A case study of 5th generation district heating and cooling based on foundation pile heat exchangers (Vejle, Denmark)

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We present the findings of a recently concluded research project, investigating the possibilities for collective heating and cooling supply of a planned, relatively small residential area (Rosborg Ø) in Ny Rosborg, Vejle, Denmark with ground source heat pumps utilising foundation pile heat exchangers (a.k.a. energy piles, EP). Individual EP foundations connect to a distribution network of uninsulated geothermal pipes, buried at shallow depth (cold district heating, CDH) from which connected consumers can supply heating with heat pumps as well as passive or active cooling.

To this end, the project has developed a geothermal screening procedure based on a combined analysis of geophysical data, borehole information, pile testing and laboratory measurements of soil thermal properties. A prototype computational temperature model of CDH networks has been developed for estimating the performance of EP based heating and cooling supply of Rosborg Ø. Finally, the project has developed a complete business (case) model for EP based CDH with a well-defined cost structure in which total fixed and variable costs can be quantified in specific projects.

The mapping of the geothermal potential demonstrates that CDH most likely can fully supply the estimated energy demand of the planned buildings in Rosborg Ø. However, recalculation of the scenario is necessary once additional information on the planned buildings become available. This conclusion is further supported by operational data from the EP foundation at the nearby Rosborg Gymnasium, demonstrating excess heating and cooling possibilities (beyond the demand of the building itself). Further analyses of the data from the Gymnasium estimates the average energy efficiency ratio to 24.8 for the passive cooling during July and early August 2018, roughly ten times higher than that of traditional Air Conditioning (AC). Moreover, the Gymnasium is able to supply its cooling needs passively 97% of the time where cooling is required, implying that the variable cost of cooling with EPs is exceptionally low.

The initial investment required for EP based CDH is higher, however, the variable costs of heating and cooling are greatly reduced relative to those of traditional District Heating (DH) and AC. Consequently, the estimated payback period for collective EP based CDH supply of Rosborg Ø is ca. 4.5 years. The relatively short payback period is due to a drastic reduction (of 80%) of the combined variable costs of heating and cooling with EPs, relative to traditional DH and AC. The contributing factors to the short payback period are the relatively low costs of electricity, the high
COP of the heat pump, a relatively high, annual fixed tariff imposed by traditional DH and finally the exceptionally low costs of passive cooling/seasonal heat storage. As such, the project demonstrates a truly renewable, economically competitive heat pump technology to supply collective building heating and cooling/seasonal heat storage for the future energy supply in Denmark.