

SYNERGY BETWEEN TRANSPORT AND ENERGY: PHOTOVOLTAIC PANELS ON CONVEYOR BELTS

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ABSTRACT: The integration of photovoltaic (PV) panels on belt conveyors offers a new approach for hybrid transport systems with electricity generation. The article analyses the technical requirements for the design of rubber conveyor belts, the selection of suitable photovoltaic modules, and solutions for protection against mechanical and climatic impacts. The possibilities for increasing energy efficiency through integrated monitoring and management systems are examined. Two types of structures for mounting photovoltaic panels on belt conveyor sections are studied. Examples are presented of the application in industrial sectors like mining, logistics, and other areas where such hybrid technology can increase efficiency and sustainability. The synergy between transport and energy is emphasised as an innovative model that combines functionality, energy independence, and economic feasibility.

Key words: synergy, belt conveyor, hybrid systems, sustainability, industrial innovations, innovations, transport – energy, FEM, Solidworks, Simulation.

СИНЕРГИЯ МЕЖДУ ТРАНСПОРТ И ЕНЕРГИЯ: ФОТОВОЛТАИЧНИ ПАНЕЛИ ВЪРХУ ЛЕНТОВИ ТРАНСПОРТЪОРИ

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РЕЗЮМЕ: Интеграцията на фотоволтаични (ФВ) панели върху лентови транспортъори предлага нов подход за хибридни транспортни системи с производство на електроенергия. В статията се анализират техническите изисквания към конструкцията на гумено-транспортни ленти, изборът на подходящи фотоволтаични модули и решенията за защита срещу механични и климатични въздействия. Разгледани са възможностите за повишаване на енергийната ефективност чрез интегрирани системи за мониторинг и управление на добива. Изследвани са два вида конструкции за монтаж на фотоволтаични панели върху секциите на лентовите транспортъори. Представени са примери за приложение в индустриални сектори като минното дело, логистиката и други направления, където такава хибридна технология може да повиши ефективността и устойчивостта. Подчертава се синергията между транспорт и енергия като иновативен модел, който съчетава функционалност, енергийна независимост и икономическа целесъобразност.

Ключови думи: синергия, гумено-транспортни ленти (ГТЛ), хибридни системи, устойчивост, индустриални иновации, иновации, транспорт – енергия, МКЕ, Solidworks, Simulation.

Introduction

Energy efficiency and sustainable production are among the key challenges facing the industrial sector today. Transport in a large part of industry is carried out by belt conveyors (Wang et al., 2023), which represent an essential component in the mining, metallurgical, and logistics industries, enabling efficient transport of materials over long distances. Conveyor systems are highly efficient but remain “significant consumers of electrical energy in mining enterprises” (Król et al., 2020).

These types of system are often installed outdoors and occupy considerable areas, while simultaneously requiring substantial amounts of electrical energy for their operation. On the other hand, the development of photovoltaic (PV) technologies provides the possibility for direct conversion of solar radiation into electrical energy. The possibility of integrating PV panels onto existing industrial facilities offers hybrid systems: creating a renewable energy source and improving the utilisation of available areas without additional land development, but this also leads to additional challenges to be addressed, as continuous movement, vibrations, dust, water, and temperature fluctuations impose high requirements on the mechanical and electrical durability of photovoltaic modules. In this context, designing a reliable and efficient integration requires careful selection of materials, mounting methods, and electrical configurations, as well as calculations of the expected energy efficiency.

The present paper aims to analyse the technical possibilities and limitations of installing photovoltaic panels on rubber belt conveyors, with attention given to the following factors: selection

of appropriate PV technologies and panels; mounting and fastening methods resistant to operational loads; energy efficiency and potential for electricity generation; economic feasibility; and the impact on the sustainability of industrial production. Photovoltaic systems are already being implemented in a number of operating mines worldwide as an alternative energy source (Renewable and Sustainable Energy Reviews, Review of Photovoltaic and Wind Power Systems Utilised in the Mining Industry - 2017).

In recent years, increasing interest has been observed in the integration of photovoltaic systems into industrial infrastructure, including rooftops, façades, noise barriers, and transport facilities. Similar studies show that the use of already built-up or functional areas for electricity generation significantly reduces the carbon footprint and optimises the energy independence of enterprises.

The application of this approach to belt conveyors is a relatively new and insufficiently explored direction, combining the principles of mechanical and electrical engineering. In addition to the technical challenges, economic aspects are also of key importance—investment cost, payback period, and the effect on operational expenses. Conducting such an analysis is important not only for assessing the feasibility of the idea, but also for establishing a foundation for future standards and industrial applications (IEA, 2023).

Photovoltaic systems for energy conversion

Photovoltaic systems are technologies for the direct conversion of solar radiation into electrical energy through the

photoelectric effect, realised in semiconductor photovoltaic cells, most commonly based on crystalline or amorphous silicon. The system typically includes solar panels for generating direct current (DC), an inverter for the conversion to alternating current (AC), structural mounting elements for installation on a given structure, energy storage batteries (in some cases), and control systems for managing the production and consumption of the generated electricity.

They offer significant environmental and economic benefits, such as reducing the carbon footprint and energy costs, while also providing the possibility for autonomous operation, integration into the electrical grid, or operation as a supplementary system (a hybrid installation that draws power from the electrical grid while additionally supplying electricity from the photovoltaic plant).

The main disadvantage of this type of technology at present is the high initial investment cost. Figure 1 shows a schematic diagram of a photovoltaic system.

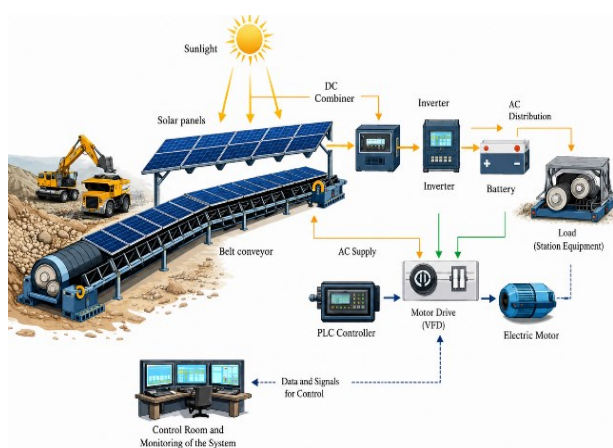


Fig. 1. Schematic diagram of a photovoltaic system

The present paper examines the installation of a photovoltaic system on rubber belt conveyors or along their route. Two types of photovoltaic (solar) panels are considered:

Rigid monocrystalline photovoltaic panels with the following technical parameters: dimensions L/H/W, mm – 1730/1118/30 mm and approximate weight of 22 kg. The product warranty from different manufacturers is about 20 years, with a 25-year power output warranty; approximate power 400–430 Wp; panel efficiency 20–22%; protection standard IP67;

Flexible monocrystalline photovoltaic panels with the following technical parameters: dimensions L/H/W, mm – 935/590/1.8 mm and approximate weight of 2.49 kg. The product warranty from different manufacturers is about 20 years, with a 25-year power output warranty; approximate power 100 Wp; panel efficiency 21%; protection standard IP67.

The photovoltaic panels described above are used on different structures mounted on a section of a rubber belt conveyor. In this study, part of the belt conveyor (one section) is considered in order to link it with a mathematical model for efficiency, the theoretically realised power from photovoltaic panel generation, the approximate installation costs, and the return on investment.

The developed approach allows evaluation of the technical applicability and economic efficiency of the system by combining engineering parameters and energy calculations within a unified analytical framework. This creates the basis for future optimisation of similar hybrid solutions in industrial conditions.

Rubber Belt Conveyors (Belt Conveyors)

Rubber belt conveyors, also referred to as belt transport conveyors, are used in many industries for transporting various materials. In the mining industry, they are applied for transporting soft and medium-hard rocks, as well as for conveying mineral resources in bulk or finely crushed form. This type of transport offers continuity, high productivity (resulting from the achievable speed), transportation at relatively steep inclination angles (12–18%), automation, centralised control, and other advantages.

The width of the conveyor belt is selected according to the mine's requirements, typically ranging from 800 to 3600 mm, depending on the required capacity. The material transport speed is usually within the range of 1–6 m/s. In the latest conveyor systems, especially those of shorter length, the drive is implemented with frequency control to regulate the transport speed.

In the mining industry, rubber belt conveyors are classified into the following types: face conveyors, main conveyors, and stacker conveyors. The present study considers only the main conveyors, also referred to as trunk or connecting conveyors. In practice, their length can be extended or shortened, but they are generally kept in operation for long periods. Another important factor for selecting main conveyors is that they rarely have additional equipment operating together with them.

In this study, rubber belt conveyors with belt width of $B_{belt}=1800$ mm and 2250 mm are considered, where the conveyors are constructed from separate sections along their length. Belt conveyors used in the mining industry consist of the following elements: a drive station (where the operator cabin, conveyor drives, tensioning system, and other components are usually installed), intermediate sections along their length (where idler rollers for the belt are mounted on the structure), and a return or turning station.

The element of the rubber belt conveyor considered in this paper is a single conveyor section with the following parameters:

- Overall dimensions (L/H/W, mm) – 6000/1610/3810 mm;
- Total weight of the section $G_{section}=3160$ kg;
- Section operating with a conveyor belt width $B_{belt} = 1800$ mm;
- Load from the section to the ground without material $G_{ground} = 0.15$ kg/cm²;
- Load from the section to the ground with material $G_{ground} = 0.29$ kg/cm².

Two types of structure for mounting photovoltaic panels on the belt conveyor sections are considered. The data presented are based on (Koprev & Aleksandrova, 2022).

Considered structures

In this study, an element of a transport system is examined, namely a section of a rubber belt conveyor. The section is constructed from a steel structure, on which upper supporting idler sets (roller carrying idlers), a lower supporting roller station (supporting the belt from below), and the corresponding pontoons of the section are mounted. The section is shown in Fig. 2 and is designed for a belt width of $B=1800$ mm; its parameters are presented above.

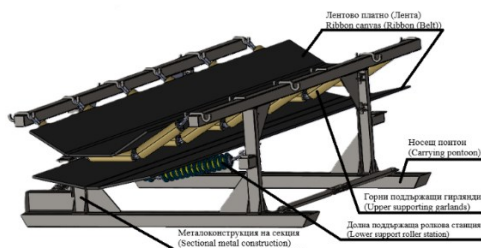


Fig. 2. Section of a rubber belt conveyor with belt width B=1800 mm

Based on the section shown in Fig. 2, two mounting options have been developed for covering the rubber conveyor belt. In this way, no additional land around the belt conveyor is used—only the existing conveyor structure.

Option 1 is presented in Fig. 3. In this option, flexible photovoltaic panels with dimensions L/H/W, mm – 935/590/1.8 mm are used, closing the space above the conveyor section diametrically. In this manner, electrical energy is generated during solar irradiation, dust emissions during conveyor operation are reduced, noise is decreased, and under adverse meteorological conditions the transported material is protected from moisture.

The approximate power that can be generated by a single flexible photovoltaic panel is about 150 W. In the presented configuration, a total of 50 flexible panels are installed. The total installed power is approximately: $50 \text{ pcs} \times 150 \text{ W} = 7500 \text{ W}$.

The designed supporting structure is made of metal profiles and is intended to be mounted onto the conveyor section using mounting brackets and rubber dampers placed between the photovoltaic support structure and the conveyor section structure, in order to minimise vibrations from the operation of the transport system. The frame is designed to withstand all loads (snow, wind, and rain), as well as the self-weight of the panels, based on the standards listed below.

The weight of the metal structure together with the photovoltaic panels is $G_{var1}=300 \text{ kg}$. The total weight of the section, including the conveyor belt, the material on the belt, and the section components, is: $G_{total} = G_{section} + G_{var1} + G_{material} = 3710 + 300 + 2652 = 6662 \text{ kg}$.

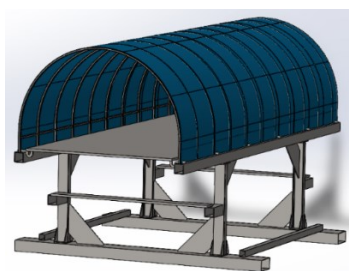


Fig. 3. Diametrical covering of a belt conveyor section with installed flexible photovoltaic panels

Option 2 is presented in Fig. 4. In this configuration, rigid monocrystalline photovoltaic panels are used with the following dimensions: L/H/W, mm – 1730/1118/30 mm – 10 panels installed of this size; and 8 panels installed with dimensions 1450/490/30 mm. These panels form a dual-pitched structure covering the space above the belt conveyor section. In this way, electrical energy is generated during solar irradiation, dust emissions during conveyor operation are reduced, noise is

decreased, and under adverse meteorological conditions the transported material is kept dry.

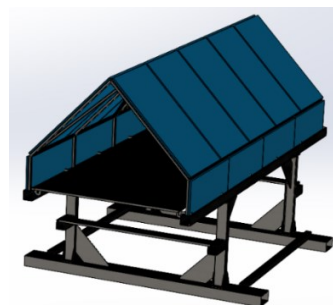


Fig. 4. Dual-pitched covering of a belt conveyor section with installed photovoltaic panels

The approximate power generated by one photovoltaic panel is about 400 W (for the 10 panels) and 250 W (for the 8 panels installed below in a vertical arrangement). In the presented configuration, a total of 18 photovoltaic panels are installed. The total installed power is approximately: $10 \text{ pcs} \times 400 \text{ W} = 4,000 \text{ W}$ and $8 \text{ pcs} \times 250 \text{ W} = 2000 \text{ W}$, or a total of 6000 W.

In this option, the supporting structure on which the photovoltaic panels are mounted includes one vertical section where 8 panels are mounted vertically, while the inclined dual-pitched part has an angle of 42 degrees. This angle is selected as an average optimal angle for maximum energy yield on the territory of the Republic of Bulgaria.

The designed supporting structure is made of metal profiles and is intended to be mounted onto the conveyor section using mounting brackets and rubber dampers placed between the photovoltaic support structure and the conveyor section structure in order to minimise vibrations from the operation of the transport system. The frame is designed to withstand all loads (snow, wind, and rain), as well as the self-weight of the panels, based on the standards listed below.

The weight of the metal structure together with the photovoltaic panels is $G_{var2} = 600 \text{ kg}$. The total weight of the section, including the conveyor belt, the material on the belt, and the section components, is: $G_{total} = G_{section} + G_{var2} + G_{material} = 3710 + 600 + 2652 = 6962 \text{ kg}$.

Experimental Study

The study is aligned with the main requirements for sizing and loading of structures and photovoltaic plants according to the following nationally applied standards:

- BDS EN 1991-1-3:2006/NA – “Snow Load” – the average value for the territory of the Republic of Bulgaria is $150\text{--}200 \text{ kg/m}^2$ ($1.47\text{--}1.97 \text{ kN/m}^2$), where the lower value applies when snow is removed and the higher value when it is not;
- BDS EN 1991-1-4:2005/NA – “Wind Load” – the average value for the territory of the Republic of Bulgaria is $0.3\text{--}0.4 \text{ kN/m}^2$;
- For “Rain Load,” a limit of 25 mm is selected, corresponding to 0.245 kN/m^2 .

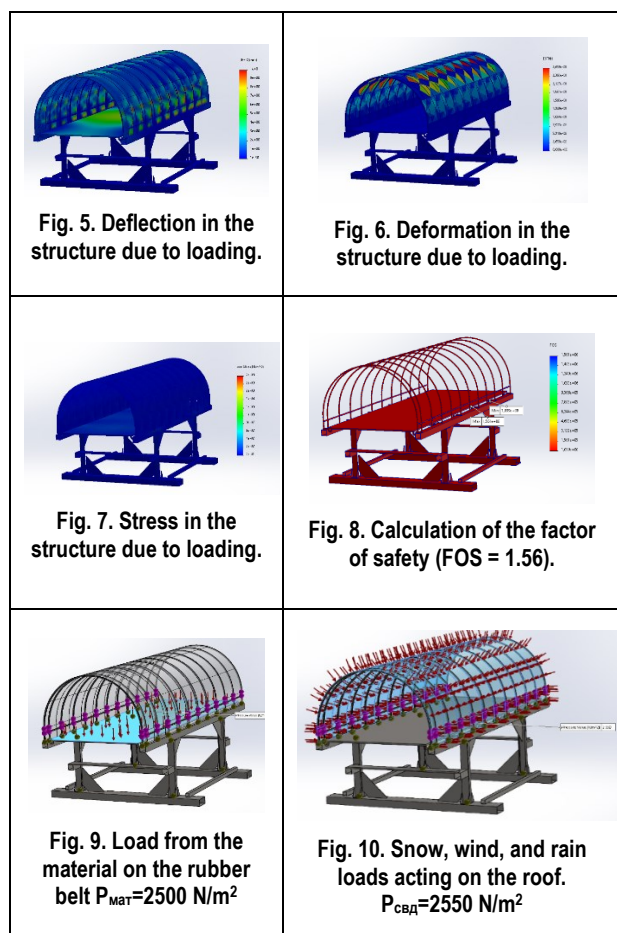
The loads acting on the rubber belt conveyor section were determined through simulation using the Finite Element Method (FEM). The section was loaded using the *SolidWorks* software product, the *Simulation* module. For the calculation of the

original section, a simplified model was created to facilitate the computational process. As described above, two options for building a photovoltaic installation along the length and on the structure of the belt conveyor were considered, using the existing sections or the conveyor steel structure, so that no additional land areas around the conveyor are required.

Option 1 is presented in Fig. 5 – Fig. 10, where flexible photovoltaic panels are used to cover the conveyor belt. In addition to generating electrical energy from the covered conveyor, dust emissions (depending on the transported material) and operational noise are significantly reduced. The weight of one flexible photovoltaic panel is approximately 2.49 kg, and the total weight of Option 1 is $G_{var1} = 300$ kg. For this option, the following loads are applied: snow load $P_{snow} = 1900$ N/m², wind load $P_{wind} = 400$ N/m², rain load $P_{rain} = 250$ N/m², together with the load from the transported material and the self-weight of the metal structure.

In this option, the total photovoltaic panel area is 26.19 m². It should be noted that the largest deflections and deformations from the conducted simulation studies occur in the conveyor belt itself, which is expected. The results obtained for the conveyor section structure are as follows:

- Deflection – min (0 mm); max (187.5 mm);
- Stresses – min (0.0363 kgf/cm²); max (1130.94 kgf/cm²);
- Deformation – min (0); max (0.658);
- Factor of safety (FOS) – min (2.1); max (6.60).



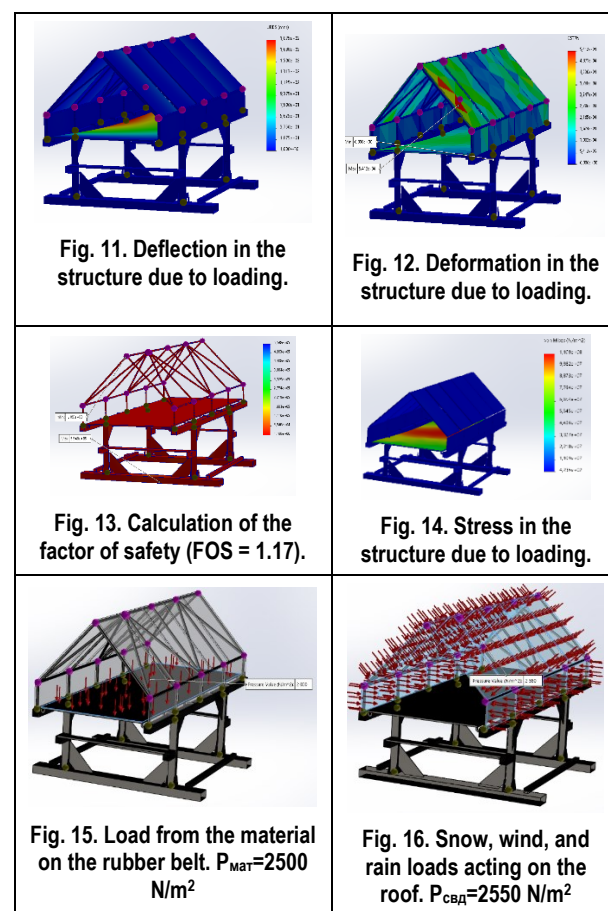
Option 2 is presented in Fig. 11 – Fig. 16 where photovoltaic panels are used to cover the conveyor belt. In addition to generating electrical energy from the covered belt conveyor, dust emissions (depending on the transported material) and

operational noise are significantly reduced. The weight of one photovoltaic panel is approximately 22 kg, and the total weight of Option 2 is $G_{var2} = 600$ kg.

For this option, the following loads are applied: snow load $P_{snow} = 1900$ N/m², wind load $P_{wind} = 400$ N/m², and rain load $P_{rain} = 250$ N/m², together with the load from the transported material and the self-weight of the metal structure.

In this option, the total photovoltaic panel area is 25.03 m². It should be noted that the largest deflections and deformations from the conducted simulation studies occur in the conveyor belt itself, which is expected. The results obtained for the conveyor section structure are as follows:

- Deflection – min (0 mm); max (185 mm);
- Stresses – min (0.004319 kgf/cm²); max (1130.94 kgf/cm²);
- Deformation – min (0); max (0.00054);
- Factor of safety (FOS) – min (1.168); max (5.50).



Calculations for the productivity and power generated by the photovoltaic panels

Option 1 is designed to be constructed using flexible photovoltaic panels with an approximate power of 150 W per panel, with a total of 50 flexible panels installed. The total installed power is approximately: 50 pcs × 150 W = 7500 W.

The calculations are based on averaged data for the entire territory of Bulgaria. In this option, the total photovoltaic panel area is 26.19 m².

Average annual solar radiation for the territory of the Republic of Bulgaria:

- System efficiency: $\eta_{system} = 0.85$;
- Panel power: $N_{system} = 50 \times 150 \text{ Wp} = 7500 \text{ Wp}$;

- Standard irradiance value for Bulgaria:
 $H_{static} = 1000 \text{ W/m}^2$.

The real output power is calculated as:

$$N_{real} = N_{system} \cdot \eta_{system} \cdot \frac{H_{potential}}{H_{static}} = 9670.88 \text{ W}$$

Through the performed calculations, the approximate annual amount of electrical energy produced by the system is determined:

$$E_{year} = N_{system} \cdot H_{potential} \cdot \eta_{system} = 9670.88 \frac{\text{kW}}{\text{h}}$$

The calculation of the annual system productivity is based on a specific conveyor section with dimensions 6000 mm in length and 3810 mm in width. These values can be extended to a given total length of a belt conveyor. In practice, belt conveyors have various lengths, but many of them are approximately 200 m, 500 m, 800 m, 1300 m, 1500 m, and 2000 m. The approximate number of sections for the lengths listed above is as follows:

- 200 m conveyor length – 33 sections;
- 500 m conveyor length – 83 sections;
- 800 m conveyor length – 133 sections;
- 1300 m conveyor length – 216 sections;
- 1500 m conveyor length – 248 sections;
- 2000 m conveyor length – 333 sections.

Using these lengths, we divide them into 6 m (6000 mm) sections and calculate the approximate annual energy for each case.

$$E_{year-200m} = N_{system-33} \cdot H_{potential} \cdot \eta_{system} = 411\,476.39 \frac{\text{kW}}{\text{h}}$$

$$E_{year-500m} = N_{system-83} \cdot H_{potential} \cdot \eta_{system} = 802\,682.63 \frac{\text{kW}}{\text{h}}$$

$$E_{year-800m} = N_{system-133} \cdot H_{potential} \cdot \eta_{system} = 1\,286\,226.38 \frac{\text{kW}}{\text{h}}$$

$$E_{year-1300m} = N_{system-216} \cdot H_{potential} \cdot \eta_{system} = 2\,088\,909 \frac{\text{kW}}{\text{h}}$$

$$E_{\text{годишно}-1500m} = N_{system-248} \cdot H_{potential} \cdot \eta_{system} = 2\,398\,377 \frac{\text{kW}}{\text{h}}$$

$$E_{year-2000m} = N_{system-333} \cdot H_{potential} \cdot \eta_{system} = 3\,220\,401.38 \frac{\text{kW}}{\text{h}}$$

The calculations are based on theoretical assumptions, and it is recommended to implement a pilot section consisting of one conveyor segment in order to collect measured data and compare them with the theoretical calculations presented in this paper.

Option 2 is designed to be constructed using photovoltaic panels with an approximate power of 400 W or 250 W per panel. In this configuration, a total of 18 panels are installed. The total installed power is approximately: 10 pcs × 400 W = 4000 W and 8 pcs × 250 W = 2000 W, or a total of 6000 W.

The calculations are based on averaged data for the entire territory of Bulgaria. In this option, the total photovoltaic panel area is 25.03 m².

- Average annual solar radiation for the territory of the Republic of Bulgaria: $H_{potential} = 1517 \text{ kWh/m}^2/\text{year}$;

- System efficiency: $\eta_{system} = 0.85$

- Panel power: $N_{system} = 18 \times 333.33 \text{ Wp} = 6000 \text{ Wp}$;

- Standard irradiance value for Bulgaria:
 $H_{static} = 1000 \text{ W/m}^2$.

The real output power is calculated as:

$$N_{real} = N_{system} \cdot \eta_{system} \cdot \frac{H_{potential}}{H_{static}} = 7736.70 \text{ W}$$

Through the performed calculations, the approximate annual amount of electrical energy produced by the system is determined:

$$E_{year} = N_{system} \cdot H_{potential} \cdot \eta_{system} = 7736.70 \frac{\text{kW}}{\text{h}}$$

The calculation of the annual system productivity is based on a specific conveyor section with dimensions 6000 mm in length and 3810 mm in width. These values can be extended to a given total length of a belt conveyor. In practice, belt conveyors have various lengths, but many of them are approximately 200 m, 500 m, 800 m, 1300 m, 1500 m, and 2000 m. The approximate number of sections for the lengths listed above is as follows:

- 200 m conveyor length – 33 sections;
- 500 m conveyor length – 83 sections;
- 800 m conveyor length – 133 sections;
- 1300 m conveyor length – 216 sections;
- 1500 m conveyor length – 248 sections;
- 2000 m conveyor length – 333 sections.

Using these lengths, we divide them into 6 m (6000 mm) sections and calculate the approximate annual energy for each case.

$$E_{year-200m} = N_{system-33} \cdot H_{potential} \cdot \eta_{system} = 255\,311.10 \frac{\text{kW}}{\text{h}}$$

$$E_{year-500m} = N_{system-83} \cdot H_{potential} \cdot \eta_{system} = 642\,146.10 \frac{\text{kW}}{\text{h}}$$

$$E_{year-800m} = N_{system-133} \cdot H_{potential} \cdot \eta_{system} = 1\,028\,981.10 \frac{\text{kW}}{\text{h}}$$

$$E_{year-1300m} = N_{system-216} \cdot H_{potential} \cdot \eta_{system} = 1\,671\,127.20 \frac{\text{kW}}{\text{h}}$$

$$E_{year-1500m} = N_{system-248} \cdot H_{potential} \cdot \eta_{system} = 1\,918\,701.60 \frac{\text{kW}}{\text{h}}$$

$$E_{year-2000m} = N_{system-333} \cdot H_{potential} \cdot \eta_{system} = 2\,576\,321.10 \frac{\text{kW}}{\text{h}}$$

The calculations are based on theoretical assumptions, and it is recommended to implement a pilot section consisting of one conveyor segment in order to collect measured data and compare them with the theoretical calculations presented in this paper. When installing photovoltaic panels on the conveyor, the space between sections should be left uncovered to allow ventilation of the volume beneath the photovoltaic panels and, accordingly, to provide cooling for the entire belt system underneath.

The installation of photovoltaic panels on belt conveyors would lead to multiple benefits, most notably that part of the energy required for their operation could be generated by utilising the existing layout of the conveyor belt. The calculations presented above in this paper are theoretical, and the arrangement of each conveyor in practice varies; however, this does not change the fact that no additional land is required for photovoltaic installation, as only the conveyor section structure or the steel framework of the belt conveyor is used.

The main argument for initiating this study is that the territory of the Republic of Bulgaria has the following sunshine duration:

- 2000–2500 hours annually in most parts of the country;
- Up to 2800 hours annually in the southern and eastern regions (the Black Sea coast, the Plain of Upper Thrace);
- Around 1800–2000 hours in mountainous and northwestern regions.

Sunshine duration by regions in Bulgaria:

- Southeastern Bulgaria (Burgas, Sandanski, Haskovo) – 2500–2800 h/year;
- Central Bulgaria (Plovdiv, Stara Zagora) – about 2400–2600 h/year;
- Northern Bulgaria (Ruse, Pleven) – 2100–2300 h/year.
- Mountain regions (Smolyan, the Rila, the Pirin, the Stara Planina) – 1800–2000 h/year.
- Sofia – on average about 2100 hours of sunshine per year.

Economic evaluation of the variants

Description	Price euro	Quantity item/m./kg.	Total price euro	Activity	Note
Steel structure for mounting photovoltaic panels	951.31	170 kg - 1 item	951.31	Fabrication of steel structure, delivery, and installation	var. 1
Steel structure for mounting photovoltaic panels	845.27	200 kg - 1 item	845.27	Fabrication of steel structure, delivery, and installation	var. 2
Flexible photovoltaic panels – 150 W	297.6	50 items	14878.59	Delivery and installation	var. 1
Photovoltaic panels – 400 W	127.8	10 items	6391.15	Delivery and installation	var. 2
Photovoltaic panels – 250 W	92	8 items	4601.63	Delivery and installation	var. 2
Control system (hybrid)	13300	1 item	13300	Delivery and installation	var. 1
Control system (hybrid)	11200	1 item	11200	Delivery and installation	var. 2
Battery	6391.1	1 item	6391.1	Delivery and installation	var. 1
Battery	5573.1	1 item	5573.1	Delivery and installation	var. 2
Inverter	2950	1 item	2950	Delivery and installation	var. 1
Inverter	2456	1 item	2456	Delivery and installation	var. 2

The estimated cost for constructing the photovoltaic power plant under Option 1 amounts to €38471.1. For Option 2, the estimated cost of constructing the photovoltaic power plant amounts to €15884.40.

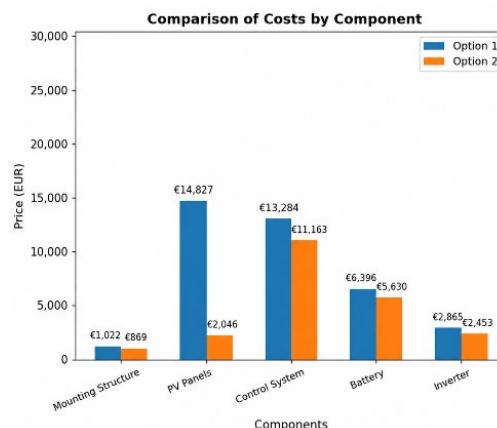


Fig. 17. Graphical representation of the costs per section for the individual components of the system

Conclusion

The conclusion confirmed by the performed calculations, the conducted study, the developed simulation models, as well as simulations carried out in different software products, is that the required investment is worthwhile. Even the smallest reduction in electricity costs on the free market represents a significant step towards sustainability and higher productivity. We preserve a large portion of land by not developing additional photovoltaic installations on it, reduce dust emissions, noise, moisture impact on the transported material, and other negative effects. The costs presented in the economic section are end-user values, and of course, with larger orders of components and parts, they may vary, potentially resulting in even greater cost efficiency.

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