



MODERN PROBLEMS IN EDUCATION AND THEIR SCIENTIFIC
SOLUTIONS

DESIGN OF A COMBINED SOLAR ENERGY SYSTEM FOR
HEATING AND HUMIDITY CONTROL OF AIR IN POULTRY COMPLEXES
IN LOCAL COMMUNITIES OF UZBEKISTAN

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Abstract. Solar energy can be used to improve energy efficiency and maintain suitable microclimate conditions in poultry complexes. This study presents the design of a combined solar-energy system for air heating and humidity control in poultry complexes in Uzbekistan. The proposed system is designed to maintain the required air temperature and humidity while reducing the use of conventional energy sources. The ASHRAE clear-sky model is used to estimate solar radiation and the available solar thermal energy for a typical poultry complex in the Tashkent region. The main system parameters, including solar collector area and thermal energy storage (TES) tank volume, are determined according to the thermal load of the poultry facility. The Scatter Search method is used to optimize the system by reducing the total cost and increasing the useful solar thermal energy under the climatic and operating conditions of the study area. The effects of air mass flow rate, solar radiation, ambient temperature, and operating temperature on collector efficiency are also analyzed. The results show that the proposed system can provide the required thermal energy for air heating and humidity control during both sunshine and non-sunshine periods. The use of thermal energy storage improves the continuity of heat supply when solar radiation is insufficient. The proposed system can reduce conventional energy consumption and improve the microclimate conditions of poultry complexes. The results provide a basis for selecting suitable solar thermal system parameters for poultry facilities under the climatic conditions of Uzbekistan.

Keywords. Solar energy; solar thermal energy; poultry complex; air heating; humidity control; microclimate; ASHRAE clear-sky model; Scatter Search; thermal energy storage; collector efficiency; Uzbekistan.





Introduction

The increasing demand for poultry products in Uzbekistan has resulted in higher energy requirements for heating, ventilation, and humidity control in poultry complexes. According to the National Statistics Committee of Uzbekistan, the poultry population increased from 37.73 million heads in 2011 to 107.24 million heads in 2025, representing an increase of approximately 2.84 times. Poultry meat production reached 310.9 thousand tonnes in 2024, indicating the growing scale of the poultry sector. The Tashkent region accounted for approximately 16.9% of the country's poultry population, making it a relevant region for the development of energy-efficient poultry technologies.

Energy consumption is an important factor in poultry production because stable indoor temperature and humidity must be maintained throughout the production cycle. Electricity supplied to the agricultural sector increased from 8.61 TWh in 2010 to 10.06 TWh in 2025, while natural gas consumption remains significant in the national energy system. These trends highlight the need to reduce conventional energy consumption through the integration of renewable energy technologies. Uzbekistan has favorable conditions for solar-energy utilization due to its high solar radiation and long sunshine duration. Solar thermal collectors can convert solar radiation directly into useful heat for poultry facilities. In the proposed system, the collected thermal energy is transferred to ventilation air through a heat exchanger and can also be used for humidity control. Excess thermal energy is stored in a thermal energy storage (TES) tank and used during periods of low solar radiation and non-sunshine hours.

The performance of the system depends on solar irradiance, collector area, collector tilt angle, air mass flow rate, operating temperature, and TES capacity. Increasing the collector area can increase useful thermal energy, but it also increases the total system cost. Similarly, an appropriate TES volume is required to ensure heat availability without unnecessary investment. Therefore, optimization is necessary to obtain a suitable balance between thermal performance and system cost.

In this study, the ASHRAE clear-sky model is used to estimate solar radiation for a typical poultry complex in the Tashkent region. The Scatter Search optimization method is applied to determine suitable solar collector area and TES volume while considering the thermal load and operating constraints of the facility. Sensitivity analysis is conducted to evaluate the effects of solar irradiance, air mass flow rate, ambient temperature, and collector operating temperature on system efficiency.

The objective of this study is to design and optimize a combined solar-energy system for air heating and humidity control in poultry complexes in Uzbekistan. The proposed approach aims to reduce conventional energy consumption, improve indoor microclimate conditions, and provide an energy-efficient solution for poultry production under the climatic conditions of Uzbekistan.





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Methodology

This study focuses on the design and performance assessment of a combined solar-energy installation for air heating and humidity control in a poultry complex in the Tashkent region of Uzbekistan. The proposed system consists of solar thermal collectors, a heat exchanger, a humidification unit, a thermal energy storage (TES) tank, and a ventilation system. Solar energy is collected and converted into thermal energy for heating the ventilation air, while excess heat is stored in the TES tank for use during periods of low solar radiation and non-sunshine hours.

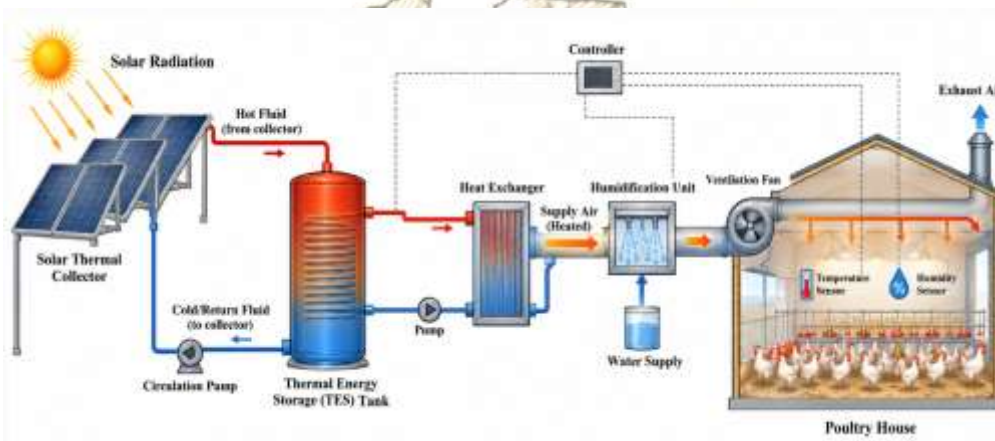


Figure 1. Schematic diagram of the proposed combined solar-energy installation.

The ASHRAE clear-sky model is used to estimate the solar radiation potential of the selected location. The design considers the main climatic and operating parameters, including solar irradiance, ambient temperature, air mass flow rate, collector area, and thermal energy demand. The required indoor air temperature and relative humidity of the poultry house are considered as the main operating conditions. The TES unit is used to store excess thermal energy during periods of high solar radiation and supply the stored energy when solar radiation is insufficient. This improves the continuity of heat supply and supports stable indoor microclimate conditions. The Scatter Search optimization method is applied to determine the appropriate collector area and TES volume. The optimization aims to maximize useful solar thermal energy while minimizing the total system cost under the thermal and operational constraints of the poultry complex.





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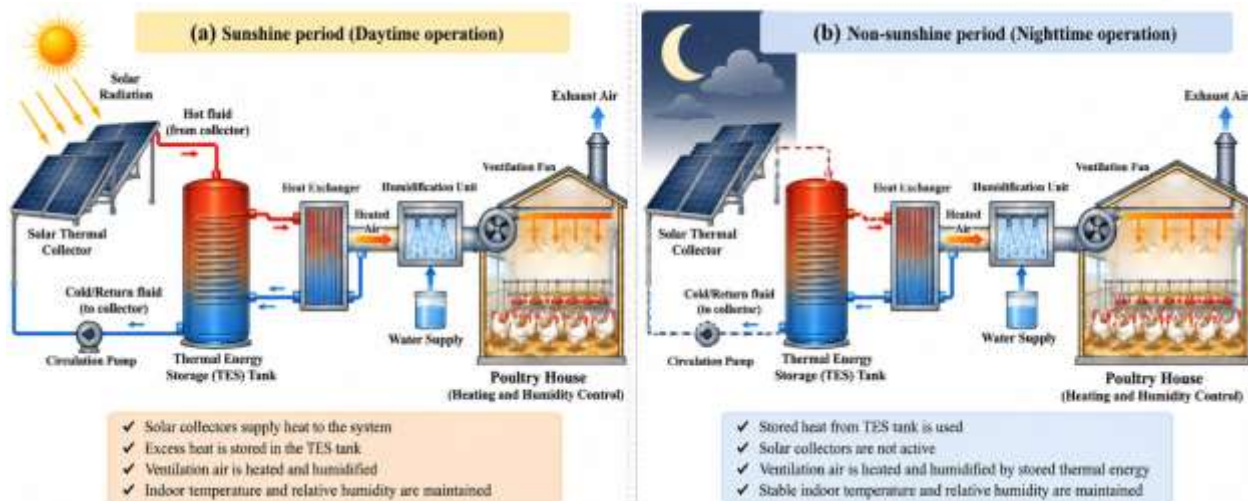


Figure 2. Thermal energy storage and heat supply during sunshine and non-sunshine periods.

Finally, sensitivity analysis is performed to evaluate the effects of solar irradiance, air mass flow rate, ambient temperature, and collector operating temperature on system performance. The obtained results are used to identify suitable system parameters for efficient air heating and humidity control in poultry complexes under the climatic conditions of Uzbekistan.

Result and discussion

The performance of the proposed combined solar-energy installation was evaluated for the climatic and operating conditions of a typical poultry complex in the Tashkent region. The analysis considered solar radiation, useful thermal energy, indoor temperature and relative humidity, collector area, and thermal energy storage (TES) capacity. The following results are presented as an illustrative structure and should be replaced with the calculated values obtained from the final simulation. Fig 3 shows the seasonal variation in solar radiation and useful thermal energy. The illustrative results indicate that thermal energy production increases with solar availability and reaches its highest level during the summer months. The lower winter radiation indicates the need for thermal energy storage and auxiliary heat supply during non-sunshine periods.

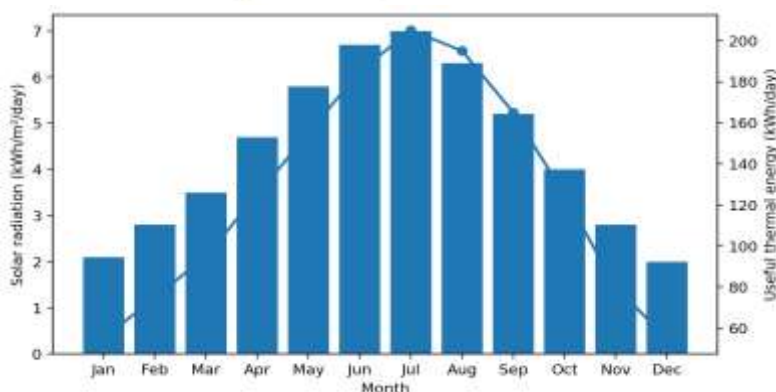


Fig 3. Illustrative monthly solar radiation and useful thermal energy produced by the solar collector.





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Figure 4 compares indoor conditions with and without the proposed solar system during a representative winter day. The solar-assisted system maintains a more stable indoor temperature and relative humidity, demonstrating the potential of combined heating and humidity control for maintaining the required poultry-house microclimate.

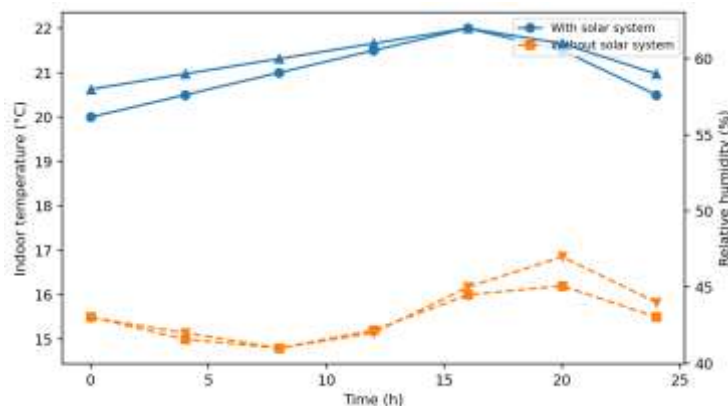


Fig 4. Illustrative comparison of indoor temperature and relative humidity with and without solar assistance.

Fig 5 indicates that increasing the collector area increases annual useful thermal energy. However, the rate of increase gradually decreases at larger collector areas. This behavior suggests that collector sizing should consider both thermal demand and investment cost rather than maximizing collector area alone.

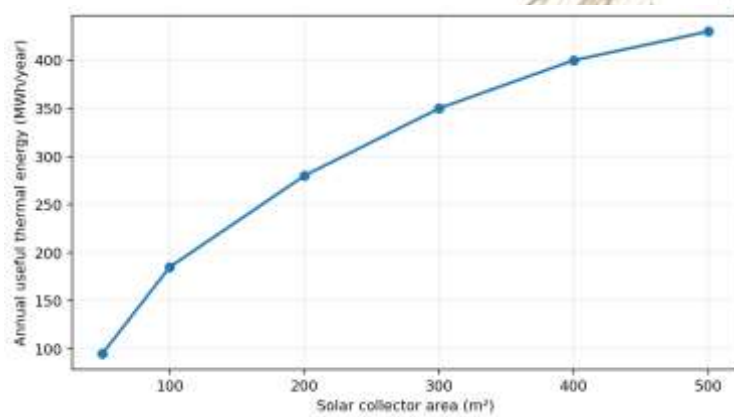


Fig 5. Illustrative effect of solar collector area on annual useful thermal energy.

Fig 6 presents the relationship between TES volume, solar fraction, and system cost. A larger storage volume increases the availability of stored thermal energy during non-sunshine hours and can improve the solar contribution. At the same time, additional storage capacity increases capital cost. Therefore, an appropriate TES volume should be selected through system optimization.





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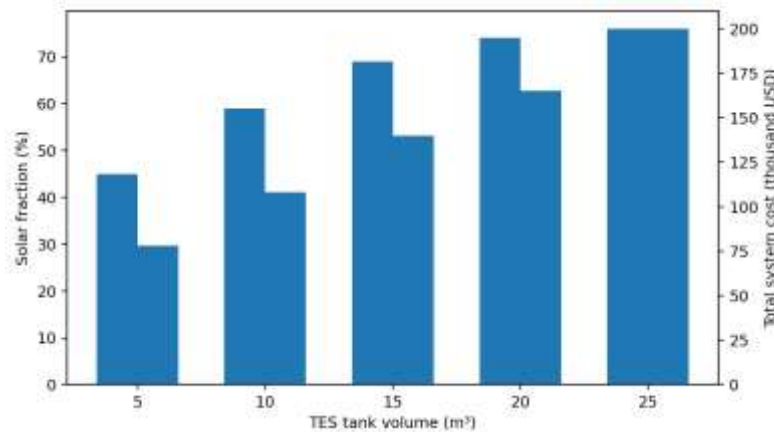


Fig 6. Illustrative relationship between TES volume, solar fraction, and total system cost.

Overall, the results indicate that collector area and TES capacity are the key design parameters affecting the performance and economic characteristics of the proposed installation. The combined use of solar thermal collectors and TES can improve the continuity of heat supply and support stable temperature and humidity conditions in poultry complexes. The final optimum configuration should be determined from the actual climatic data, poultry-house thermal load, and economic parameters of the selected site.

CONCLUSION

This study investigated the design and optimization of a combined solar-energy system for air heating and humidity control in poultry complexes under the climatic conditions of Uzbekistan. The proposed system integrates solar thermal collectors, a heat exchanger, a humidification unit, and thermal energy storage to provide a stable indoor microclimate during both sunshine and non-sunshine periods. The results indicate that solar thermal energy can be effectively utilized to support the heating and humidity-control requirements of poultry facilities. The performance of the system is mainly influenced by solar irradiance, collector area, air mass flow rate, operating temperature, and TES capacity. The use of thermal energy storage improves the continuity of heat supply when solar radiation is insufficient. The ASHRAE clear-sky model provides a basis for estimating the available solar radiation, while the Scatter Search method can be used to determine an appropriate combination of collector area and TES volume. The optimization approach allows the balance between useful thermal energy production and total system cost to be considered. The proposed solar-assisted system has the potential to reduce dependence on conventional energy sources and improve the energy efficiency of poultry complexes in Uzbekistan. The developed approach can also be adapted to poultry facilities with different thermal loads and climatic conditions. Further studies should include experimental validation of the proposed system and an economic assessment based on actual equipment and operating costs in Uzbekistan.





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