FEASIBILITY REPORT FOR A SOLAR PV PROJECT IN QASHQADARYO

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Site Characteristics and PV Project Context

Institutional profile

Address: Qashqadaryo region, Karshi district, Khudoyzod street, 68

Figure 1 Location of the school relative to the North

The complex of buildings with a total area of 2 398.21 m² is located on a land plot with an area of 21,422.84 m². The buildings were constructed in two stages—in 2001 and 2012. The structures were built of brick, and their seismic resistance is rated at 7–8 points according to cadastral data.

The strategic case for School PV

Schools are considered well-suited for solar power installations. Because they operate primarily during daytime hours, electricity is consumed when solar panels generate the highest output. This alignment allows on-site generation to be utilized with high efficiency. In the energy audit, solar installation is identified as a key strategy for reducing dependence on the grid and securing stable energy costs. As schools function as long-term community institutions, a reliable foundation is provided for this type of infrastructure investment.

Energy dynamics and electrical demand

The school's electricity demand is primarily driven by daytime academic activities, including lighting, IT equipment, and circulation pumps. Since heating is provided by non-electric sources, the load remains relatively predictable throughout the year. However, recorded data over the last three years reveals significant inconsistencies:

Table 1

Energy consumption during last 3 years

Duration	2023	2024	2025
Consumption	8 310 kWh	15 870 kWh	18 664 kWh

During the site visit, a Fluke 1775 power quality analyzer monitored the electrical system for 24 hours. The grid frequency was stable, remaining between 49.97 Hz and 50.03 Hz.

However, a serious phase imbalance was detected and requires attention. The building's electrical load is not evenly distributed across the three phases. Most of the demand is carried by Phase 3, while Phases 1 and 2 are lightly loaded:

Phase 3: Peak load of 9.5 kW

Phases 1 & 2: Peak load of about 2 kW each

The maximum difference between phases reached about 85%, with an average imbalance of 40–45%. This uneven loading causes voltage differences: Phase 3 remains at about 230 V, while Phases 1 and 2 drop to around 217 V.

Despite these issues, the school is a good candidate for solar PV installation. The building operates mainly from 08:00 to 17:00, which matches peak solar production hours. Electricity use is lower in summer, but solar generation is highest during this period. Solar PV will reduce energy costs and provide additional benefits. Excess electricity produced in summer can be exported to the grid when consumption is low. During winter, when demand is higher, the school can benefit from these savings and reduced electricity expenses.

The building is supplied by a transformer that serves the school. The transformer is connected to a 10 kV network and has a rated capacity of 100 kVA. The school is supplied through a 160 A switch located downstream of the main switch. The proposed PV system can be connected at the main receiving point on the low-voltage side. The existing metering system is analogue, with a meter model EX518, installed within the transformer enclosure. It is recommended to assess the transformer loading and the electrical distribution system to ensure safe and efficient integration of the PV system.

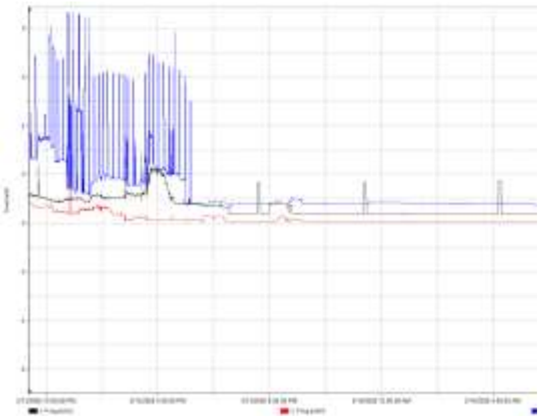

Figure 2 Three-Phase Load

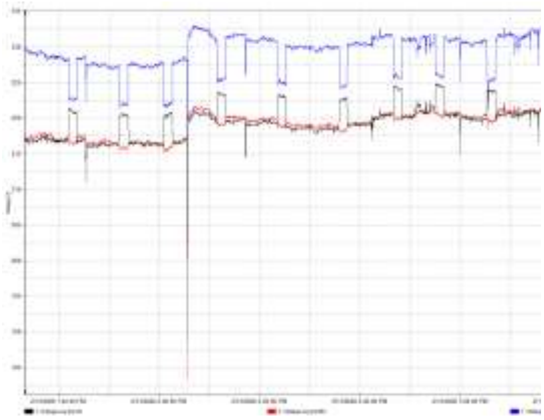

Figure 3 Three-Phase Voltage

Disbalance *Disbalance*

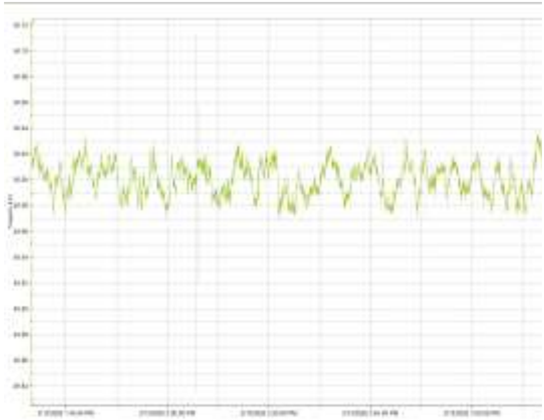

Figure 4 Changes in Frequency

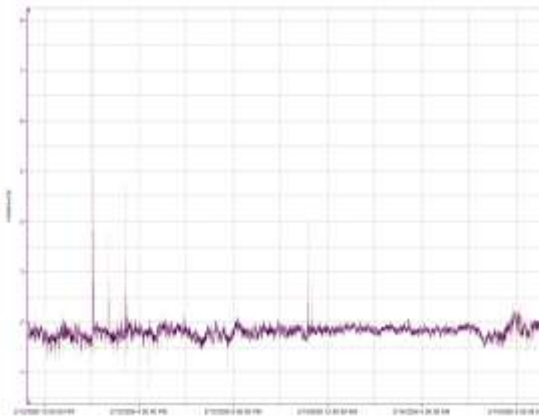

Figure 5 Disbalance in Voltage (%)

Building envelope and roof availability

The roof of the educational complex, renovated in 2012, was completely replaced with slate sheets. The structure is a classic gable attic system with a slope of 14–15 degrees, supported by a wooden load-bearing framework. A visual inspection of the roof covering revealed several significant defects. The slate sheets show signs of physical wear, including cracks and chips along surfaces and edges, compromising the overall integrity of the roof. Gaps at the sheet joints further reduce watertightness. Based on the roof condition, renovation or re-construction is required. Due to these limitations, it is not currently possible to specify a connection between the proposed PV installation and the roof in the conceptual design. The attic floor is a multi-layer structure over 250 mm thick, comprising reinforced concrete slabs (200 mm and 50 mm) with a concrete screed. Despite the robustness of this construction, throats in the screen and open technological openings were observed during the survey.

Technical Design and System Specification

System dimensioning

The building orientation is highly favorable for maximizing photovoltaic (PV) generation potential. With an azimuth of 180°, the roof faces true south, which is considered optimal for achieving maximum annual solar energy yield under fixed-tilt conditions. Based on the available roof area and structural configuration, the site demonstrates a PV installation potential of approximately 65 kW AC, corresponding to a DC nameplate capacity of 79.9 kW. DC/AC ratio is 1.33.

A heat pump system is planned for the building to meet its heating requirements. The total heated area is 2,158 m², with an estimated heating energy demand of approximately 151 kWh. An air-to-air heat pump with COP of 3.0 is proposed, requiring about 50 kW of electrical power to deliver the necessary heating capacity. The PV system has been designed to maximize the use of available roof space. It is important to note that the highest heating demand occurs during winter months, coinciding with a significant reduction in solar generation. During this period, PV output is expected to decrease by 60–70% compared to peak production levels, primarily due to reduced solar irradiance and shorter daylight hours.

The reference system utilizes 555 W modules. The array configuration is designed to optimize roof space utilization while maintaining adequate inter-row spacing to mitigate shading losses and ensure safe access for maintenance. A fixed-mount system is recommended to reduce structural complexity and improve long-term reliability. To minimize temperature-related efficiency losses, appropriate mounting clearance and ventilation must be incorporated into the design.

The recomended roof tilt of 25 degrees is suitable for a fixed-mount installation and supports effective annual energy production without requiring tilt modification. To further reduce temperature-related performance losses and enhance natural ventilation beneath the modules, a two-layer mounting structure is recommended. This configuration should provide approximately 15–17 cm clearance between the module backsheet and the roof surface, promoting airflow and improving long-term operational stability. System sizing purposes, it has been assumed that the PV system should be designed to achieve maximum feasible capacity based on available roof potential, ensuring effective solar energy generation and optimal utilization regardless of consumption data uncertainty.

Cable & Connectors

The DC and AC cables for the photovoltaic system will be selected based on the system’s electrical design, including operating voltage, current, installation method, and cable length. All cables will be properly secured, protected, and routed to prevent mechanical damage and overheating. The existing cable management on the roof is in poor condition and should be upgraded before installation.

DC cables will be specifically designed for photovoltaic applications, UV-resistant, double-insulated, and compliant with relevant IEC standards. Based on the selected solar modules and inverter, 4 mm^2 DC cables are recommended.

AC cables will be fire-resistant and properly insulated. Since the AC cables will run inside the building, they should be installed in metal cable trays to protect them from mechanical damage and other external impacts.

All module connections will use certified MC4-compatible connectors to ensure secure, weatherproof, and low-resistance connections between the solar modules and the inverter.

Construction

For the mounting structure, it is recommended to use aluminum rails. Aluminum provides high corrosion resistance and low structural weight, making it well-suited for rooftop photovoltaic installations. Its lightweight properties minimize additional load on the existing roof structure, while its durability ensures reliable long-term performance under outdoor environmental conditions.

Detailed specifications of the aluminum mounting system will be provided in the conceptual design stage. At present, the conceptual design does not include specific details regarding the connection between the roof structure and the aluminum rails, as the roof requires renovation. The renovation design has not yet been developed; therefore, final mounting and anchoring solutions will be defined after completion of the roof rehabilitation design.

In practice, the roof structure and PV aluminum mounting system are connected using L-type connectors. Figure 8 shows a typical connection detail. However, it is recommended to perform a detailed structural assessment of the roof after reinforcement works and to consider local wind and snow load conditions when finalizing the anchoring design.

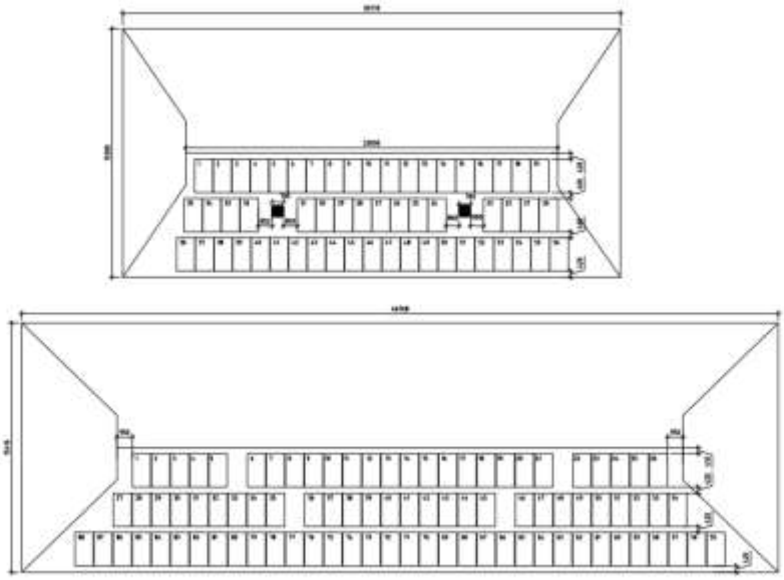

Figure 6 Layout of the RTS

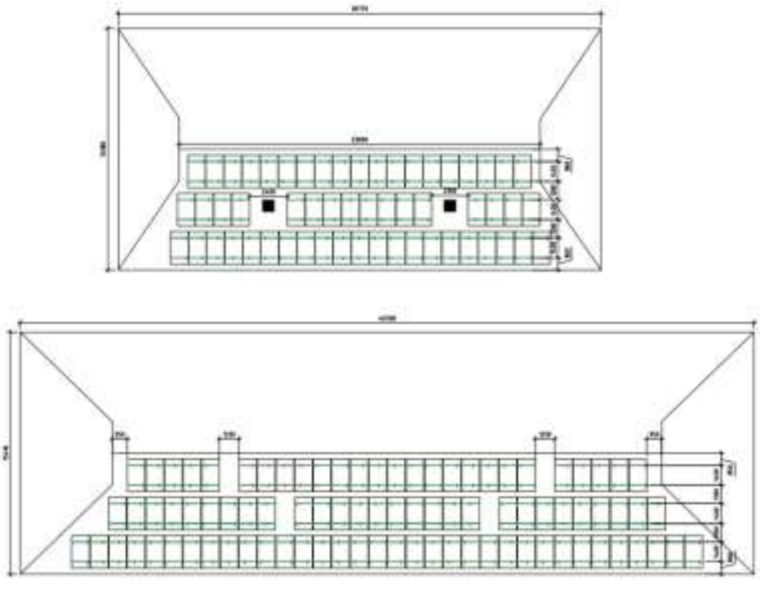

Figure 7 Mounting construction

Performance Modelling

The performance of the proposed PV system at School № 35 was modeled using monthly solar irradiation, ambient temperature, and system parameters. The simulation considers both global horizontal irradiance and effective irradiance on the tilted PV array, with losses due to temperature and system inefficiencies included.

The graph of normalized energy illustrates the monthly distribution of energy production and losses. The total useful energy delivered by the inverter peaks in **July at approximately 4.07 kWh/kWp/day**. Collection losses from the PV array are highest during the summer months, reaching **0.75 kWh/kWp/day**, while system losses such as inverter and auxiliary losses are relatively minor at **0.9 kWh/kWp/day**. The energy output is lowest during the winter months (December and January), reflecting lower solar irradiation and shorter daylight hours.

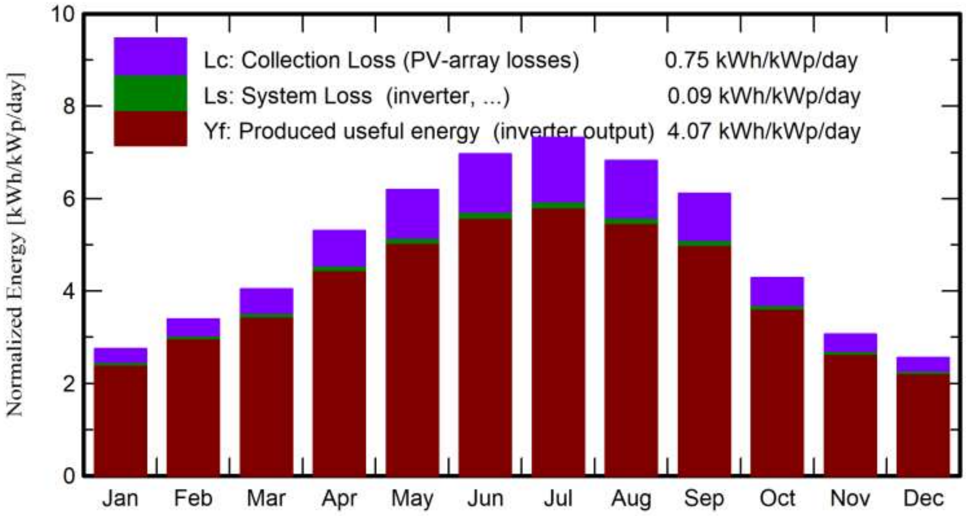

Figure 8 Normalized Energy

The results show that monthly energy generation varies according to seasonal solar availability. The system is expected to produce the highest energy during summer months, with **July** generating approximately **14.74 MWh at the array** level and **14.41 MWh delivered to the grid**, corresponding to a **performance ratio (of 0.794**. Conversely, the lowest production occurs in **December**, with **5.65 MWh at the array** and **5.53 MWh fed to the grid (PR = 0.874).**

Overall, annual PV generation is estimated at **125.65 MWh** at the array and **122.83 MWh exported to the grid**, with an **average performance ratio of 0.829.** The variation in PR throughout the year reflects seasonal effects, including higher module temperatures during summer, which slightly reduce efficiency, and lower irradiation levels during winter months.

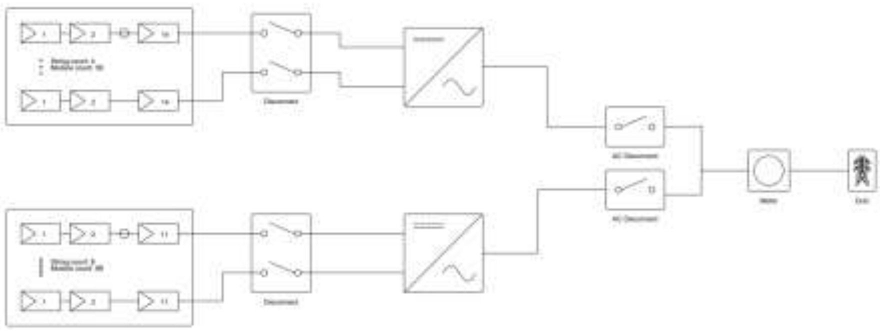

Figure 9 SLD of the RTS

These results demonstrate that the PV system can reliably supply a significant portion of the school's electricity demand, particularly during periods of high solar availability, while maintaining a stable and efficient operation throughout the year.

The PV system starts with a global horizontal irradiation of 1627 kWh/m², which increases to 1797 kWh/m² on the collector plane due to a +13.6% transposition gain. After accounting for 2.8% IAM losses and applying a module efficiency of 21.49% over 372 m² of collectors, the array produces 143.65 MWh of nominal energy at STC.From there, the system experiences several losses: 0.6% due to irradiance level, 6.4% from temperature, 3.0% from module quality, 2.0% from mismatch, and 1.0% from ohmic wiring — bringing the array output down to 125.65 MWh at MPP. On the inverter side, 2.2% is lost during operation, while all other inverter-related losses remain at 0.0%, with no night consumption. The final energy injected into the grid is 122.83 MWh.

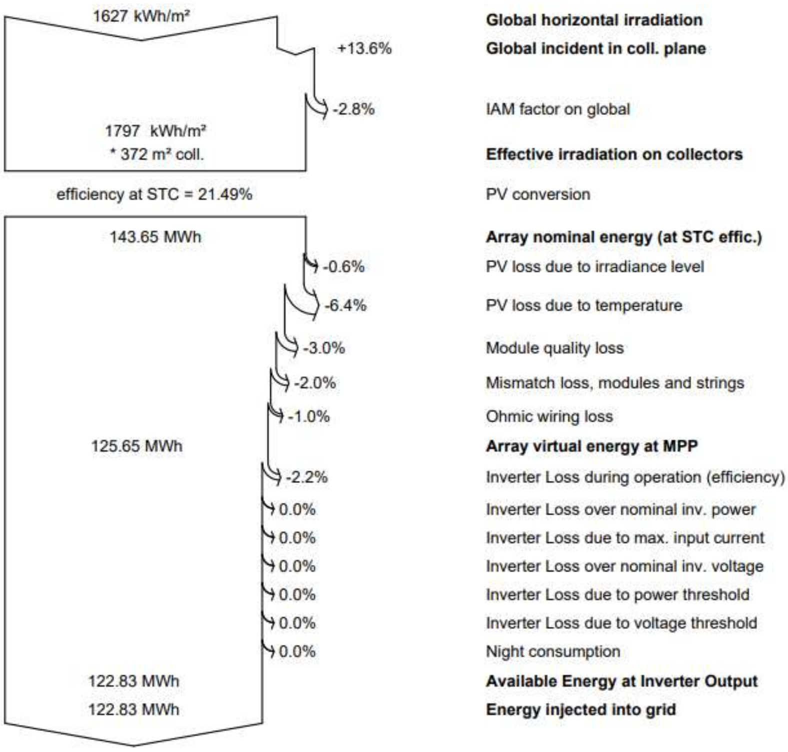

Figure 10 Loss diagram

Financial Analysis Summary

This subsection provides a full cost-benefit assessment of the proposed 79.9 kWp DC (65 kW AC) rooftop PV system at School №35, addressing CAPEX, indicative bill-of-quantities (BoQ), annual savings, self-consumption / export assumptions, payback, 30-year lifecycle performance, and greenhouse-gas (GHG) reductions. The analysis applies the financial framework adopted in the building's Energy Audit Report — discount rate 6%, energy-cost escalation 10% per year, project lifetime 30 years, and an electricity tariff of USD 0.0826/kWh (commercial rate per the Excel financial model[1]). The CAPEX line items and unit rates are sourced from the Solar PV cost section of the same Excel financial model.

Capital Expenditure (CAPEX) and Indicative BoQ

The total turnkey CAPEX for the proposed system is estimated at USD 22,798, equivalent to USD 350.73/kW AC or USD 285.33/kWp DC. The indicative bill of quantities is presented below, with line items and unit rates taken directly from the Excel financial model's Solar PV cost section.

Table 2

CAPEX

Cost Component	Basis	Total (USD)
PV modules	144 × USD 84.00/module	12,096
Inverters	USD 79.75/kW AC × 65 kW	5,184
Construction (mounting)	USD 42.00/kW AC × 65 kW	2,730
Cabling (lump sum)	Lump sum	350
Installation	USD 37.50/kW AC × 65 kW	2,438
Total turnkey CAPEX		**22,798**
Specific cost (per kW AC)		350.73
Specific cost (per kWp DC)		285.33

Annual Savings, Payback and Lifecycle Performance

The table below summarises the financial performance of the proposed PV system across Year-1 and the 30-year lifecycle, under both the base case (net-metering) and the sensitivity scenario (net-billing). Operational metrics — generation, O&M, CO_2 — are unaffected by the tariff structure; only revenue-driven metrics differ between scenarios.

Table 3

Cost-benefit analysis

Metric	Unit	Base (Net-metering)	Sensitivity (Net-billing)
Year 1 — Operational Performance			

[1] Excel financial model refers to the excel doc including the consolidated financial and economic analysis per building against 3 components

Energy generation to grid	MWh	122.83	122.83
Electricity cost savings	USD	10,146	7,102
O&M cost	USD	228	228
Net annual savings	USD	9,918	6,874
CO_2 emissions avoided	t CO_2/yr	57.4	57.4
Investment & Payback			
Total turnkey CAPEX	USD	22,798	22,798
Specific cost	USD/kW AC	350.73	350.73
Simple payback period	years	2.3	3.3
Discounted payback (6%)	years	2.4	3.4
30-Year Lifecycle Performance			
Lifetime energy generation	MWh	3,430	3,430
Lifetime electricity savings (nominal)	USD	1,504,491	1,053,144
Lifetime O&M cost (nominal)	USD	6,839	6,839
Net Present Value (NPV) @ 6%	USD	448,694	306,305
Internal Rate of Return (IRR)	%	53.1%	39.8%
Levelized Cost of Electricity (LCOE)	USD/kWh	0.0161	0.0161
30-Year GHG Reduction			
Cumulative CO_2 emissions avoided	t CO_2	1,602	1,602
Indicative carbon value (avg WB shadow price)	USD	98,506	98,506

Greenhouse-Gas (GHG) Reduction

The proposed PV system displaces grid electricity, which is supplied predominantly from natural-gas-fired thermal plants in Uzbekistan. At the JICA-referenced grid emission factor of 0.467 t CO_2/MWh, the system avoids approximately 57.4 t CO_2 in its first year and 1,602 t CO_2 cumulatively over its 30-year operational lifetime (accounting for 0.5% per year PV degradation). Valued at the World Bank shadow price of carbon (average USD 61.5/t CO_2 over the appraisal horizon), this represents a societal carbon-abatement value of approximately USD 98,506, in addition to the direct financial savings shown above. This contribution supports Uzbekistan's Nationally Determined Contribution (NDC) commitments under the Paris Agreement and aligns with UNICEF's child-rights-based climate action framework.

Conclusion of Financial Analysis

The proposed PV system at School №35 demonstrates very strong economic viability, with a simple payback of 2.3 years under net-metering (3.3 years under the conservative net-billing sensitivity) and a 30-year NPV of USD 448,694 at a 6% discount rate. Combined with cumulative CO_2 savings of 1,602 t and the broader educational and demonstration value of a school-based PV installation, the investment delivers a robust combination of financial, environmental, and social returns. Final design refinements, vendor selection, and grid-connection arrangements should be confirmed at the procurement stage; the figures above are indicative and serve to frame the order of magnitude of expected outcomes.

Note: Financial figures above are indicative and based on the parameters of the Excel financial model (discount rate, escalation, tariff, BoQ unit rates, and emission factor). The base case assumes net-metering at full retail tariff; the sensitivity assumes net-billing with 60% of generation sold at 50% of the retail tariff

Conclusion

The feasibility assessment indicates that School №35 is a suitable candidate for a rooftop photovoltaic (PV) installation, if roof rehabilitation and electrical improvements are completed beforehand. The building's south-facing orientation, roof tilt, and daytime operating schedule support efficient solar energy utilization. A system with an installed capacity of approximately 79.9 kWp DC (≈65 kW AC) is expected to generate about 122.23 MWh annually, demonstrating strong solar potential and reliable performance under local conditions. Key issues requiring resolution prior to installation include the deteriorated roof condition, severe three-phase load imbalance, and inconsistent historical consumption data. Addressing these factors through roof renovation, electrical system balancing, and improved metering is essential for safe and effective system operation.

References

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