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COMPARATIVE ENERGY AND ECONOMIC ASSESSMENT OF PV/T, PV AND SOLAR THERMAL SYSTEMS USING POLYSUN SOFTWARE UNDER LITHUANIAN CLIMATIC CONDITIONS

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Abstract

Solar water-heating systems use solar radiation to raise water temperature for domestic use. Hybrid photovoltaic-thermal (PV/T) collectors integrate a photovoltaic module with a thermal absorber, enabling simultaneous electricity and heat generation from the same aperture area. This paper uses Polysun software to simulate and compare a PV/T water collector with photovoltaic (PV) and solar-thermal (ST) systems under Lithuanian climatic conditions. The electrical and thermal performance of the PV/T system is evaluated, and a representative PV/T domestic hot-water system for Lithuanian residential buildings is designed and simulated. Finally, the annual energy yields and the economic feasibility of the investigated systems are discussed.

Keywords: Solar thermal energy, PV/T, Polysun simulation, Solar thermal collector.

INTRODUCTION

Energy is a fundamental requirement of modern society. Adequate energy supply supports industrial development and technological progress [1]. However, rising global energy demand and continued reliance on fossil fuels are intensifying environmental impacts, and energy crises are becoming more frequent. Expanding the use of clean renewable energy sources is therefore an important response to these challenges. Under the Paris Agreement, at least 55 countries, including EU Member States, agreed to increase the use of renewables to combat global warming. EU Member States have set a target for renewables to account for 27% of the EU's energy consumption by 2030, and the EU aims to reduce greenhouse-gas emissions by 55% by 2030 compared with 1990 levels [2]. Solar energy is one of the most promising renewable resources that can address climate-change and environmental-pollution challenges. In recent years, the installation of photovoltaic (PV) modules has expanded rapidly. Nevertheless, the efficiency of a PV module decreases as the module temperature increases. Without cooling, efficiency typically decreases by 0.03–0.05% for every 1°C increase in temperature, and decreases of up to 69% have been reported at a module operating temperature of 64°C [3]. This limitation can be addressed by hybrid photovoltaic-thermal (PV/T) systems, which can generate both electrical and thermal energy from the same module area simultaneously [4]. As a result, overall energy efficiency can exceed 75% [4, 5], surpassing the efficiency of separately operated photovoltaic or solar-thermal systems [6, 7]. In addition, integrating PV/T collectors with heating and cooling (H/C) technologies makes it possible not only to prepare hot water and provide space heating or cooling, but also to generate electricity, thereby covering a large share of a building's

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energy demand [8].

Given climate-change trends, cooling demand is expected to continue to grow, while the energy required for heating may decrease. In this context, solar heating and cooling (SHC) systems based on PV/T collectors are a particularly promising technology: they can be flexibly adapted to both heating and cooling needs, contributing to the optimization of energy consumption and the reduction of global warming [8, 9].

Recent studies show the strong potential of PV/T systems, compared with conventional PV systems, to reduce module surface temperature and increase electricity-generation efficiency [10, 11]. In some cases, the generation efficiency of a PV/T collector can increase by up to 22.2%, and the maximum PV-module temperature can decrease by up to 30% compared with an uncooled PV collector [12]. It should be noted that the cited studies were conducted in countries where solar irradiance is substantially higher than in Lithuania.

In Lithuania, recent studies highlight rapid growth in the installation of solar power plants and the potential of urban rooftops for PV deployment, while also emphasizing the impact of seasonality on heat and electricity production and the need to adapt systems to local climate conditions and building energy needs [13, 14]. Technical and economic studies in Lithuania show that optimizing roof and facade areas, combining systems with seasonal heat storage, and applying smart management can increase the economic attractiveness of solar energy from a regional perspective [15]. Therefore, PV/T research focused on Lithuanian conditions (e.g., average irradiance, winter conditions, and the seasonality of building heat demand) is relevant for practical implementation.

The aim of this work is to use Polysun software to conduct a comparative efficiency analysis of a hybrid PV/T water collector, photovoltaic PV and solar-thermal (ST) systems, and to assess the suitability of these systems for Lithuanian climatic conditions.

METHODOLOGY

A range of tools is available for modelling building energy systems, so selecting an appropriate platform is important. A recent comparative study of PV, PVT and ST systems across 26 European countries further demonstrated that system performance and economic feasibility depend strongly on climatic conditions and energy prices. Methodologically, the authors developed a mathematical model simulation across 26 European countries, using MATLAB for simulations and thermodynamic calculations and REFPROP for thermophysical property data [16]. The Polysun software used in this study enables effective simulation of solar-thermal, photovoltaic and geothermal systems. Compared with many alternative packages, it offers a wider set of input parameters and a more user-friendly graphical interface [17]. In addition, Polysun results correlate well with experimental data; differences of around 9% have been reported [18].

To compare the performance of a PV/T system with standalone PV and solar-thermal (ST) systems, the collector area of all systems was set to be identical. A hybrid PV/T system typically produces substantially more thermal than electrical energy from the same area [19, 20]. Therefore, PV/T is particularly suitable for applications with a high and steady heat demand (e.g., hospitals, hotels and swimming pools).

Description of the systems

A site in Panevezys, Lithuania (55.74826° N, 24.37376° E) was selected. A laundry facility is located at this site, allowing excess hot water to be utilized in production. Three system configurations were modelled: PV/T, PV and ST. After selecting a system layout in Polysun, the boundary conditions were specified and the component parameters were set. Each system comprised 50 modules with a total area of 99 m².

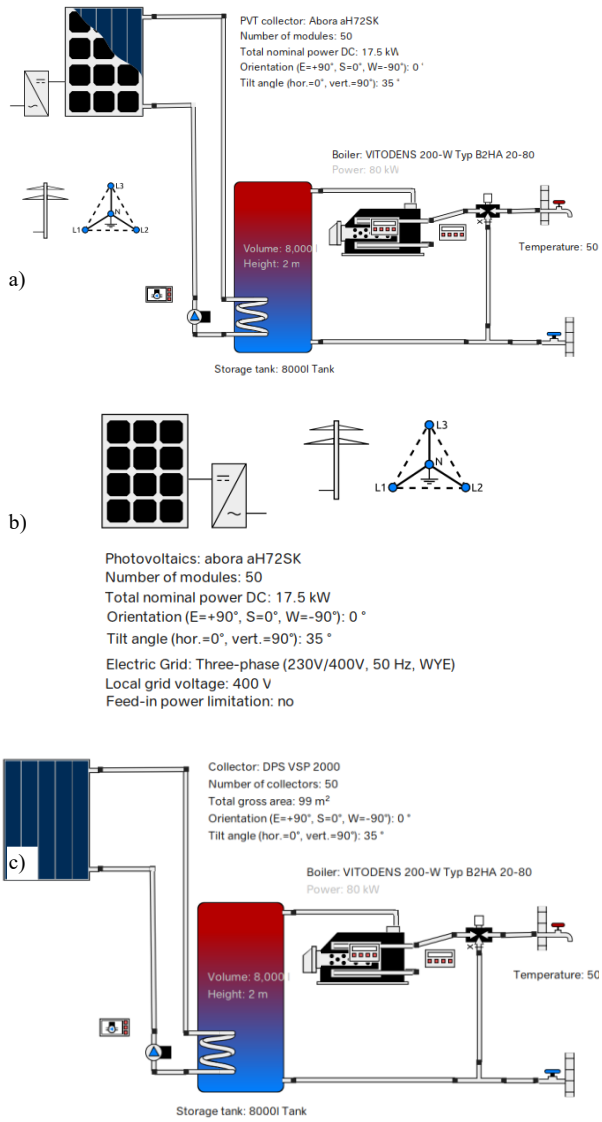


Fig.1. *Polysun schematic structure: a) photovoltaic-thermal system (PV/T), b) photovoltaic system (PV), c) solar-thermal system (ST)*

Polysun allows the selection of components from specific manufacturers, increasing the realism of the simulations. Abora aH72SK modules were selected for the PV/T and PV systems, and DPS VSP 2000 modules for the ST system. The boiler and storage-tank capacity were kept identical across the systems. All modules were installed at a tilt angle of 35°. The system schematics are shown in **Fig. 1**.

Energy equations

The electrical performance of a PV/T panel is measured and given as an instantaneous peak power at a solar irradiance of 1000 W/m² and an ambient and PV cell temperature of 25°C. The electrical efficiency of a PV/T panel is given as the ratio between the peak power and (PVT area x 1000 W/m²).

The reduction of the electrical efficiency of a PV/T panel with increasing PV cell temperature is given by equation 1, which represents the traditional linear expression for the PV electrical efficiency η_{el} [21].

$$\eta_{el} = \eta_{0,el}(1 - \beta(T_c - T_{ref})) \qquad (1)$$

where T_c is PV cell temperature, °C; T_{ref} is reference temperature equal to 25°C, °C; β is the coefficient of temperature, °C^{-1}; $\eta_{0,el}$ is the electrical efficiency of the PV/T panel at a temperature of 25°C.

The thermal efficiency of a PV/T panel can often in a simplified way be given by equation 2 [20].

$$\eta_{th} = \eta_0 - \alpha_1 \frac{T_m - T_a}{G} - \alpha_2 \frac{(T_m - T_a)^2}{G} \qquad (2)$$

where η_{th} is the thermal efficiency of the PV/T panel; η_0 is the peak thermal efficiency of the PV/T panel; α_1 is the heat loss coefficient of the PV/T panel at ambient temperature, W/(m²K); α_2 is temperature dependence of heat loss coefficient of the PV/T panel, W/(m²K²); T_m is the mean solar collector fluid temperature in the PV/T panel, °C; T_a is the ambient air temperature, °C; G is the solar irradiance on the PV/T panel, W/m². Then, the overall efficiency η can be defined by equation 3.

$$\eta = \eta_{el} + \eta_{th} \qquad (3)$$

where η general efficiency of the PV/T panel; η_{el} and η_{th} is the electrical and thermal efficiency of PV/T panels, respectively.

RESULTS AND DISCUSSION

The systems were designed using identical initial parameters, as summarized in **Table 1**.

As shown in **Table 1**, the electrical power of the PV/T and PV systems was 17.5 kW. Although the module area was the same, differences in construction meant that the annual solar irradiation incident on the active module area differed. For the PV system this was 118,442 kWh, whereas for the PV/T and ST systems it was 113,607 kWh (**Fig. 2**).

Table 1: **Initial system parameters**

	PV/T	PV	ST
Number of modules	50	50	50
Collector area (A), m^2	1,98	1,98	1,98
Hot water demand, l	5000	-	5000
Temperature setting, °C	50	-	50
Storage Tank Capacity, l	8000	-	8000
Tilt angle, °	35	35	35
Electrical power, kW	17,5	17,5	-

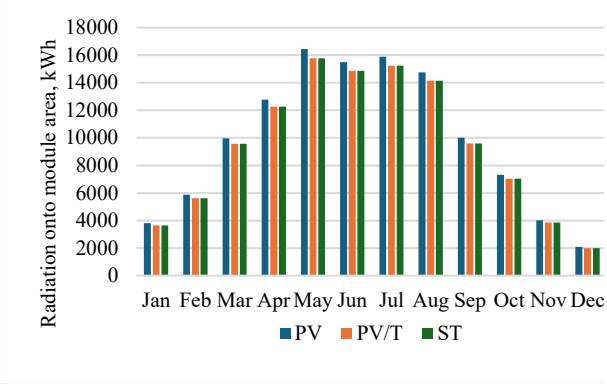


Fig. 2. *Annual solar radiation onto module area in PV, PV/T and ST systems*

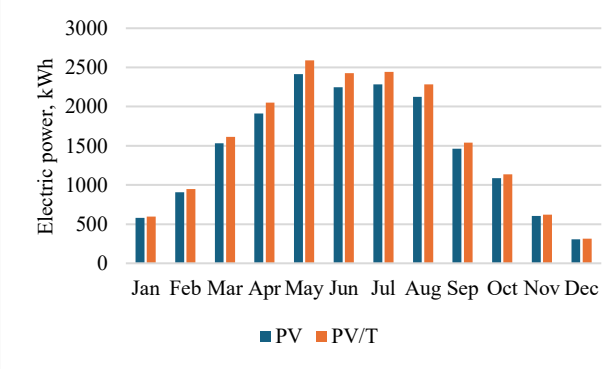


Fig. 3. *Annual amount of electricity generated in hybrid and photovoltaic systems*

Nevertheless, the hybrid system generated 18,562 kWh of electricity annually, while the PV system generated 17,454 kWh. The annual electricity yields are shown in **Fig 3**.

The electricity yield of the hybrid system was 5.97% higher, due to lower operating surface temperatures. In the PV/T system, the maximum average annual module temperature was 28.5°C (**Fig. 4**), while in the PV system it reached 41.2°C. This is particularly evident in **Fig. 4**, where PV module temperatures reached around 60°C during the summer months.

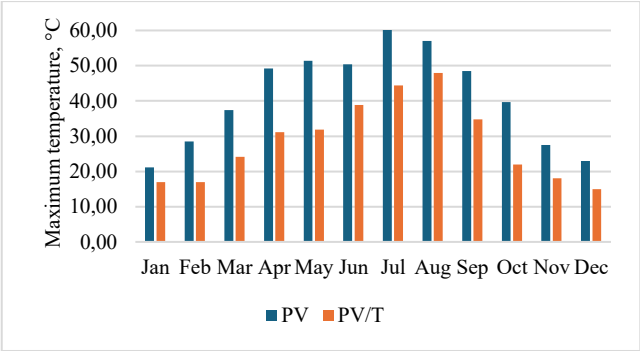


Fig. 4. *Maximum temperature of working surfaces in PV and PV/T systems*

The PV/T system produces both electricity and hot water. Here, its thermal performance is compared with that of a solar-thermal (ST) system. For both systems, the domestic hot-water set-point temperature was 50°C; when the delivered temperature was lower, a gas boiler supplied auxiliary heat. **Fig. 5** shows the annual solar-thermal energy supplied to the PV/T and ST systems.

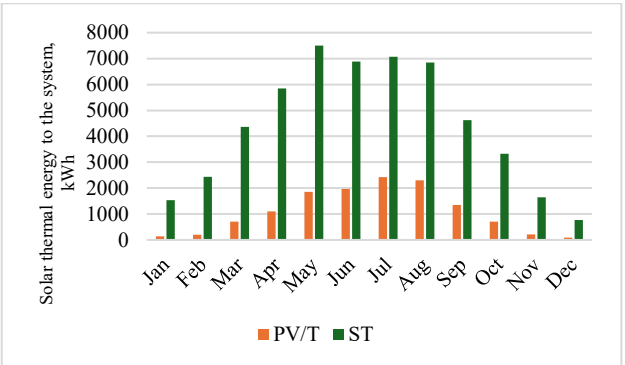


Fig. 5. *Annual solar thermal energy to the PV/T and ST systems*

The total amount of solar thermal energy produced and fed into the system differs by more than four times. The ST system produced 52,871 kWh of energy, while the PV/T system produced only 13,052 kWh.

This is because the thermal absorber in a PV/T collector receives solar radiation through the PV layer rather than directly. **Figs. 6** and **7** illustrate this effect.

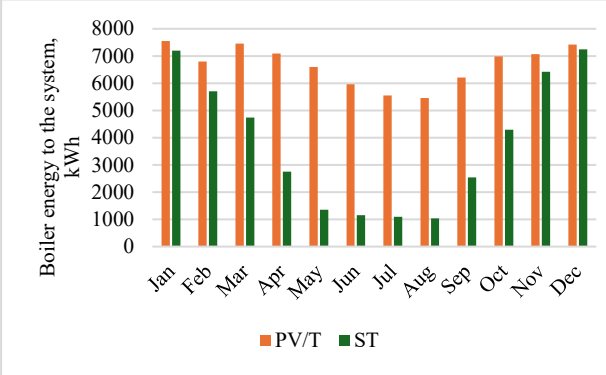


Fig. 6. *Annual boiler energy to the PV/T and ST systems*

Fig. 6 shows the auxiliary boiler energy required to maintain the hot-water set-point temperature. The solar-thermal system required 1.76 times less auxiliary energy than the PV/T system. **Fig. 7** shows the solar fraction for each system. In the hybrid system, the average annual solar fraction was below 14%, whereas in the solar-thermal system it was 54%.

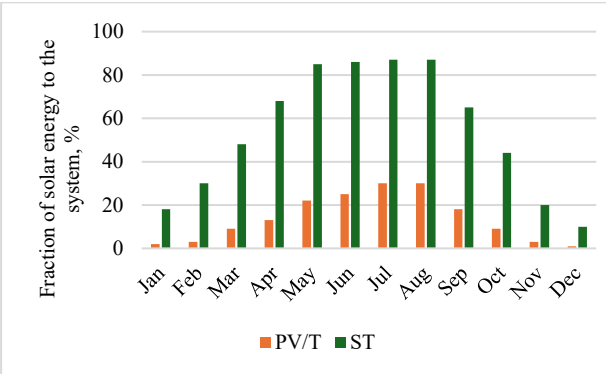


Fig. 7. *Fraction of the solar energy to the PV/T and ST systems*

Considering the total annual energy delivered, the PV/T system produced 31,615 kWh, which is higher than the PV system but lower than the solar-thermal system. The annual totals are shown in **Fig. 8**.

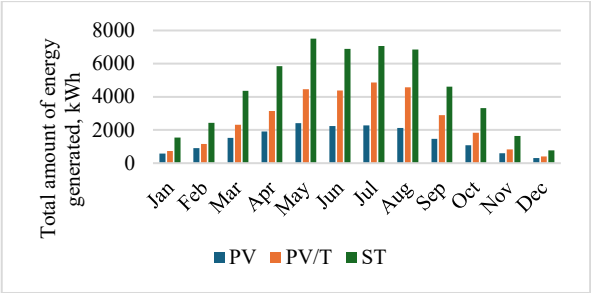


Fig. 8. *Annual total amount of energy in PV, PV/T and ST systems*

Figure 9 shows the evolution of the net present value (NPV) of the analyzed systems over the project lifetime. The NPV analysis demonstrates a clear distinction in economic performance among the three technologies. Photovoltaic (PV) systems exhibit the highest net present value, achieving payback within approximately 6–7 years and reaching a cumulative NPV of ~43 k€ over the 30-year period. Solar-thermal (ST) systems show moderate performance, with positive NPV occurring around year 12–13 and reaching ~31 k€ by year 30.

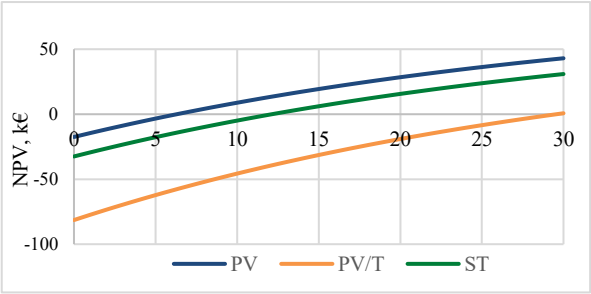


Fig. 9. *Net Present Value (NPV) Comparison of PV, PV/T, and Solar Thermal Systems over 30 Years*

Conversely, combined photovoltaic-thermal (PV/T) systems display the lowest economic return, remaining largely negative for most of the analysis period and only approaching break-even at the project end. These results indicate that, under the given assumptions, PV/T systems may require further optimization or subsidies to become financially viable.

CONCLUSION

This study conducted a comparative techno-economic assessment of hybrid photovoltaic–thermal (PV/T), photovoltaic (PV), and solar-thermal (ST) systems under identical installation conditions for Lithuanian climatic conditions using Polysun simulations. The results reveal distinct differences in both energy performance and economic viability among the analyzed technologies.

The PV/T system demonstrated a modest electrical advantage, producing 5.97% more electricity than the PV system due to reduced operating temperatures enabled by thermal energy extraction. However, this improvement was accompanied by a substantial reduction in useful thermal output compared to the dedicated solar-thermal system. The ST configuration delivered more than 4 times higher annual thermal energy, resulting in a significantly higher solar fraction and markedly lower auxiliary boiler demand.

Economic evaluation based on net present value (NPV) indicates that the PV/T system is currently the most expensive and least economically attractive option among the analyzed configurations. Despite its dual-generation capability, the PV/T system remained economically unfavorable throughout most of the project lifetime, reaching break-even only at the end of the 30-year analysis period. In contrast, the PV system achieved the highest NPV and the shortest payback period, while the ST system exhibited moderate but stable long-term economic performance.

The primary advantage of the PV/T system lies in applications where installation area is severely constrained, as it can provide combined electrical and thermal energy output using approximately half the area required by two separate PV and ST systems. However, under current cost levels and technological maturity, and considering that installation area is generally not a limiting factor in Lithuania, PV/T systems cannot be recommended as an economically viable solution.

Overall, the results indicate that, under present Lithuanian conditions, PV and solar-thermal systems represent a more rational and cost-effective choice. Further reductions in PV/T system costs or targeted policy support would be necessary to improve the competitiveness of hybrid systems in similar climatic regions.

REFERENCE

[1] Komarova, A.V., Filimonova, I.V., Kartashevich, A.A. Energy consumption of the countries in the context of economic development and energy transition. Energy reports, 2022; 8, pp. 686-690.

[2] The European Council, Paris agreement. Available at : https://www.consilium.europa.eu/en/press/press-releases/2023/10/16/paris-agreement-council-submits-updated-ndc-on-behalf-of-eu-and-member-states/

[3] Hasan, K., Yousuf, S. B., Tushar, M. S. H. K., Das, B. K., Das, P., Islam Md. S. Effects of different environmental and operational factors on the PV performance: A comprehensive review. Energy Science & Engineering, 2022; 10, pp.656–675.

[4] Joshi, S.S., Dhoble, A.S. Photovoltaic - Thermal systems (PVT): Technology review and future trends. Renewable and Sustainable Energy Reviews, 2018, 92, 848–882.

[5] Das, D., Kalita, P., Roy, O. Flat plate hybrid photovoltaic- thermal (PV/T) system: A review on design and development. Renewable and Sustainable Energy Reviews, 2018, 84, pp.111–130.

[6] Herrando, M., Ramos, A., Zabalza, I., Markides, C. A comprehensive assessment of alternative absorber-exchanger designs for hybrid PVT-water collectors. Applied Energy, 2019, 235, 1583–1602.

[7] Evangelisti, L., Vollaro, R.L., Asdrubali, F. Latest advances on solar thermal collectors: A comprehensive review. Renewable and Sustainable Energy Reviews, 2019, 114, pp. 1-20.

[8] Herrando, M., Ramos, A. Photovoltaic-Thermal (PV-T) Systems for Combined Cooling, Heating and Power in Buildings: A Review. Energies, 2022, 15, 3021.

[9] Jiao, C., Li, Z. An Updated Review of Solar Cooling Systems Driven by Photovoltaic–Thermal Collectors. Energies, 2023, 16, 5331.

[10] Bayoumi, M. Potential of façade-integrated PVT with radiant heating and cooling panel supported by a thermal storage for temperature stability and energy efficiency. Journal of Facade Design and Engineering, 2021, 9, 1, 47-58.
[11] Adun, H., Ishaku, H. P., Jazayeri, M., Adedeji, M., Shefik, A., Dagbasi, M. Is the installation of photovoltaic/thermal for residential use in the MENA region feasible? A techno-economic and emission reduction discourse of the MENA region's commitment to the Paris Agreement. Journal of Cleaner Production, 2022, 369, 133138.
[12] J Cai, Z Quan, T Li, L Hou, Y Zhao, M Yao. Performance study of a novel hybrid solar PV/T ground-source heat pump system. Procedia Engineering, 2017, 205, 1642-1649.
[13] Pazeraite, A.; Brandisauskas, D. Assessment of the Barriers towards More Rapid Development of Solar Power: The Case of Lithuania. Energetika 2022, 68, 68–78.
[14] Valancius, K., Mikucioniene, R. Solar energy as a tool of renovating soviet-type multi apartment buildings. Sol. Energy 2020, 198, 93–100.
[15] Kozlovas, P., Gudzius, S., Ciurlionis, S., Jonaitis, A., Konstantaviciute, I., Bobinaite, V. Assessment of Technical and Economic Potential of Urban Rooftop Solar Photovoltaic Systems in Lithuania. Energies, 2023, 16, 5410.
[16] Han, H., Kurses M., Harraz, A.A., Xu, J. Comparative study of PV, PVT, and solar thermal systems for residential applications in Europe. Energy, 2025, 336, 1-14.
[17] Dziugaite-Tumeniene, R., Streckien, G. Solar hot water heating system analysis using different software in single family house. In Environmental Engineering. Proceedings of the International Conference on Environmental Engineering, 2014, ICEE (Vol. 9, p. 1). Vilnius Gediminas Technical University, Department of Construction Economics and Property.
[18] Mohammed, A. K., Hamakhan, I. A. Analysis of energy savings for residential electrical and solar water heating systems. Case Studies in Thermal Engineering, 2021, 27, 101347.
[19] Qingyang, J., Jichun, Y., Yanying, Z., Huide, F. Energy and exergy analyses of PV, solar thermal and photovoltaic/thermal systems: a comparison study. International Journal of Low-Carbon Technologies, 2021, 16(2), 604-611.
[20] Ahmed, M. T., Rashel, M. R., Islam, M., Hoque, T. T., Tlemçani, M., Janeiro, F. M. Characterization, Performance, and Efficiency Analysis of Hybrid Photovoltaic Thermal (PVT) Systems. Energies, 2025, 18(5), 1050.
[21] Furbo, S., Perers, B., Dragsted, J., Gomes, J., Gomes, M., Coelho, P., ... & Kaliasas, R. Best practices for PVT technology. In SWC 2021: ISES Solar World Congress, 2021, 420-429. International Solar Energy Society.