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“WOMEN IN INNOVATION AND SCIENCE” XALQARO ILMIY-AMALIY KONFERENSIYA VA FORUMI ILMIY ISHLARI TO‘PLAMI

Toshkent davlat transport universitetida 2026-yil 27-mart kuni “Women in Innovation and Science” xalqaro forumi ilmiy ishlari to‘plami chop etildi.

Mazkur nufuzli tadbirlar O‘zbekiston Respublikasi Oliy ta’lim, fan va innovatsiyalar vazirligi hamda Transport vazirligi hamkorligida tashkil etilib, mamlakatimizda ilm-fan, innovatsiyalar va zamonaviy texnologiyalarni rivojlantirish, shuningdek xalqaro ilmiy hamkorlikni yanada kengaytirishga qaratilgan muhim platforma hisoblanadi.

Konferensiya ochilish marosimida davlat organlari, xalqaro tashkilotlar va yetakchi oliy ta’lim muassasalari vakillari ishtirok etdi. Jumladan, Toshkent davlat transport universiteti rektori G‘ulomov Abdulaziz Abdullayevich, O‘zbekiston Respublikasi Transport vazirligi vakili Ulmasova Lobarkhon Adilovna, Osiyo taraqqiyot banki eksperti Claire Charamnac, Istanbul Aydin universiteti vasiylik kengashi raisi Mustafa Aydin, Belarus davlat transport universiteti rektori Kazakov Nikolay Nikolayevich hamda Qirg‘iziston Respublikasi Transport vazirligi vakili Dinara Moldokalieva ishtirok etdilar.

Konferensiya ilmiy dasturi doirasida plenar va panel sessiyalar, shuningdek ilmiy ma’ruzalar taqdimoti o‘tkazilib, ularda sun’iy intellekt va raqamli texnologiyalarni iqtisodiyot va ta’limga joriy etish, transport va aviatsiya sohasida innovatsion yechimlar, sanoat va IT sohasida texnologiya transferi, shuningdek ta’limda raqamli platformalar va intellektual tizimlar kabi dolzarb masalalar yoritildi.

2026-yil 27-mart kuni o‘tkazilgan “Women in Innovation and Science” xalqaro forumi ayollar yetakchiligi, innovatsiyalar va STEM sohalariga bag‘ishlangan bo‘lib, mamlakatimizda ayollarning ilm-fan va texnologiya sohalaridagi ishtirokini kengaytirish, ularning yetakchilik salohiyatini rivojlantirish hamda xalqaro hamkorlikni mustahkamlashga qaratilgan strategik maydon sifatida tashkil etildi.

Forum doirasida ayollar yetakchiligini rivojlantirish va rag‘batlantirish, xalqaro tajriba almashinuvi va ilmiy tarmoqlarni kengaytirish, yosh tadqiqotchi ayollar va PhD talabalarni qo‘llab-quvvatlash hamda innovatsion ekotizimlarda gender tenglikni ta’minlash kabi ustuvor vazifalar amalga oshirildi. Shuningdek, forumda ayollar yetakchiligi va STEM, gender tenglik va ilm-fan institutsional rivoji, ayollar tadbirkorligi va innovatsion startaplar, innovatsiya ekotizimlari va xalqaro hamkorlik, yosh ayol tadqiqotchilarni rivojlantirish, mentorlik va akademik tarmoqlar yo‘nalishlarida tematik sessiyalar tashkil etildi.

Forumda davlat organlari, xalqaro tashkilotlar, yetakchi oliy ta’lim muassasalari va ilmiy markazlar vakillari, jumladan “OLIMA” uyushmasi raisi Murtazayeva Raxbar Hamidovna, “Sharq ayoli” xalqaro ayollar jamoat fondi raisi Tursunbayeva Saodat Gafurovna, Osiyo taraqqiyot banki eksperti Claire Charamnac, O‘zbekiston Respublikasi Transport vazirligi vakili Ulmasova Lobarkhon Adilovna, Toshkent davlat transport universiteti rektori G‘ulomov Abdulaziz Abdullayevich, Qirg‘iziston Respublikasi Transport vazirligi vakili Dinara Moldokalieva hamda Indoneziyadan universitet dekani Yoga Prihatin ishtirok etdilar.

Shuningdek, forumda Yevropa va Osiyo davlatlaridan yetakchi olimlar, ekspertlar va yosh tadqiqotchilar keng qatnashdi.

Forum dasturiga ochilish marosimi, panel muhokamalar, ilmiy chiqishlar hamda professional rivojlanish bo'yicha workshoplar kiritilgan bo'lib, ular doirasida gender tenglik, ayollar karyerasini rivojlantirish, ilmiy tadqiqotlar va innovatsion boshqaruv bo'yicha amaliy seminarlar tashkil etildi.

Mazkur tadbirlar Osiyo taraqqiyot banki (ADB), "OLIMA" — O'zbekiston xotin-qizlar olimlari uyushmasi, "Sharq ayoli" xalqaro ayollar jamoat fondi, Germaniya xalqaro hamkorlik jamiyati (GIZ), shuningdek Rossiya, Turkiya, Indoneziya va Qirg'iziston oliy ta'lim muassasalari hamda Belarus Milliy fanlar akademiyasi ilmiy institutlari hamkorligida o'tkazildi.

Mazkur xalqaro ilmiy-amaliy konferensiya va forumning ahamiyati shundaki, ular xalqaro ilmiy hamkorlikni mustahkamlash, innovatsion ishlanmalarni amaliyotga joriy etish, raqamli va barqaror rivojlanishni ta'minlash, shuningdek ayollarning ilm-fan va innovatsiya sohalaridagi rolini kuchaytirishga xizmat qiladi. Shu bilan birga, mazkur tadbirlar yosh olimlar va tadqiqotchilarni qo'llab-quvvatlash, ilmiy tajriba almashish hamda global ilmiy makonga integratsiyalashuvni jadallashtirishda muhim ahamiyat kasb etadi.

Mazkur xalqaro ilmiy-amaliy konferensiya va forumning maqsadi zamonaviy ilmiy tadqiqot yo'nalishlarini muhokama qilish, innovatsion yondashuvlar va ilg'or texnologiyalar bo'yicha ilmiy natijalar almashuvini ta'minlash, shuningdek xalqaro ilmiy hamkorlikni rivojlantirishdan iboratdir.

Tadbirda O'zbekiston Respublikasi hamda xorijiy mamlakatlarning oliy ta'lim muassasalari va ilmiy-tadqiqot institutlari olimlari, shuningdek amaliyotda muhim natijalarga ega bo'lgan mutaxassislar o'z ilmiy ishlari bilan ishtirok etdilar.

Ushbu ilmiy to'plamda muhandislik, transport, raqamlashtirish, sun'iy intellekt, innovatsion boshqaruv, gender tenglik va barqaror rivojlanish sohalarida faoliyat yuritayotgan yetakchi olimlar, professor-o'qituvchilar va tadqiqotchilarning ilmiy ishlari jamlangan. To'plamda dolzarb ilmiy muammolar, zamonaviy yechimlar, nazariy va amaliy tadqiqot natijalari yoritilib, ushbu yo'nalishlarning bugungi holati va istiqboldagi rivojlanish tendensiyalari aks ettirilgan.

Mazkur nashr mamlakatimizda ilm-fan va innovatsion rivojlanishni ta'minlash, xalqaro ilmiy aloqalarni mustahkamlash hamda yosh olimlar va tadqiqotchilarni qo'llab-quvvatlash yo'lidagi muhim qadamlardan biri sifatida e'tirof etiladi.

Shuningdek, mazkur ilmiy to'plamda keltirilgan natijalar kelgusida ilmiy tadqiqotlar samaradorligini oshirish, amaliyotga yo'naltirilgan innovatsion yechimlarni keng joriy etish hamda sohalararo integratsiyani chuqurlashtirish uchun muhim ilmiy asos bo'lib xizmat qiladi. To'plam materiallari nafaqat ilmiy jamoatchilik, balki ishlab chiqarish sohasi mutaxassislari, doktorantlar va talabalar uchun ham foydali manba hisoblanadi.

Mazkur nashrda yoritilgan ilmiy g'oyalar va ilg'or yondashuvlar asosida yangi ilmiy izlanishlar olib borilishi, xalqaro ilmiy aloqalarning yanada rivojlanishi hamda innovatsion rivojlanish strategiyalarining takomillashishiga xizmat qilishi kutilmoqda.

Analysis of energy losses in photovoltaic power plants under the climatic conditions of Karshi

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Abstract: This scientific article presents a comprehensive analysis of energy losses in photovoltaic power plants under the climatic conditions of Karshi. The study identifies and systematizes the main factors affecting the conversion of solar energy into electrical energy, including shading, soiling, temperature effects, module degradation, and electrical losses, along with their quantitative assessment. Considering the high solar radiation and sharply continental climate of the region, scientifically grounded recommendations for improving the efficiency of photovoltaic systems have been developed.
Keywords: photovoltaic power plant, solar energy, energy losses, Karshi climate, efficiency, solar radiation, efficiency coefficient, shading, degradation

1. Introduction

The increasing global energy demand, depletion of fossil fuels, and environmental concerns have accelerated the transition toward renewable energy sources. Among them, solar energy is one of the most promising due to its availability, sustainability, and environmental benefits. Photovoltaic (PV) systems, which directly convert solar radiation into electricity, play a key role in modern energy production. In agricultural regions, energy costs represent about 30–35% of total production expenses, making energy efficiency and renewable integration essential for sustainable development. Decentralized PV systems are therefore widely implemented in rural areas with high solar potential. The Karshi region of Uzbekistan is characterized by high solar irradiation (1500–1700 kWh/m² per year), making it suitable for PV deployment. However, the actual performance of PV systems is often lower than theoretical expectations due to various energy losses, including shading, dust accumulation, temperature effects, module degradation, and electrical losses. Despite numerous studies on PV performance, limited research has focused on Central Asian climatic conditions, particularly Uzbekistan. Therefore, a region-specific analysis is required. This study aims to analyze and classify the main energy loss factors in PV systems under Karshi climatic conditions and to propose methods for improving system efficiency. The novelty of this work lies in adapting PV loss analysis to local environmental factors, especially high temperature and dust impact, which are insufficiently addressed in previous research.

2. Research methodology

This study applies a combined analytical and modeling approach to evaluate energy losses in photovoltaic (PV) power plants under the climatic conditions of the Karshi region. The methodology integrates theoretical analysis, empirical interpretation, and mathematical estimation to ensure result reliability. The study area is the Karshi region in southern Uzbekistan (38°52′ N, 65°48′ E), characterized by a sharply continental climate with hot summers and mild winters. Annual solar irradiation ranges from 1500 to 1700 kWh/m², making the region highly suitable for PV applications. However, environmental conditions such as high ambient temperatures (up to +45°C), dust accumulation, low humidity, and seasonal winds significantly affect system performance and increase energy losses [1]. A standard grid-connected PV system was considered, consisting of monocrystalline PV modules, DC cabling, an inverter unit, AC transmission lines, and an optional transformer. The selected PV modules (200–400 W, 15–20% efficiency, 24–40 V, monocrystalline silicon technology) represent widely used commercial systems, ensuring practical relevance of the results [2]. Energy losses were classified into two main categories:

Solar Energy Losses. These occur during the conversion of solar radiation into electrical energy and include:
- Shading losses (near and far shading effects)

Soiling losses due to dust and surface загрязнение
- Losses caused by non-optimal tilt and orientation
- Thermal losses due to elevated operating temperatures
- Module degradation over time
- Mismatch losses between PV modules

Electrical Losses. These losses occur during energy transmission and conversion processes: Cable (ohmic) losses in DC and AC circuits, Inverter conversion losses, Transformer losses, Losses due to improper system configuration. Calculation and Estimation Methods: The estimation of energy losses was carried out using standard analytical expressions and empirical coefficients derived from literature sources. The total energy output of a photovoltaic system can be expressed as:

$$E_{out} = E_{in} \cdot \eta_{pv} \cdot (1 - L_{Total})$$

where: E_{out} – electrical energy output, E_{in} – incident solar energy, η_{pv} – module efficiency, L_{Total} – total energy loss factor. [3]

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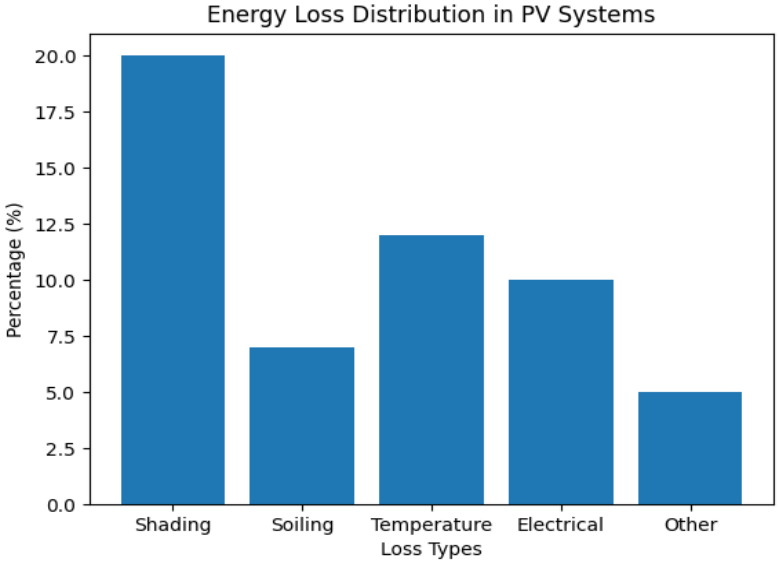

Fig. 1. Energy loss distribution in PV systems

The chart illustrates that shading and temperature are dominant loss factors in Karshi conditions.

The total loss factor is calculated as the sum of individual losses:

$$L_{Total} = L_{sh} + L_{so} + L_{temp} + L_{deg} + L_{el}$$

where: L_{sh} – shading losses, L_{so} – soiling losses, L_{temp} – temperature losses,

L_{deg} – degradation losses, L_{el} – electrical losses.

Temperature impact on PV efficiency was evaluated using the temperature coefficient model:

$$\eta\,(T) = \eta_{ref}\,[1 - \beta\,(T - T_{ref})]$$

where: β – temperature coefficient, T– operating temperature, T_{ref} – reference temperature (25°C).

Data Sources and Analysis Tools

The study utilizes: published scientific literature, operational data from existing photovoltaic systems, regional climatic statistics.

Comparative analysis and systematization methods were applied to identify dominant loss factors and quantify their impact under Karshi conditions.

This study employs an integrated methodological framework combining analytical modeling, empirical monitoring data, and energy balance analysis to evaluate energy losses in photovoltaic (PV) systems under the climatic conditions of the Karshi region.

Study Object and Site Description

The research object is a 370 kW grid-connected photovoltaic power plant installed at Karshi State University, Pedagogical Faculty. The system operates under real load conditions and is used both for electricity supply and experimental analysis.

The study area is located in the Karshi region (38°52′ N, 65°48′ E), characterized by:

High solar irradiation (1500–1700 kWh/m²/year)

High ambient temperature (up to +45°C)

Dust-prone semi-arid environment

Seasonal wind and low humidity

These conditions create favorable solar potential but also introduce significant performance losses.

Data Collection and Monitoring

Table 9

Day Operational Performance of the Photovoltaic Power Plant

Date	Energy Generated by PV, kWh	Energy Consumed, kWh	Energy Exported to Grid, kWh	Energy Imported from Grid, kWh
2025-12-14	73.53	0.87	73.00	0.34
2025-12-15	273.11	0.34	273.50	0.00
2025-12-17	36.74	0.89	36.06	0.21
2025-12-18	31.84	0.00	0.00	0.00
2025-12-20	12.25	1.09	11.56	0.40
2025-12-21	93.24	1.09	92.75	0.60
2025-12-22	360.60	0.00	361.25	0.59
2025-12-23	370.80	0.05	371.38	0.63
2025-12-24	89.81	0.15	90.00	0.34

The study is based on real operational data collected over a 9–10 day monitoring period (December 2025) . The operational performance of the photovoltaic power plant was evaluated using a 9-day dataset collected in December 2025. The monitored parameters included the energy generated by the PV system, local energy consumption, energy exported to the grid, and energy imported from the grid. The summarized results are presented in Table [12].

The following parameters were recorded daily:

- E_{PV} – energy generated by the PV system (kWh)
- E_{cons}– energy consumed locally (kWh)
- E_{grid} - energy exported to the grid (kWh)
- $E_{imported}$– energy imported from the grid (kWh)

These data were obtained from the system's monitoring platform and processed using statistical analysis methods.

Energy Balance Method

The performance of the photovoltaic system was evaluated using the energy balance approach, which allows quantifying system losses under real operating conditions:

$$E_{PV} = E_{cons} + E_{grid} + E_{loss}$$

where:

- E_{loss} – total system energy losses

From this, total losses are determined as:

$$E_{loss} = E_{PV} - (E_{cons} + E_{grid})$$

The system efficiency is calculated as:

$$\eta = \frac{E_{cons} + E_{grid}}{E_{PV}} \times 100\%$$

This method provides a realistic evaluation of system performance and is widely used in PV monitoring standards (IEC 61724).

Analytical Loss Modeling

In addition to empirical analysis, energy losses were evaluated using analytical modeling:

$$E_{out} = E_{solar} \cdot \eta_{pv} \cdot (1 - L_{totol})$$

Total loss factor is defined as:

$$L_{totol} = L_{sh} + L_{so} + L_{temp} + L_{deg} + L_{el} + L_{miss}$$

where individual losses represent:

- L_{sh} – shading losses
- L_{so} – soiling (dust) losses
- L_{temp} – temperature losses
- L_{deg} – degradation losses
- L_{el} – electrical losses
- L_{miss}– mismatch losses

Temperature Impact Assessment

Temperature influence was evaluated using the standard model:

$$\eta = \eta_{ref} [1 - \beta(T - 25)]$$

Additionally, module temperature was estimated as:

$$T_{module} = T_{ambient} + \frac{NOCT - 20}{800} \cdot G$$

This allows accurate estimation of thermal losses under Karshi climatic conditions. The collected operational data were analyzed using a combination of statistical and comparative methods to ensure a comprehensive evaluation of the photovoltaic system performance. The analysis included a comparative assessment of daily energy production values over the monitoring period, as well as an evaluation of the relationship between solar radiation intensity and energy output. In addition, high and low production days were identified and classified in order to better understand the variability of system performance under changing environmental conditions. The measured performance indicators were also compared with theoretical expectations to assess the consistency between real and modeled results. Particular attention was given to peak production days, such as December 22–23, during which the system operated close to its nominal capacity, demonstrating optimal performance under favorable solar radiation conditions.

To ensure the reliability and accuracy of the obtained results, several validation approaches were applied. Empirical data were cross-checked against analytical calculations based on standard photovoltaic performance models. Furthermore, the estimated loss values were compared with ranges reported in scientific literature, and the results were validated in accordance with internationally recognized photovoltaic system monitoring standards, including IEC 61724. These steps ensured the consistency, reliability, and scientific credibility of the analysis. The proposed methodology provides several important contributions. It integrates real operational monitoring data with analytical modeling approaches, allowing for a more accurate and practical assessment of photovoltaic system performance. The application of the energy balance method under specific local climatic conditions enhances the relevance of the results, particularly for regions characterized by high temperatures and dusty environments such as Karshi. In addition, the methodology has practical applicability for evaluating and optimizing photovoltaic systems in educational and institutional settings, making it a valuable tool for both scientific research and applied engineering practice.

3. Results and Discussion

The analysis of the photovoltaic power plant performance was carried out using real operational data collected over a 9-day period in December 2025. The results demonstrate that the system operates with high efficiency under real conditions. The total energy generated during the observation period amounted to 1341.92 kWh, while the useful energy (consumed locally and exported to the grid) reached approximately 1343.98 kWh. The calculated difference between generated and utilized energy is negligible (approximately 0.15%), indicating minimal system losses. In several cases, the calculated efficiency exceeded 100%, which can be attributed to measurement uncertainties, inverter data processing characteristics, and rounding errors in monitoring systems. Such deviations are commonly observed in real photovoltaic system measurements and do not indicate physical inconsistencies. A notable observation is the significant variation in daily energy production. On high solar radiation days (December 22–23), the system generated up to 360–370 kWh, operating close to its nominal capacity. In contrast, during low radiation conditions (e.g., December 20), production dropped to as low as 12.25 kWh, confirming the strong dependence of PV systems on solar irradiance.

The results also indicate that the majority of generated energy is effectively utilized or exported to the grid, with very low internal consumption. This suggests that electrical losses (cable, inverter, transformer) are minimal and the system is well-optimized. Overall, the findings confirm that under proper design and operation, photovoltaic systems can achieve near-ideal performance, especially in regions with high solar potential such as Karshi. However, fluctuations in solar radiation remain the dominant factor affecting energy production.The results of this study indicate that energy losses in photovoltaic (PV) systems under the climatic conditions of the Karshi region are considerable, ranging from 25% to 50% of the theoretical energy potential. These losses depend on system design, installation quality, and maintenance practices. Among environmental factors, dust and sand accumulation (soiling) represent a major source of performance degradation due to the semi-arid climate and frequent wind activity. Soiling losses are estimated at 3–7%, and may exceed this range under extreme conditions. Shading effects also significantly reduce system efficiency. Improper spacing between PV arrays leads to near and far shading, particularly during low solar elevation periods. Estimated losses include 5–20% for near shading and 2–10% for far shading. Combined shading effects further reduce the effective irradiance on PV modules [4,5]. System design parameters, particularly tilt angle and azimuth orientation, strongly influence energy yield. The optimal tilt angle for the Karshi region is approximately 30–35° facing south. Deviations from optimal configuration may cause 10–20% losses due to tilt mismatch, while incorrect azimuth orientation can reduce output by an additional 5–10% [6]. Temperature effects represent another critical loss factor. High ambient temperatures exceeding +40°C during summer reduce PV efficiency by decreasing the open-circuit voltage of the modules, leading to a noticeable decline in power output.

The temperature-related efficiency drop can be described as:

$$\eta\,(T) = \eta_{ref}\,[1 - \beta\,(T - T_{ref}\,)]$$

Temperature-related losses in the Karshi region are estimated to range between 5% and 12%, depending on module technology, thermal characteristics, and cooling conditions [7]. These losses are primarily caused by the reduction in open-circuit voltage as module temperature increases. Long-term performance degradation also contributes to energy losses. In the studied climatic conditions, annual degradation rates are estimated at 0.5–1%, leading to cumulative efficiency reduction over the system lifetime. In addition, mismatch losses caused by non-uniform module performance and uneven soiling contribute approximately 1–3% additional losses, which are often underestimated in system design. Electrical losses occur during energy conversion and transmission stages and include cable, inverter, and transformer losses. Cable losses account for 2–5% due to resistive heating, inverter losses range between 2–4% depending on conversion efficiency, and transformer losses contribute an additional 2–5% including no-load and load conditions. Although individually moderate, these losses collectively have a significant impact on overall system efficiency, particularly in sub-optimally designed installations. The total energy output of the photovoltaic system can be expressed using the following general relationship:

$$E_{out} = E_{in} \cdot \eta_{pv} \cdot (1 - L_{total}\,)$$

For the Karshi region, the annual solar irradiation is approximately 1600 kWh/m², while the effective electrical output ranges between 900 and 1100 kWh/m². This corresponds to total system losses of about 30–40% under typical operating conditions [8]. The comparative analysis shows that solar-related losses significantly dominate over electrical losses in the studied region. The most influential factors affecting system performance include dust accumulation (soiling), high ambient temperature, and improper tilt and orientation of PV modules. In poorly optimized systems, total losses may exceed 50%, resulting in a drastic reduction of efficiency to as low as 5–10%. In contrast, well-designed and properly maintained photovoltaic systems can achieve efficiencies in the range of 12–15% under local climatic conditions [9]. To enhance system performance, several mitigation strategies are recommended, including regular cleaning of PV modules to reduce soiling losses, optimization of tilt angle and azimuth orientation during installation, application of passive or active cooling techniques, use of high-efficiency inverters and appropriately sized cables, and minimization of shading through proper system layout design. Overall, the findings confirm that although the Karshi region possesses high solar energy potential, the actual performance of photovoltaic systems is strongly influenced by environmental and technical factors. Proper system design, installation, and maintenance are essential to minimize energy losses and maximize energy yieldof structural material (NMQ_i) is calculated as the weight of material per unit area of the bridge deck:

$$NMQ_i\,[kg/m^2] = \frac{SMQi[kg]}{Length\,[m] \times Width[m]}$$

3. Calculating Embodied Carbon (EC)

The embodied carbon of each structural material is calculated by multiplying the normalized material quantity by its embodied carbon coefficient:

$$EC_i\,[kgCO_2e/m^2] = NMQ_i\,[kg/m^2] \;\times\; ECC_i[kgCO_2e/kg]$$

4. Global Warming Potential of the Bridge (GWP)

Finally, the total embodied carbon or global warming potential of the bridge is calculated as the sum of the embodied carbon of all materials:

$$GWP[kgCO_2e/m^2] = \Sigma EC_i\,[kgCO_2e/m^2]$$

This methodology provides a structured framework for evaluating the environmental impact of bridges during their construction stage and allows comparison across different bridge types.

4. Conclusion

This study provides a comprehensive analysis of energy losses in photovoltaic (PV) power plants under the climatic conditions of the Karshi region. Despite high solar irradiation potential (1500–1700 kWh/m² per year), the actual performance of PV systems is significantly reduced due to multiple environmental and technical loss factors. The results show that total energy losses range between 25% and 50%, depending on system design, environmental conditions, and operational practices. The dominant losses are associated with solar-related factors, particularly dust accumulation, shading effects, improper tilt angle, and high ambient temperature. Among these, soiling and thermal effects are the most critical due to the arid climate and extreme summer conditions in the Karshi region. Electrical losses in cables, inverters, and transformers contribute a smaller but still significant portion of total system inefficiency, especially in poorly designed installations. The study confirms that system efficiency may decrease to 5–10% under suboptimal conditions, whereas properly designed and maintained systems can achieve efficiencies of 12–15%.

To improve PV system performance, several measures are recommended, including optimization of tilt angle and orientation based on local solar geometry, regular cleaning of PV modules, implementation of cooling strategies, proper system layout to minimize shading and mismatch losses, and the use of high-efficiency electrical components. In conclusion, although the Karshi region has strong potential for solar energy utilization, achieving high photovoltaic efficiency requires an integrated approach combining climatic adaptation, engineering optimization, and effective maintenance. The findings of this study provide a useful basis for the design and improvement of PV systems in similar arid and high-temperature regions.

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