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Seasonal heat storage systems: Present state of large-scale closed systems in Europe

Christoph Bott, Ingo Dressel, and Peter Bayer

Institute of new Energy Systems (InES), Technische Hochschule Ingolstadt, Ingolstadt 85049, Germany
(christoph.bott@thi.de)

Europe is a leading player in the development and application of seasonal sensible heat storage applications. Technically closed thermal energy storage systems (TES) have especially been a main focus of research programs and demonstration facilities during the last decade. Meanwhile, many applications are operating in an economically efficient way, integrated into district heating systems and storing mainly solar energy from summer to winter. In our presentation, we review the state-of-the-art of these TES based on 31 locations in Europe with a total available storage volume of nearly 800,000 m^3. These represent a capacity of 56,600 MWh assuming optimised storage utilisation with a temperature spread of 70 K. Three main technical variants of closed systems are distinguished: Pit Thermal Energy Storages and Tank Thermal Energy Storages are water-filled, sealed pits or enclosed basin constructions. In contrast, Water-Gravel Thermal Energy Storages contain soil or gravel in addition to water, allowing static loads to be placed on their top surfaces. Most facilities and systems with the greatest storage volumes are located in Germany, Denmark, and Sweden. There is a continuous progress observed in the development and improvement of various technical system components. Nevertheless, the major challenges standing in the way of global market maturity include avoidance of defective waterproofing, mitigation of energy and exergy losses caused among others by long-term material fatigues, and reduction of the often substantial construction costs. Also with respect to optimal TES operation, the potentials are still overlooked. In many cases, for example, the return temperatures are suboptimal, and in others, no suitable thermal stratification was achieved. Advanced, smart integration of heating and cooling networks enables storage of industrial excess energy, geothermal energy, and waste heat from e.g. data centres. Finally, we also reveal that a potential future direction for more flexible control and diverse use of different sources is the combination of multiple storage facilities of different sizes and different temperature levels.