



World Conference on Agricultural and Earth Sciences

Hosted Online from Istanbul, Turkey

Date: 20th October, 2026

Website: <https://econferencia.com>

THEORETICAL FOUNDATIONS FOR OPTIMISING A HYBRID SOLAR ENERGY AND HEAT PUMP SYSTEM FOR BUILDING HEATING AND COOLING

B. B. Boynazarov

M. O. Boboeva

Fergana State Technical University, Fergana, Uzbekistan

Abstract

This study examines the principal energy performance indicators of a building heating and cooling system that integrates solar energy, a heat pump and thermal energy storage. It establishes the need to optimise the PVT solar panel and collector, heat pump capacity, storage volume and control system together. Approaches to heat balance, automatic control and energy storage reported in local and international research are synthesised for a hybrid system suited to Uzbekistan's sharply continental climate.

Keywords: Solar collector, PVT, heat pump, ISK, ESK, thermal energy storage, MISK, optimization.

Introduction

Integrating renewable energy sources with high-efficiency heat pumps is an important way to reduce the energy used for building heating and cooling. Solar energy availability and building demand do not fully coincide over time. An efficient hybrid system must therefore combine a solar collector and PVT panel, a heat pump, thermal energy storage and an adaptive control algorithm as a single energy system.



World Conference on Agricultural and Earth Sciences

Hosted Online from Istanbul, Turkey

Date: 20th October, 2026

Website: <https://econferencia.com>

Developing a hybrid heating and cooling system suited to Uzbekistan, formulating its mathematical model and optimising its main parameters are key tasks. A review of the literature indicates that the coefficient of performance (ISK) and energy efficiency ratio (ESK) depend strongly on evaporation and condensation temperatures. Solar heat can reduce compressor load by raising the temperature at the evaporator inlet [1–3].

The simplified energy balance of the hybrid system is given by the following equation:

$$\dot{Q}_{quyosh} + \dot{Q}_{in} + \dot{Q}_{ia} = \dot{Q}_{iyuk} + \dot{Q}_{iabq} + \dot{Q}_{iy} \quad (1)$$

$\dot{Q}_{quyosh}$ – useful thermal power obtained from solar energy;

$\dot{Q}_{in}$ – thermal power produced by the heat pump;

$\dot{Q}_{ia}$ – thermal power discharged from the thermal energy store;

$\dot{Q}_{iyuk}$ – the building's heating or cooling load;

$\dot{Q}_{iabq}$ – thermal power supplied to the thermal energy store for charging;

$\dot{Q}_{iy}$ – the rate of heat loss in the system.

In heating mode, the heat pump's principal performance indicator is $ISK = \dot{Q}_{in}$; in cooling mode, it is $ESK = \dot{Q}_{iyuk}$. For annual assessment, it is appropriate to use the seasonal performance indicator (MISK), which accounts not only for compressor electricity consumption but also for that of circulation pumps, fans and auxiliary equipment.

Research on solar greenhouses also provides useful methodological findings for hybrid building systems. When losses through the transparent envelope and soil were calculated using a heat balance, the losses through a single-layer covering were 508 W/m² at a solar irradiance of 620 W/m², while losses through the soil were 58 W/m² [4]. This finding shows that, alongside increasing the energy input, reducing losses through the system envelope is one of the main ways to improve overall performance.



World Conference on Agricultural and Earth Sciences

Hosted Online from Istanbul, Turkey

Date: 20th October, 2026

Website: <https://econferencia.com>

Studies of greenhouses with transformable enclosures have considered adapting the heated volume to changes in outdoor temperature as a means of minimising energy consumption [5]. A study of automated thermal control recommended limiting the auxiliary heating source when solar energy is sufficient and activating a backup source when it is not [6]. In a hybrid building system, this logic can be used to allocate priority automatically among solar energy, thermal storage and the heat pump.

Four key parameters should be considered together when configuring an optimal system: the solar collector/PVT area A_s , the nominal heat pump capacity P_{inq} , the storage volume V_{iax} and the automatic control settings. A larger A_s increases the solar fraction but also raises the risk of excess heat and increases capital costs. A larger P_{inq} can meet peak loads more rapidly, but may increase cycling and electricity demand at partial load. V_{iax} makes it possible to shift solar energy to evening demand; however, heat losses also increase as the storage volume grows. The main objective should therefore be to minimise annual electricity consumption and levelised energy cost while maximising MISC and the share of the building's heating or cooling demand met by solar energy. For Uzbekistan's climate, calculations should use hourly meteorological data, with separate control algorithms configured for winter and summer. In winter, solar heat is directed towards warming the evaporator source and charging the thermal store; in summer, electricity generated by the PVT system is used to meet compressor demand.



World Conference on Agricultural and Earth Sciences

Hosted Online from Istanbul, Turkey

Date: 20th October, 2026

Website: <https://econferencia.com>

Table 1. Key Parameters for Optimising the Hybrid Heating and Cooling System and Their Effects

Parameter to be optimised	Main effect
A_s – collector/PVT area	Solar fraction and evaporator source temperature
P_{inq} – heat pump capacity	Peak load and part-load performance
V_{iax} – storage volume	Load shifting over time and compressor cycling
T_{bh} – set-point temperature	ISK, ESK and pump electricity consumption

An important feature of the proposed methodology is that the hybrid system's design parameters and control algorithm are not treated separately. For example, if storage-tank volume is selected solely on the basis of daily heat demand, storage capacity may be excessive during periods of high solar irradiance and insufficient during cold, cloudy periods. The value of V_{iax} should therefore be determined together with the hourly load profile, solar collector/PVT output and the heat pump's minimum stable operating time.

Three operating conditions are proposed for system control. In the first, solar energy exceeds the building load and the surplus is directed to thermal storage. In the second, solar input meets part of the load and the heat pump supplies the remaining capacity. In the third, solar energy is very limited, so the stored reserve and heat pump operate together. Transitions between these modes should be made automatically on the basis of temperature and energy indicators.

Another important consideration for the local climate is the marked difference between the heating and cooling seasons. In winter, the priority is to keep the evaporator inlet temperature as high as possible and reduce the compressor pressure ratio. In summer, priority shifts to using electricity from PVT modules



World Conference on Agricultural and Earth Sciences

Hosted Online from Istanbul, Turkey

Date: 20th October, 2026

Website: <https://econferencia.com>

in line with the cooling load. If surplus thermal energy is available, directing it to hot-water production or another process demand can improve the system's overall annual performance.

For experimental research, it is recommended that at least the following quantities be measured continuously: collector/PVT inlet and outlet temperatures; heat-transfer-fluid mass flow rate; temperatures at different layers of the thermal store; heat pump electrical power; indoor and outdoor air temperatures; solar irradiance; and the building's heating or cooling load. These data provide a sufficient basis for checking the energy balance, determining ISK, ESK and MISK, and identifying model parameters. This makes it possible to establish experimentally recommended optimal ratios of collector area, heat pump capacity and storage capacity for conditions in Uzbekistan [7–17].

Conclusion

A hybrid heating and cooling system based on solar energy and a heat pump is a promising solution for providing energy-efficient buildings in Uzbekistan. System performance is determined not only by the efficiency or ISK of individual devices, but also by how well the collector/PVT area, heat pump capacity, storage capacity and control strategy work together. Research on heat balance, energy storage and automatic control can provide a direct methodological basis for developing a dynamic model of this system for local conditions. The next stage should use parametric modelling and an experimental rig to identify optimal ranges for annual MISK, solar fraction and economic performance.



World Conference on Agricultural and Earth Sciences

Hosted Online from Istanbul, Turkey

Date: 20th October, 2026

Website: <https://econferencia.com>

References

1. Fan Y. et al. Scientific and technological progress and future perspectives of the solar assisted heat pump (SAHP) system. *Energy*, 2021, 229, 120719. <https://doi.org/10.1016/j.energy.2021.120719>
2. Sezen K., Gungor A. Comparison of solar assisted heat pump systems for heating residences: A review. *Solar Energy*, 2023, 249, 424–445. <https://doi.org/10.1016/j.solener.2022.11.051>
3. Kazem H.A. et al. A systematic review of photovoltaic/thermal applications in heat pumps systems. *Solar Energy*, 2024, 269, 112299. <https://doi.org/10.1016/j.solener.2023.112299>
4. Rasakhodjaev B.S. et al. Calculation specifics in the study of solar greenhouses with thermal energy accumulator in mind. *IOP Conf. Ser.: Earth Environ. Sci.*, 2023, 1212, 012041. <https://doi.org/10.1088/1755-1315/1212/1/012041>
5. Rasakhodzhaev B.S. et al. Investigation of solar greenhouses with transformable (adjustable) body depending on indoor and outdoor air temperature. *IOP Conf. Ser.: Earth Environ. Sci.*, 2022, 1070, 012030. <https://doi.org/10.1088/1755-1315/1070/1/012030>
6. Rasakhodzhaev B.S. et al. Study of the Thermal Control System in the Energy Efficient Greenhouse with Transformable Body. *J. Sib. Fed. Univ. Eng. & Technol.*, 2022, 15(6), 684–690. <https://doi.org/10.17516/1999-494X-0425>
7. Rasakhodzhaev B.S., Khamdamov A.R. Research of the Energy Efficient System of a Solar Greenhouse with Solar Energy Storage. *Applied Solar Energy*, 2024, 59(6), 878–886. <https://doi.org/10.3103/S0003701X23600200>
8. Mirsoli Uzbekov, Akmal Kuchkarov, Bekzod Boynazarov, Muxammadrafiq Toxirov and Shermuhammad Muminov. Optimization of geometrical parameters of the heat receiver of a solar air heating collector. *BIO Web Conf.*, 84 (2024) 05036, DOI: <https://doi.org/10.1051/bioconf/20248405036>



World Conference on Agricultural and Earth Sciences

Hosted Online from Istanbul, Turkey

Date: 20th October, 2026

Website: <https://econferencia.com>

9. Akmal Kuchkarov, Mirsoli Uzbekov, Bekzod Boynazarov, Bekzod Abdukarimov, Olmosbek Mamatov and Shermuhammad Muminov. Determining the optimal placement scheme and height of elements that accelerate heat exchange processes in solar air heater collectors through mathematical modeling. BIO Web Conf., 84 (2024) 02022, DOI: <https://doi.org/10.1051/bioconf/20248402022>
10. Bekzod Abdukarimov, Muxammadrafiq Toxirov, Bekzod Boynazarov, Jamshid Obidov and Farangiz Tillaboyeva. The effect of heat losses and heat transfer coefficient on the efficiency of the solar air heater collector. E3S Web of Conf., 452 (2023) 04006. DOI: <https://doi.org/10.1051/e3sconf/202345204006>
11. Uzbekov, M.O., Boynazarov, B.B. Studies of the thermal and hydraulic characteristics of the heat carrier of a solar air heating collector. J. Sib. Fed. Univ. Eng. & Technol., 2022, 15(5), 534–540. DOI: 10.17516/1999-494X-0414
12. Uzbekov M.O., Boynazarov B.B. Issues of development of solar collectors with high efficiency, J. Sib. Fed. Univ. Eng. & Technol., 2021, 14(8), 942–949. DOI: 10.17516/1999-494X-0364.
13. B.B.Boynazarov, M.O.Uzbekov, F.N. Nasretdinova. Conducting experiments and analysis on different solar air heating collectors//Journal of Engineering and Technology (JET) ISSN(P):2250-2394; ISSN(E): Applied Vol. 13, Issue 2, Jun 2023, 31– 38.
14. B.B.Boynazarov, M.O.Uzbekov, F.N. Nasretdinova. Analysis of solar energy devices// Scientific and Technical Journal of N am IET. ISSN 2181-8622. Vol 8, Issue 2. pp. 197-204.
15. B.B.Boynazarov, M.O.Uzbekov. Providing heat energy to greenhouses using solar air heater collectors//Web of scientist: International scientific research journal, ISSN: 2776-0979, Volume 4, Issue 6, June, 2023. pp 350-359.



World Conference on Agricultural and Earth Sciences

Hosted Online from Istanbul, Turkey

Date: 20th October, 2026

Website: <https://econferencia.com>

16. Energy saving using solar air heater collectors. Mirsoli Uzbekov, Bekzod Boynazarov, Feruza Nasretdinova, Iqboljon Zoxidov, Abdulahad Ashurov and Zuhridin Hamidjonov. E3S Web of Conf., 508 (2024) 02001. DOI: <https://doi.org/10.1051/e3sconf/202450802001>

17. The influence of artificial turbulization on the efficiency of heat exchange in the channels of solar air heating collectors. Mirsoli Uzbekov, Bekzod Boynazarov, Javlonbek Madaminov, Feruza Nasretdinova, Zuhridin Hamidjonov and Mirkamol Rakhimov. E3S Web Conf., 538 (2024) 01022. DOI: <https://doi.org/10.1051/e3sconf/202453801022>