# TECHNO-ECONOMIC ASSESSMENT OF STAND-ALONE SOLAR PHOTOVOLTAIC SYSTEMS FOR HOUSEHOLD ENERGY INDEPENDENCE IN UZBEKISTAN

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***Abstract.*** *This investigation is reviewed the technical and economic factors affecting the feasibility of stand-alone solar PV systems for household energy independence in Uzbekistan. The research adopts a comparative analytical methodology based on established approaches to off-grid electrification and renewable energy system assessment.*

***Keywords:*** *solar photovoltaic systems, off-grid electrification, household energy independence, techno-economic assessment, battery storage, renewable energy, Uzbekistan.*

## Introduction

The increasing demand for reliable electricity and the transition towards sustainable energy systems have stimulated interest in decentralized renewable energy technologies. Stand-alone solar photovoltaic systems provide an alternative to conventional grid-connected electricity by generating and storing energy at the household level. Their potential applications include residential buildings in areas with unreliable electricity supply and households seeking greater energy autonomy.

The feasibility of these systems depends on several interconnected factors, including solar radiation, household electricity consumption, equipment efficiency, battery capacity, installation costs, and maintenance requirements. Mandelli demonstrate the importance of distinguishing between different off-grid electrification configurations when assessing their technical characteristics and practical applications.[3]

Similarly, Bhattacharyya emphasizes the importance of appropriate analytical methods when evaluating off-grid electricity supply options.[1]

In Uzbekistan, solar photovoltaic technology warrants particular investigation because local solar resources may support decentralized electricity generation. Nevertheless, annual solar availability alone cannot establish whether a household can operate independently throughout the year. Energy storage and seasonal variations must also be considered.[5]

## Methods

The analysis is employed a comparative analytical approach informed by published research on off-grid electrification, renewable energy economics, and solar resource assessment.

The proposed framework consists of four stages.

First, household electricity demand is estimated using daily consumption records and annual electricity requirements. Second, the potential electricity generation of a photovoltaic system is assessed using installed capacity, local solar resource data, and system performance assumptions.

Third, battery storage requirements are examined in relation to nighttime consumption, desired backup duration, and usable battery capacity. Fourth, the lifecycle costs of the system are compared with the costs of alternative electricity supply arrangements.

The assessment distinguishes between three configurations: conventional grid-connected electricity, hybrid solar systems retaining grid access, and stand-alone solar systems incorporating battery storage.

Economic evaluation should include initial equipment and installation costs, inverter and battery replacement, maintenance, and other operating expenses. Where reliable financial data are available, the net present cost and levelized cost of electricity can be calculated to compare alternative configurations over an equivalent assessment period.

The Global Solar Atlas can provide preliminary solar resource information, while actual household electricity records and verified equipment quotations are required for a reliable case study. [3] As this paper is based on a literature-informed analytical framework rather than an original field experiment, no measured performance figures or experimentally established payback periods are claimed.

**Results**

The analysis identifies four principal factors influencing the technical and economic feasibility of stand-alone solar PV systems.

First, solar resource availability determines the potential for electricity generation.

However, effective system performance also depends on panel orientation, shading, conversion losses, and seasonal variations. Consequently, system capacity should be determined using location-specific solar data rather than general assumptions about annual sunshine.

Second, battery storage is a critical component of household energy independence.

Photovoltaic panels generate electricity during daylight hours, whereas household demand may continue throughout the night. Sufficient storage capacity is therefore necessary to maintain supply when solar generation is unavailable. Increasing battery capacity, however, raises initial investment costs and introduces future replacement expenses.

Third, household consumption patterns strongly influence system design. A household with high electricity demand or substantial evening consumption may require a larger photovoltaic array and greater storage capacity than a household with lower demand. Energy efficiency measures can reduce the required system size and potentially improve economic feasibility.

Fourth, lifecycle cost assessment is essential for comparing off-grid and grid-connected alternatives. The initial purchase price alone does not reflect the total cost of ownership. Battery degradation, component replacement, maintenance, and the cost of maintaining reliable electricity during periods of low solar generation must also be considered.

Taken together, these findings indicate that off-grid solar PV systems should be evaluated according to their ability to meet household demand reliably and their total lifecycle cost. The most technically independent configuration is not necessarily the least expensive option.

**Discussion**

The analysis is highlighted the relationship between technical reliability and economic viability.

Although solar photovoltaic technology can support decentralized electricity generation, complete household independence requires a system capable of accommodating variations in both energy generation and consumption. Battery storage represents one of the most important economic considerations because it increases the upfront cost and affects the long-term replacement schedule. For households connected to an existing electricity network, a hybrid configuration may offer a practical alternative by combining solar generation with grid access. A stand-alone configuration may be more appropriate where grid access is unavailable, unreliable, or inconsistent with household priorities. The research date are consistent with the broader literature on off-grid electrification, which emphasizes that technology selection must account for local conditions, electricity demand, and the economic characteristics of competing supply options [1].

For Uzbekistan, future empirical studies should examine different household consumption profiles and regional solar conditions. Researchers should also collect current equipment prices, battery lifespan estimates, installation costs, and applicable electricity tariffs. Sensitivity analysis can then establish how changes in these variables influence the overall economic outcome.

The principal limitation of the present study is the absence of original household consumption measurements and verified local cost data. Therefore, the analysis identifies the relevant feasibility factors but does not establish a definitive payback period or claim that off-grid systems are economically preferable for all Uzbek households.

**Conclusion**

Stand-alone solar photovoltaic systems offer a potential pathway towards household energy independence in Uzbekistan. Their feasibility depends on solar resource availability, household electricity demand, battery storage requirements, system reliability, and lifecycle costs.

The analysis demonstrates that technical independence and economic attractiveness should be evaluated separately. A system may be capable of meeting household electricity demand but remain financially less attractive than a grid-connected or hybrid alternative.

A comprehensive assessment should therefore combine location-specific solar resource data, actual household consumption records, equipment prices, and lifecycle cost calculations.

Further empirical research using these data would enable a more precise evaluation of the suitability of stand-alone solar PV systems for different household conditions in Uzbekistan.

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