EGU24-18386, updated on 09 Dec 2024
https://doi.org/10.5194/egusphere-egu24-18386
EGU General Assembly 2024

Integration of a seasonal borehole thermal energy storage into a transformed cooling network

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A rapid decarbonisation of the heating and cooling sector requires accelerated retrofitting of buildings, increased use of renewable energy and waste heat utilisation (European Commission, 2016). From 2023, the German Heat Planning Act will legally mandate this development for cities and municipalities, with a special obligation to utilise unavoidable waste heat (BMWSB, 2023). In the transformation of future heating and cooling networks, a synergy of different energy sources is crucial, whose complementary strengths and weaknesses must be coordinated. A holistic concept for the future heating and cooling supply at campus level has been developed in cooperation with various disciplines from the fields of energy technology, building energy technology and engineering geology at the TU Berlin, using the university campus in Berlin-Charlottenburg as a example. Key components of the concept include load shifting between buildings, heat recovery from data centres and process cooling, expansion of a cooling network and the use of chillers as heat pumps during the heating season (Stanica et al, 2022).

The project also investigated the use of a seasonal geothermal energy storage system. The hydrogeological and urban planning parameters support the use of a borehole thermal energy storage (BTES). The subsurface is characterised by glacial fluvial sands and clays from the last ice ages, which have high thermal conductivity and capacity. The groundwater temperature is approximately 12°C and the subsurface has a very low groundwater flow velocity, which favours a high efficiency of the BTES. On the North Campus there is a 12,900 m² open space that can accommodate about 130 heat exchangers and has a heat storage capacity of about 1.2 GWh/a.

The cooling demand for the North Campus is approximately 4.7 GWh/a. The cooling systems are to be supported by free cooling at outdoor temperatures below 0°C and by the BTES at temperatures above 0°C. The special point here is that the so-called regeneration of the storage in summer is realised by the existing waste heat on the campus and not by solar thermal energy. This allows the available roof space for photovoltaic systems to be used to generate additional electricity for the operation of the individual systems. To operate sustainably and efficiently, the chillers require an inlet temperature between 6 and 12°C.

The dynamic interaction between the BTES and the associated heating and cooling system has a significant impact on the efficiency of such underground storage system. In order to optimise the design of the BTES and to ensure sustainable operation of all components, all systems were considered holistically and coupled with each other. The results of this study show that utilising the maximum amount of free space as storage in combination with the other cooling sources is not efficient. The storage capacity for the BTES is about 500 MWh/a. The use of the BTES has significantly increased the use of waste heat and reduced electricity consumption for the chillers by 200 MWh/a. In addition, 200 t of CO_2 per year will be saved, which corresponds to a further increase of 20 %.