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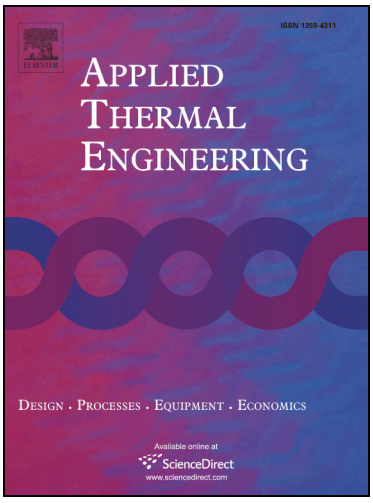

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Application of large underground seasonal thermal energy storage in district heating system: A model-based energy performance assessment of a pilot system in Chifeng, China

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Abstract

Seasonal thermal energy storage (STES) technology is a proven solution to resolve the seasonal discrepancy between heating energy generation from renewables and building heating demands. This research focuses on the performance assessment of district heating (DH) systems powered by low-grade energy sources with large-scale, high temperature underground STES technology. A pilot DH system, located in Chifeng, China that integrates a 0.5 million m^3 borehole thermal energy storage system, an on-site solar thermal plant and excess heat from a copper plant is presented. The research in this paper adopts a model-based approach using Modelica to analyze the energy performance of the STES for two district heating system configurations. Several performance indicators such as the extraction heat, the injection heat and the storage coefficient are selected to assess the STES system performance. Results show that a lower STES discharge temperature leads to a better energy performance. A sensitivity analysis of the site properties illustrates that the thermal conductivity of soil is the most influential parameter on the STES system performance. The long-term performance of the STES is also discussed and a shorter stabilization time between one and two years could be achieved by discharging the STES at a lower temperature.

Keywords: Building performance simulation; district heating; industrial waste heat; Modelica; seasonal thermal energy storage; solar thermal collectors;

Nomenclature

c	Specific heat capacity, J/(kg·K)	B	Baseline
C	Thermal capacitance, J/K	dem	Demand
d	Density, kg/m^3	ex	External
g	Grout	ext	Extraction
IC	Influence coefficient	in	Indoor
IP	Value of input parameter	inj	Injection
k	Thermal conductivity, W/(m·K)	inl	Inlet
mf	Mass flow rate, kg/s	int	Internal
OP	Value of output parameter	r	Return
Q	Heat gain, kW	ref	Reference
R	Thermal resistance, K/W	s	Stable
S	Storage coefficient		
s	Soil		
T	Air temperature, ^oC		
t	Time, year		

1 The fundamental idea of STES in district heating systems

1.1 Status of the heating market in China

The buildings sector is responsible for almost one-third of the global final energy demand. The situation in China is particularly acute. In 2010, China replaced the United States as the largest energy consumer in the world. With its rapidly growing economy and improvement in living standards, China is witnessing a rapid expansion of its building industry, resulting in ever increasing energy demands. If building heating systems in China continue to be supplied by fossil fuels, China will suffer from increasing greenhouse gas emissions, and will miss the opportunity to gain economic benefits from alternative energy sources.

The Chinese government developed a national heating reform to improve building energy efficiency. As part of an effective approach to improving total energy efficiency, developments of district heating systems have grown exponentially since 2005 [1]. In addition, the government has promoted a series of standards and plans to adjust energy structure. The 13th Renewable Energy Development Five Year Plan (13th FYP) has set a target of increasing the share of non-fossil energy in the total primary energy consumption to 15% by 2020 and to 20% by 2030. One of the key objectives is to use renewable energy sources to substitute for 150 million metric tons coal equivalent energy from fossil fuels in the heating and domestic sector [2]. The plan provides opportunities for the development of 4th generation district heating systems, which aim to include more types of renewable energy sources (RES) and to recover industrial waste heat as supply sources [3].

As for the status of district heating in China, China now ranks second only after Russia in installed capacity of district heating systems. However, district heating systems in China still typically rely on coal and gas to generate heat. Nonetheless, the demand for district heating in China is expected to significantly increase in the near future. This is