:

- Collection of DH use data for different building types.
- Development of a modeling framework for simulating the heat flows in a local thermal grid, including different building types and multiple heat suppliers.
- Simulation of different scenarios and verification of the simulation results from the basis of the operating experiences of the local DH provider, Statkraft Varme.
- Participation in relevant conferences in the field and publication of project results in scientific publication.
- Dissemination of the results to the general public via pop-scientific articles and open seminars.

Groups that have played a key role in the project implementation:

- The research group in Energy efficiency at SINTEF Energy Research carried out the majority of the R&D tasks. The core team consisted of Hanne Kauko (project leader), Karoline Husevåg Kvalsvik (main responsibility for modeling) and Ingrid Camilla Claussen (quality assurance and project supervision).
- Norwegian University of Science and Technology (NTNU), Institute of Energy and Process Engineering, contributed with scientific expertise in the field, with associate professor Natasa Nord as the main contributor. In addition, Daniel Rohde (PhD candidate in KPN INTER-ACT) contributed significantly in the modeling work. The collaboration with NTNU created also the necessary contact point towards potential Master and project students for the project.
- Statkraft Varme AS was the project owner, and a main contributor in the project with their expertise and practical knowledge in running DH systems. Statkraft Varme provided also DH use data for new apartment blocks.
- Municipality of Trondheim contributed with DH use data from public buildings (schools, nurseries and nursing homes), as well as with up-to-date information on city planning. The latter was important for identifying relevant areas to be studied in the project.

4 Project's implementation and use of resources

In the initial project application, the project owner was the real estate company Ren Risvollan AS, and the project was directed for developing a smart thermal grid solution for the Risvollan neighborhood in Trondheim. Due to uncertainties related to the building process and ownership at Risvollan, Ren Risvollan AS withdrew from the project at an early stage. Luckily, Statkraft Varme was willing to take over as a project owner. At the same time, the direction of the project was changed towards the development of a generic early stage decision tool for the design of thermal grids for building areas, as described in section 1. Owing to a smaller project consortium and changed scope, the project budget was reduced by approximately 50 %.

The R&D work in the project has been carried out by SINTEF, as stated above, with strong support from Statkraft Varme. SINTEF Buildings and Infrastructure was involved as the second research partner, however after the above-mentioned change in the project scope, their role and contribution became minimal.

During the project, there have been five steering committee meetings, and six workshops and smaller working meetings to discuss the modeling work in more detail. These meetings have been extremely fruitful, with good discussions among the project partners. The project and these meetings were also acknowledged by the project owner at several occasions. In addition to the internal meetings, an open seminar on Green area development and low-temperature DH was arranged in August 2017, engaging relevant players from the public sector, energy companies and real estate developers to collaborate in city planning, and hence to achieve green area development [3].

The main results from the simulations were presented at the international conference for Smart Energy Systems and 4th Generation District Heating in 2016 and 2017, and published in two scientific publications [1, 2] (the second one is under review). Three Master's theses were written within the project [4, 5, 6], and one of the master students worked also as a summer student for Statkraft Varme during 2016 [7]. The project was additionally disseminated to the general public via three pop-scientific publications [8, 9, 3].

5 Anticipated significance of the results

Many of the biggest cities in Norway have ambitious goals regarding electrification and decarbonization. As an example, Trondheim aims to reduce direct climate gas emissions with 80 % with respect to 1991 level by 2030. Consequently, the demand of electricity for transport will increase drastically, and the role of DH in unloading the electric grid becomes increasingly important. To achieve green area development, and to be able to cover the peak energy demands in the future, it is important to utilize the synergies between DH and the electric grid.

In this context, the knowledge developed in the DSTG project is extremely relevant and timely. The developed modeling and simulation framework has already shown to be extremely relevant for the work in FMEs HighEFF and ZEN, and the framework will be developed and utilized further in the newly granted KPN projects LTTG+ and RockStore. As a result of the open seminar arranged within the project [3], new collaboration projects involving the electric supplier TrønderEnergi, Statkraft Varme and the municipality of Trondheim are under development to respond to the challenges in the changing energy market.

Finally, the business model of Statkraft Varme is gradually evolving from operating a centralized DH system at a high temperature level (3rd generation DH), towards the operation of several smaller low-temperature systems with multiple heat sources (4th generation DH). The project results are thereby important for Statkraft Varme in improving their business model.

6 Plans for disseminating and utilizing the results

As mentioned above, the results are utilized in the newly granted KPN projects, LTTG+ and RockStore; in FMEs HighEFF and ZEN; as well as in project initiatives involving different energy companies and the municipalities. Statkraft Varme is involved in many of these projects and initiatives, such that the fruitful collaboration that was started in DSTG will be carried on – and Statkraft Varme will be able to benefit from the outcomes of DSTG also through the new projects.

The significance of the development work on thermal grids has also been recognized centrally at SINTEF, which has an internal focus area in smart cities.

7 Results that are expected to be finalised after the completion of the project

The second journal publication will be finalized at the start of 2018. In addition, a manual on the modeling tool will be provided for Statkraft Varme during start of 2018, along with a demonstration session for the entire company to show how the model is used.

References

[1] H. Kauko, K. Kvalsvik, D. Rohde, A. Hafner, and N. Nord, "Dynamic modelling of local low-temperature heating grids: a case study for norway," *Energy*, p. 13, 2017.

[2] H. Kauko, K. Kvalsvik, D. Rohde, N. Nord, and Å. Utne, "Dynamic modelling of local district heating grids with prosumers: A case study for norway," *Under review in Energy*, 2017.

[3] H. Kauko, "Store muligheter for grønn områdeutvikling i Trondheim," *SINTEFblogg*, September 2017. https://blogg.sintef.no/sintefenergy-nb/store-muligheter-for-gronn-omradeutviklingi-trondheim/.

[4] S. Schumacher, "Smart and cost efficient energy interactions in building complexes." Master's Thesis, Norwegian University of Science and Technology (NTNU), 2015.

[5] J. Clauss, "Feasibility study for upgrading the current heat distribution network of an existing building complex to a smart thermal grid." Master's Thesis, KTH School of Industrial Engineering and Management, 2015.

[6] E. K. L. Nielsen, "Lavtemperatur-varmenett." Master's Thesis, Norwegian University of Science and Technology (NTNU), 2017.

[7] E. K. L. Nielsen, "Fjernvarme til framtidens bygningsmasse," tech. rep., Statkraft Varme, 2016.

[8] H. Egge, "Spillvarme inn i norske hjem," *Gemini*, April 2016. https://gemini.no/kortnytt/spillvarme-inn-i-norske-hjem/.

[9] H. Egge, "Our cities are hidden power stations," *Gemini*, January 2018. https://geminiresearchnews.com/2018/01/cities-hidden-power-stations/.