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ENERGY SMART LIVESTOCK FARMING
TOWARDS ZERO FOSSIL FUEL CONSUMPTION

Experimental assessment of a solar photovoltaic-thermal (PVT) system in a livestock (swine) farm in Italy

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Motivation

Increased consumption of fossil fuels in the agricultural sector

Dual nature of energy (heat and electricity) demand in livestock farms

Overall efficiency of a PVT system is considerably higher compared to standalone PV and solar thermal systems

Case studies are scarce on the utilization of PVT systems in agricultural sector

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State-of-the-art

- Case study in southern Italy showed that replacement of fossil fuel-based system with PVT system could lead to a significant **decrease of 65-75% in CO_2-equivalent emissions** [Wallerand et al., Renewable Energy, 2017]
- Strategic incorporation and utilization of solar energy could offer **attractive economic and environmental prospects** for dairy farms [Wallerand et al., Renewable Energy, 2017]
- A case study performed in northern Italy reported **attractive payback periods ranging from 3.7 to 8.6 years** [Maturo et al., Energy Reports, 2021]
- A potential to prevent 2300 tCO_2/year in on-site electricity production and 1296 tCO_2/year through biogas replacement [Maturo et al., Energy Reports, 2021]
- In a simulation model based on a farm in southern Italy, the authors used the advantages of spectral splitting in a PVT system and observed that **emissions equivalent to 890 tonnes/year of CO_2 could be prevented** [Wang et al., Renewable Energy, 2020]
- PVT collector system **case study for cassava drying in Thanjavur, India** [Veeramanipriya et al., Solar Energy, 2020]
- Overall **efficiency of a PVT system is about 30% more than PV and solar thermal systems** when considered separately [Furbo et al., Ramos et al., Energy Conversion and Management, 2017]

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Research gap

1

Standalone PV and solar thermal systems provide only one type of energy, and the hybrid energy requirements are not met

2

Absence of an efficient energy storage system

3

Lack of a standardized solar central

4

Case studies are scarce on the utilization of PVT systems in agricultural sector

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Objectives of the present work

- Replacement of a fossil fuel (LPG) based energy consumption system in a swine farm in Mirandola, Italy
- Provide renewable heating and electricity for the nursery barn (Building 16)
- Integrating the PVT system with a borehole thermal energy storage (BTES) system and heat pump
- Design and development of a standardized solar central (SC) that could be used in other similar applications

Fig. 1: Picture of the nursery barn

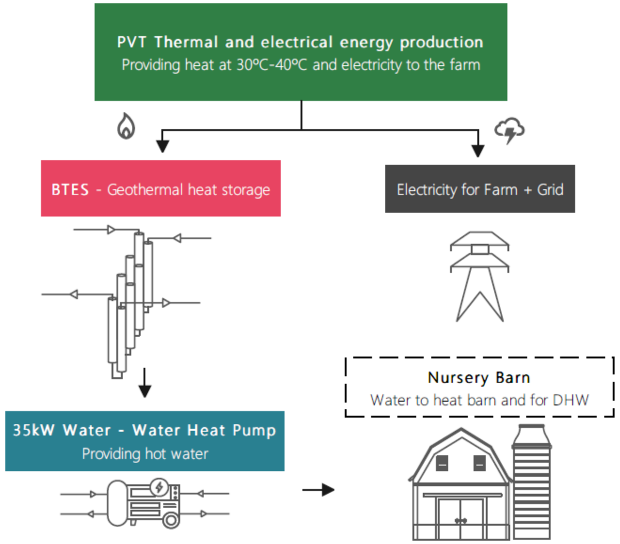

Fig. 2: Schematic of PVT-BTES-HP system

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Methodology

- Heating was provided using a 34 kW LPG boiler (7500 kg/year) and thermal lamps in the nursery barn
- Cooling was achieved using evaporative cooling
- Annual energy demand was estimated
- Two types of heating demand: domestic hot water for cleaning and disinfection of the barns and space heating for maintaining a temperature of 25-30 degC for the comfort of piglets
- Total annual heating demand was estimated to be 90 MWh (60 MWh for hot water and 30 MWh for heating)

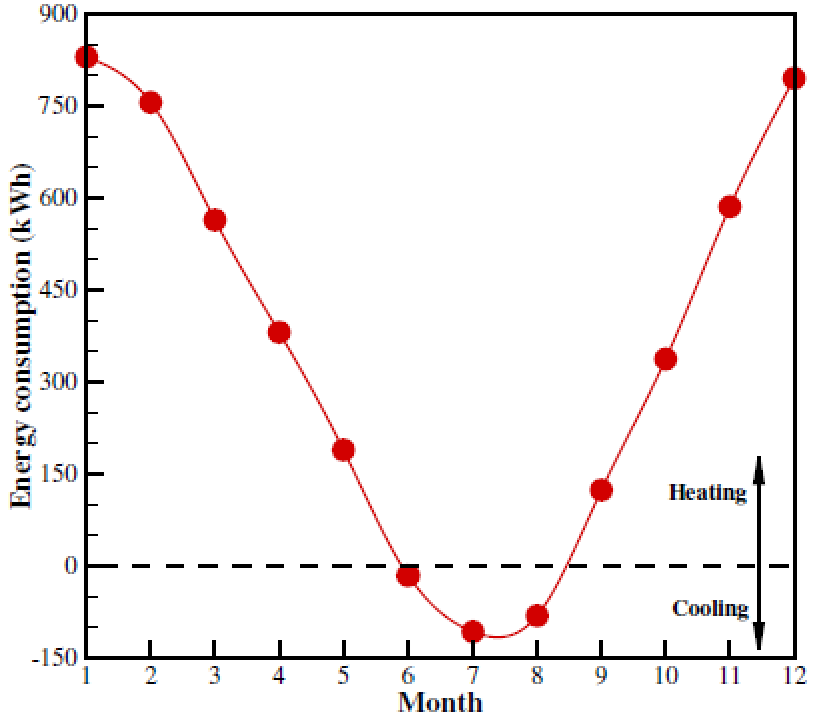

Fig. 3: Annual energy demand of Building 16

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System design

PVT collector	24 nos
Model	Samster-SunPro 320 W
Total aperture area	39.3 m2
Total electrical capacity	7.68 kWe
Maximum circuit voltage	797 V
Maximum circuit current	9.64 A
Total thermal capacity	25 kWth
Flow rate in the thermal circuit	39 l/min
Heat pump	35kW water-to-water
System fluid	Ethylene glycol (35%)

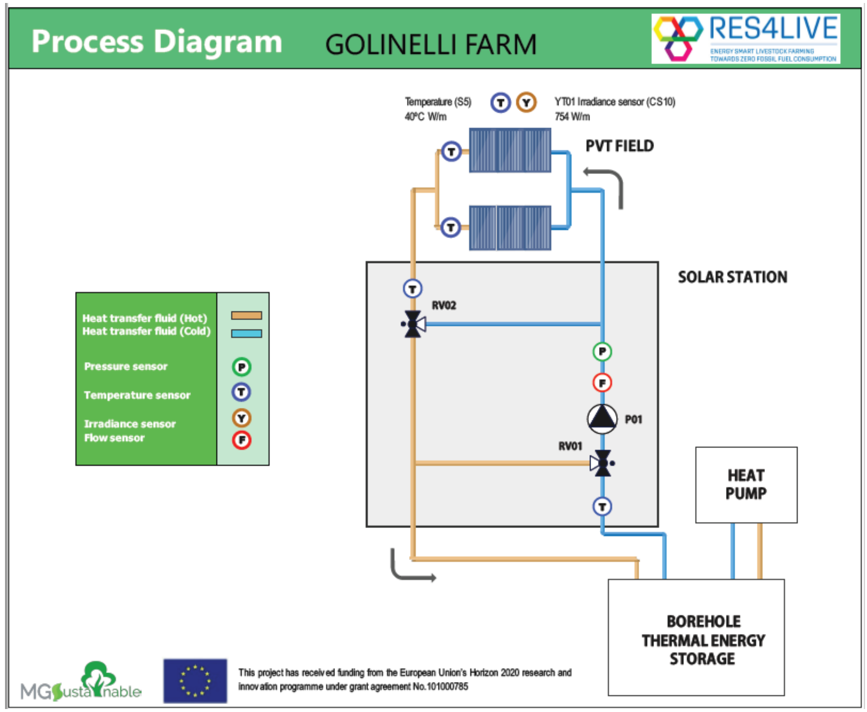

Fig. 4: Process diagram

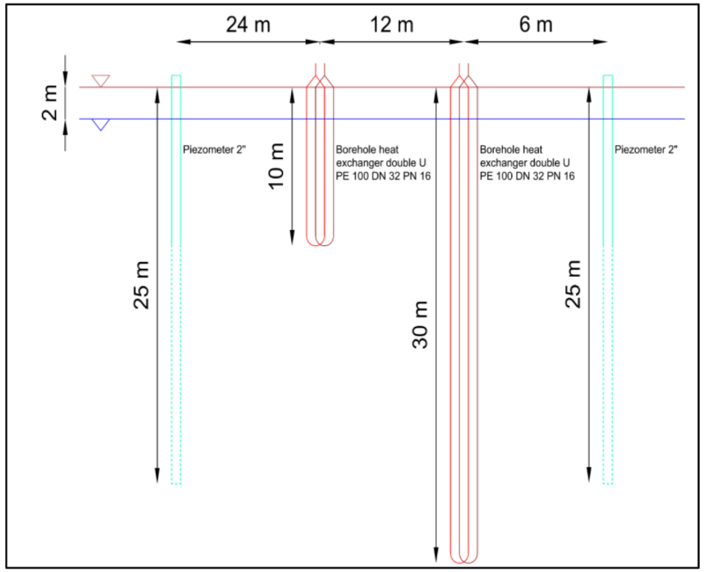

Fig. 5: Arrangement of borehole heat exchangers

Heat production analysis

- Analysis for May and June
- For May, daily thermal energy production was high for day 22 and negligible for days 10-11
- Day 19 was cloudy indicating lower energy production
- Between May 20 and 31, the thermal energy production was much higher
- For June, thermal energy production was nearly consistent, except for June 5 and 10
- Average thermal energy produced during June was nearly 28% higher compared to that of May
- Total heat energy production during May was 1807 kWh and for June, it was 2220 kWh

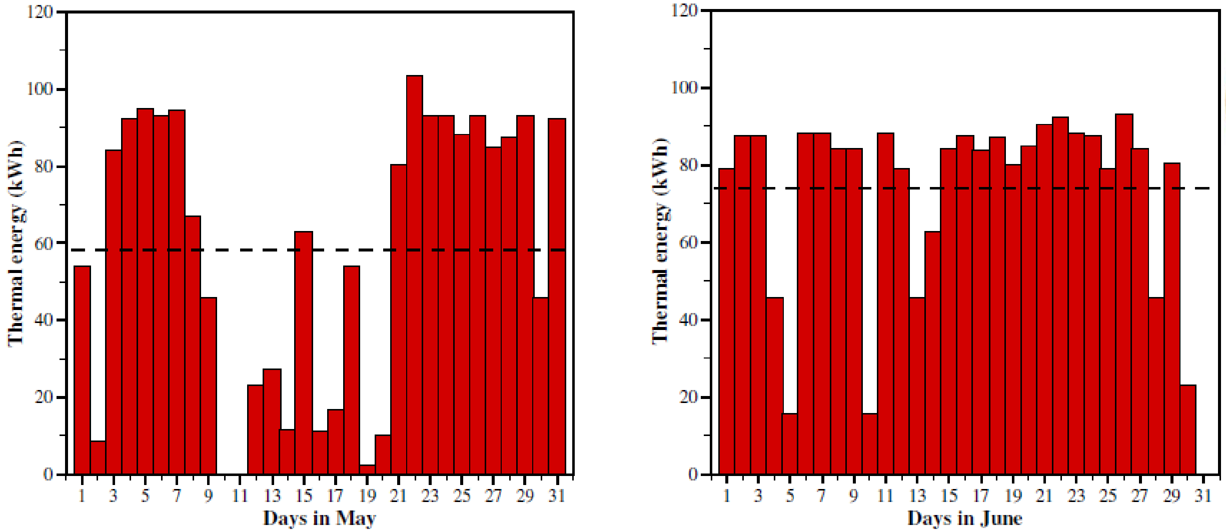

Fig. 6: Thermal energy production during May and June

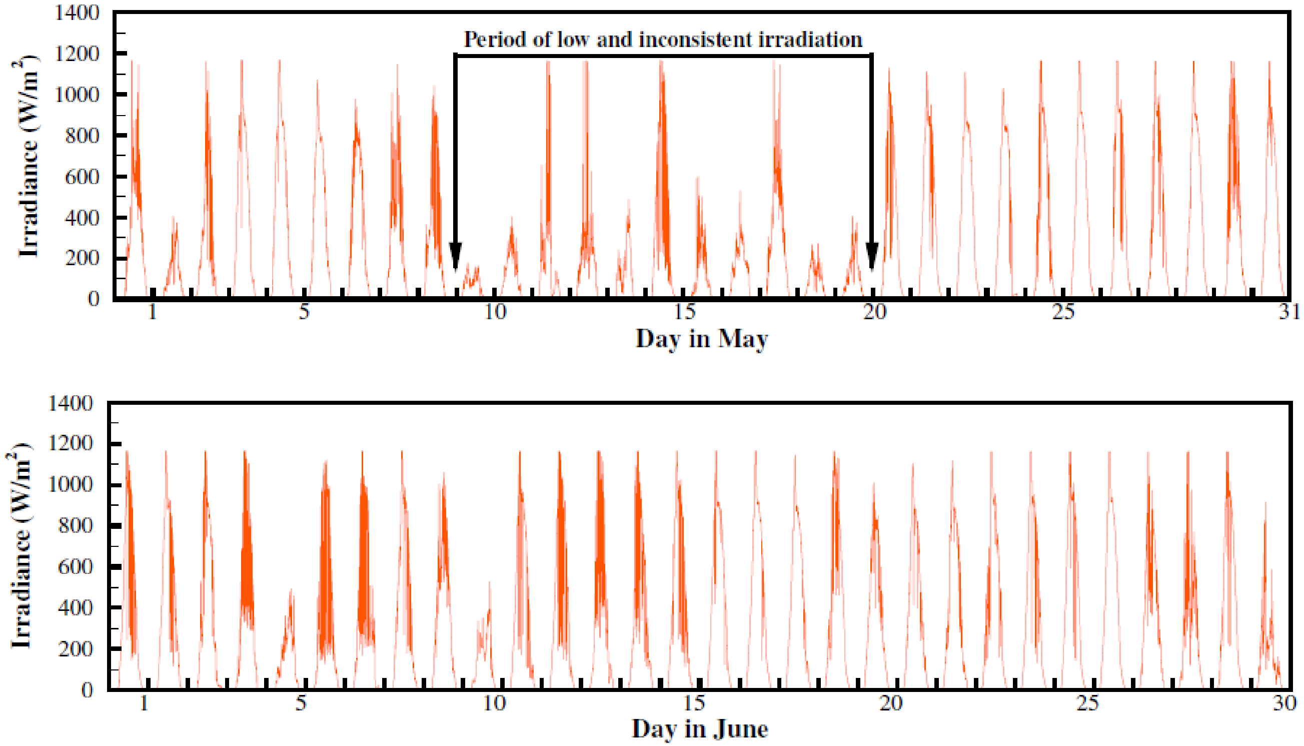

Fig. 7: Irradiance levels during May and June

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Heat production analysis (contd...)

- Thermal power curves were significantly driven by the collector outlet temperature (TT02)
- Ambient temperature (T_a) was also an influencing factor
- Energy production reached its peak during midday hours (11hrs to 15hrs)
- Days being longer in summer, the energy production continued until 20hrs)

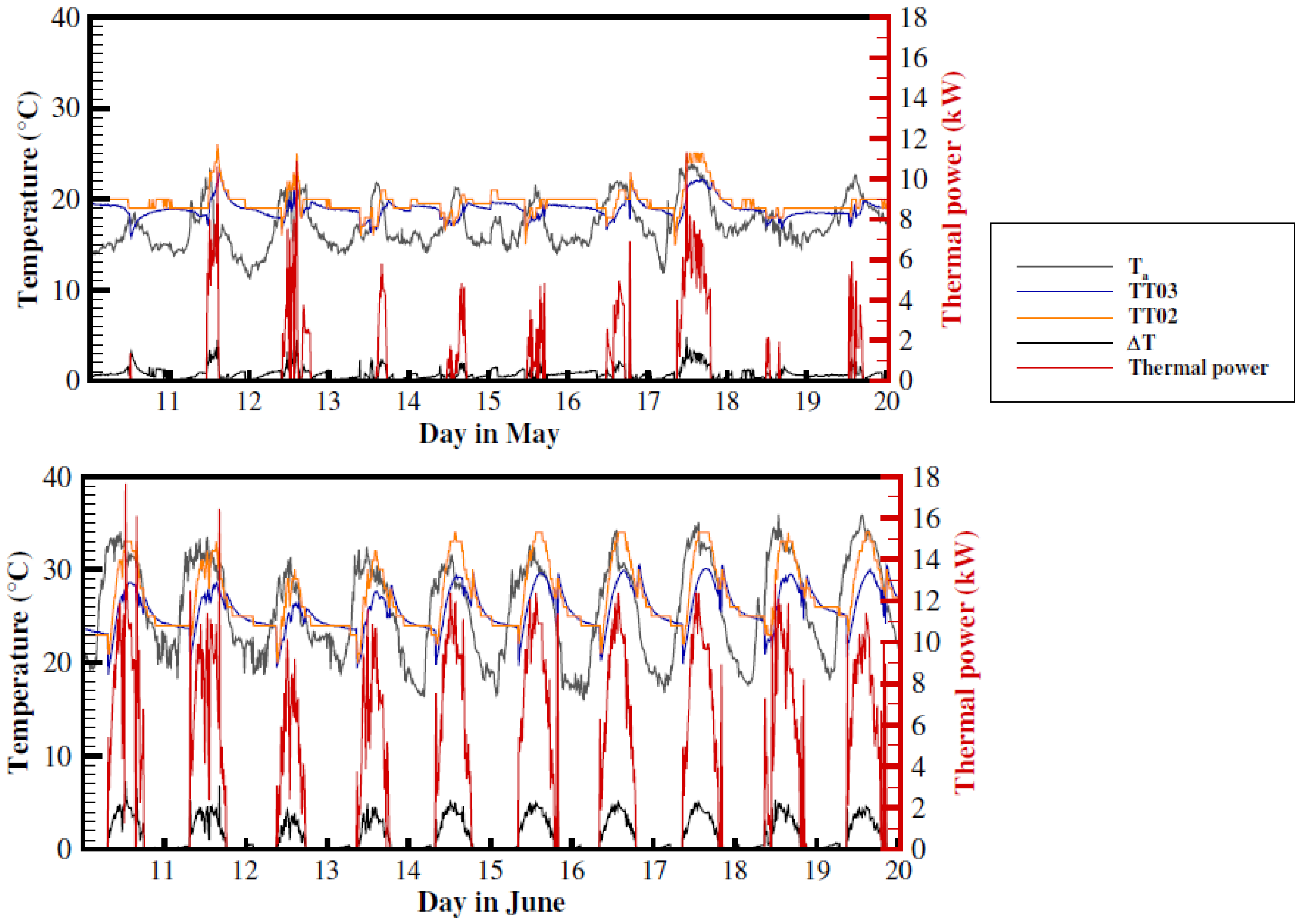

Fig. 8: Sensor data for 10 days (11-20) during May and June

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Electricity production analysis

- Given the Italian local regulations, the electricity metering was not able to be commissioned at the same time as the thermal part of the PVT system
- Electrical production of the PV array was estimated through TRNSYS simulations
- EPW weather files for Mirandola were used to run the simulations with a time step of 5 minutes
- Electrical production of the PV system was estimated to be 0.86 MWh and 1.11 MWh for May and June, respectively

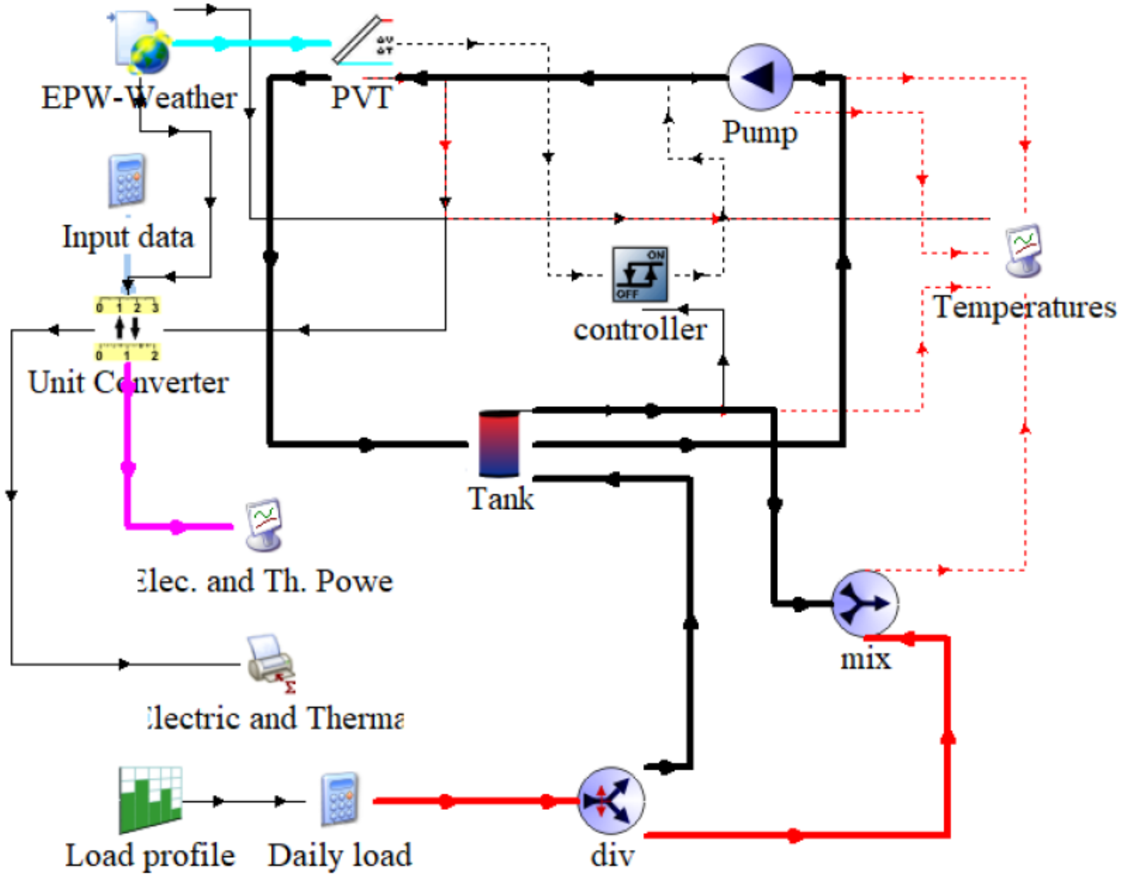

Fig. 9: PVT system setup at TRNSYS simulation environment

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Conclusions and scope for future work

- During the 2-month analysis, the standardized solar central was found to be efficient
- Thermal energy available for storage during May was lower than that of June, due to comparatively low irradiance during May
- During May, there was a period of low and irregular irradiation that had a major impact on thermal energy production
- The RES system could partially meet the electrical energy needs of the farm
- Project led to replacing fossil fuel-based energy consumption in the nursery barn with RES and additional efficiency enhancement thus reducing emissions equivalent to 22,650 kg of CO_2/year
- BTES installed capacity is ready for a further expansion

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Thank you

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