ENABLING PV in Armenia

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Objectives of the ENABLING PV project

Solar photovoltaic (PV) is one of the fastest-growing sectors in global energy. A key factor driving this growth is the increasing competitiveness of PV electricity due to the continuous reduction in costs. According to IRENA, solar energy accounted for approximately 73% of the total renewable energy capacity added worldwide in 2023, reaching 345 GW out of a total of 473 GW. However, to achieve the 1.5 °C trajectory and the global goal of tripling renewable energy capacity by 2030, it is crucial to rapidly scale up renewables (with a primary focus on PV) not only in leading markets like China but also in newcomer markets taking their first steps in this direction.

In this context of accelerating the solar PV international markets, my consulting firm eclareon and the German Solar Industry Association (BSW-Solar) initiated a joint research project called "ENABLING PV" in 2013. The aim of this project is to promote the deployment of PV technologies in foreign markets where their potential is not yet fully realized. To achieve this, we organize roundtable discussions in partner countries where local stakeholders meet with German and local PV companies, as well as experts from the fields of science and education. We provide the latest information on the potential PV applications and solutions in partner countries through our ENABLING PV research. Based on this information, pilot installations or training measures are discussed, planned, and implemented in collaboration with local stakeholders.

Armenia is a very good example of a country making initial yet very successful strides in developing its PV market. The dynamically evolving regulatory environment, electricity market liberalization, and the already established ecosystem of local companies actively working in the PV sector present significant opportunities for stakeholders from Germany and other countries in strengthening cooperation.

Berlin, November 12, 2024

Christoph Urbschat
Managing Partner
eclareon GmbH

Executive Summary

Armenia, the smallest country in South Caucasus by area, population, GDP, and GDP per capita, and lacking a seacoast, has nonetheless demonstrated impressive economic growth in recent years. As an energy-deficient country reliant on nearly 80% of its energy consumption by imports from neighboring countries (primarily Russia), it has faced persistent energy security and energy poverty issues exacerbated by conflicts with Azerbaijan and disruptions in regional energy connectivity. The Armenian government considers the development of domestic energy sources—primarily renewables—and increased energy efficiency as pivotal to addressing this strategic challenge. Achieving Armenia's ambitious decarbonization goals for 2030 and 2050 will similarly require further expansion of renewables.

For decades, hydropower has been the predominant renewable energy source in Armenia, driven by the country's mountainous terrain. However, solar energy is the fastest-growing segment: the share of PV in electricity generation has surged dramatically over the past two years. In terms of absolute PV electricity production and its growth rates, Armenia leads other South Caucasian countries. By 2024, Armenia had installed approximately 470 MW of PV capacity, with over half of this from about 17,000 small-scale (primarily rooftop) installations. While the development of new utility-scale projects has slowed due to changes in business models, distributed PV generation is experiencing a significant boom. This growth is supported by a burgeoning ecosystem of more than a dozen Armenian companies that have been active in the development, engineering and supply of equipment focused on photovoltaics in recent years.

In the regulatory domain, Armenia has made substantial progress by establishing a set of strategic documents, including the Energy Law, a Long-Term Energy Strategy (adopted in 2021), and a Renewable Energy Development Program (2022), while continuing to implement consistent reforms aimed at full liberalization of the energy sector and optimization of support mechanisms for renewables. Medium-term goals include achieving a 15% share of PV in electricity generation and deploying energy storage systems with a capacity of up to 1200 MWh by 2030, with a long-term target of 1.5 GW of PV by 2040. The total potential for solar PV installations by 2040-2050 is 2.6 GW, comparable to the total installed capacity of all power plants in Armenia as of 2023.

The successful realization of these ambitious plans will depend on overcoming key barriers, primarily related to electricity grid bottlenecks due to aging infrastructure, the increasing share of variable renewables, and limited connectivity with neighboring countries. Additionally, challenges include addressing the slow pace of market liberalization, potential land use conflicts, and the introduction of new scalable business models for PV projects.

This report provides a detailed overview of the PV sector and the energy landscape as a whole. Readers will find not only a description of the regulatory environment but also references to primary sources, contact details for Armenian stakeholders, and local engineering firms that can assist in understanding the nuances of the Armenian energy sector. The authors hope this will facilitate the acceleration of partnerships between Armenian companies and their counterparts in Germany and other countries, ultimately supporting the rapid deployment of PV in Armenia and achieving the country's strategic objectives.

1. Introduction to Armenia's Energy Sector

1.1 Overview of the Economy and Energy Sector

Armenia, a landlocked country situated in the South Caucasus with an area of 29,740 square kilometers, shares borders with Azerbaijan, Georgia, Iran, and Turkey.[i] The country is characterized by its predominantly mountainous terrain, which offers significant potential for hydropower development. Armenia has a population of 2.9 million, with 36% residing in rural areas, including remote regions (World Bank, 2024)[ii].

The Gross Domestic Product (GDP) of Armenia stands at USD 19.5 billion, with a GDP per capita of USD 6,572 (2023). Among the South Caucasus countries, Armenia has the smallest land area, population, GDP, and GDP per capita. However, since 2017, the annual growth rate has remained above 5.2% (excluding the COVID-19 pandemic year of 2020), with growth reaching 12.6% and 8.7% in 2022 and 2023 respectively, making Armenia one of the fastest-growing economies in the region. This growth is partly due to the influx of migrants, businesses, and capital, as well as Armenia's increasing role as a logistics hub amid regional geopolitical conflicts (World Bank, 2024). The Armenian economy places significant importance on the commercial and public services sector and high remittances from the Armenian diaspora.

Armenia is an energy-deficient country, with net energy imports ranging from 50 to 75 PJ annually between 2011 and 2021 (IEA, 2023)[iii]. The country imports natural gas and oil to meet the majority of its energy needs (78.6% of the total energy supply in 2020), primarily from Russia, with natural gas dominating the final energy consumption mix, with approximately 80% of it in 2020 being consumed almost equally by three key sectors: power and heat generation, residential, and mobility (IEA, 2024)[iv].

This situation is rooted in Armenia’s historical integration into the unified energy systems of the former USSR. The collapse of these connections amid conflicts with neighboring Azerbaijan and Turkey have led to long-term challenges with energy security and supply in Armenia over recent decades. Specifically, energy poverty has affected nearly 30% of Armenian households (defined as households spending more than 10% of their budget on energy resources), with many households lacking sufficient energy for heating during cold periods (Energy Charter, 2017)[v]. As a result, the government prioritizes energy security and the development of domestic energy sources as a key long-term energy policy goal, with a focus on renewables and measures to enhance energy efficiency (IEA, 2022).

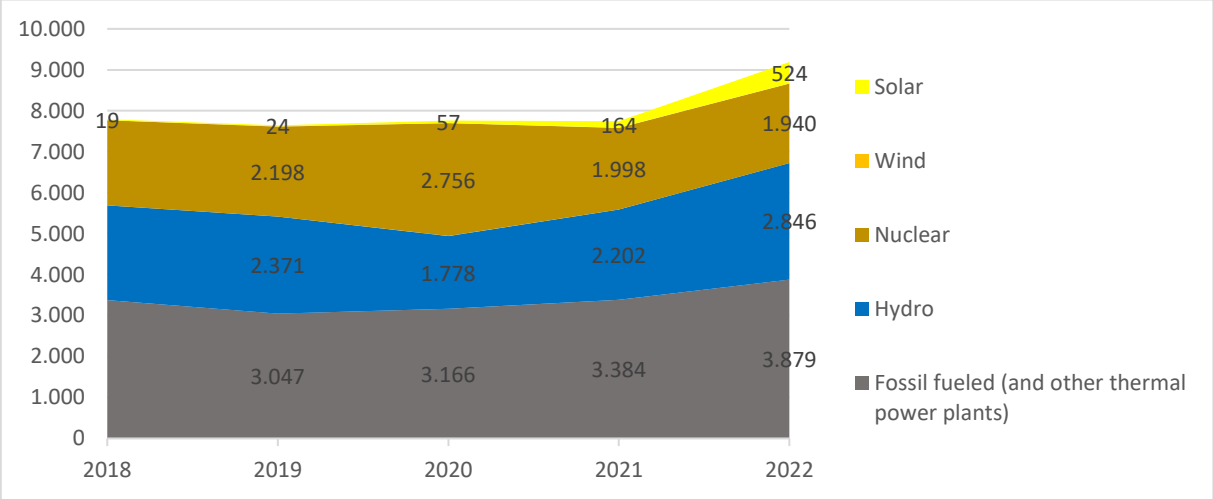
Currently, Armenia's own energy sources include the Metsamor Nuclear Power Plant, launched in 1976, which is the only nuclear plant in the Caucasus and Central Asia. The extension of its operation is a priority for the energy policy. Hydropower is the second most important local energy resource, while solar energy represents the fastest-growing segment.

Decarbonization policies also influence the development of the energy sector and the economy overall. Armenia joined the Paris Agreement in 2017 and, under its updated Nationally Determined Contributions (NDCs) adopted in 2021, has committed to reducing greenhouse gas (GHG) emissions by 40% from 1990 levels by 2030 (UNFCCC, 2021)[vi]. For the long term, Armenia aims to reduce GHG emissions to 2.07 t CO2 eq per capita by 2050 (UNFCCC, 2024)[vii]. Achieving these targets, as well as those related to energy security, will require a significant further expansion of renewables.

1.2 Electricity Generation

In Armenia, electricity is primarily generated from thermal power plants using natural gas (42.2% in 2022), followed by hydropower plants (31%) and the Metsamor Nuclear Power Plant (21%) (Figure 1). The shares of wind and bioenergy in this mix are minimal, largely due to logistical challenges associated with transporting equipment to mountainous regions that are optimal for wind farms. The share of hydropower has remained relatively stable. In this context, the share of solar PV in 2022 was 5.6%, having increased nearly eightfold since 2020.

Figure 1: Electricity Generation by Source in Armenia, 2018-2022 (GWh/year)



Source: IRENA, 2024[viii]

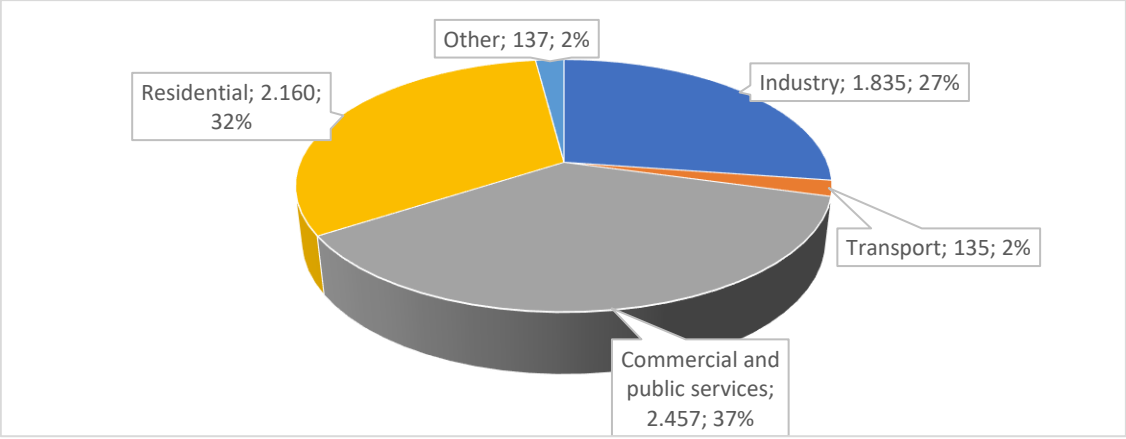
The installed capacity of power plants in Armenia is approximately 4.1 GW, but the available capacity is much lower, around 2.9 GW, as about half of the plants are over 40 years old and in significant disrepair (IEA, 2022). The most significant power plants include the Metsamor Nuclear Power Plant, which provides a base portion of the power load profile, as well as the Hrazdan Thermal Power Plant (including the Hrazdan-5 unit), the Sevan-Hrazdan cascade of hydropower plants, the Vorotan cascade of hydropower plants, and the ArmPower CCGT.

1.3 Electricity Demand

In Armenia, electricity consumption is significantly lower than production, primarily due to the continuous export of electricity to Iran under the "gas-for-electricity" agreement. Under this barter arrangement, much of the gas imported from Iran is converted into electricity in Armenia and subsequently exported back to Iran. In 2022, Armenia exported 17% of its produced electricity (Armstat, 2024)[ix].

The key sectors consuming electricity in Armenia are residential, commercial, and public services, which together accounted for nearly 70% of total final consumption in 2022 (Figure 2).

Figure 2: Electricity Consumption by Sector in GWh and Their Shares of Total Consumption in 2022



Source: Armstat (2024)

1.4 Structure of the Electricity Sector

1.4.1 Key Government Ministries and Agencies

Key government ministries and agencies influencing Armenia's energy sector include (Shatvoryan et al, 2024; IEA, 2022)[x]:

- **The Ministry of Territorial Administration and Infrastructures (MTAI):** develops and implements energy policy, market reforms, national energy efficiency action plans, and investment plans for state-owned enterprises;
- **The Public Services Regulatory Commission (PSRC):** independent regulator in the energy, water, and telecommunications sectors; responsible for tariff methodology, licensing, and import/export regulation;
- **The Ministry of Environment (MENV):** develops and implements policies for environmental protection and sustainable resource management, oversees environmental impact assessments, and monitors Armenia's commitments under the UN Framework Convention on Climate Change;
- **Urban Development Committee (UDC):** develops and enforces energy efficiency regulations, standards, and norms in the building sector;
- **The Ministry of Economy (MEC):** responsible for quality control, setting energy efficiency standards for products, and monitoring compliance;
- **The Renewable Resources and Energy Efficiency Fund (R2E2)**: supports investments in energy efficiency and renewable energy through financing mechanisms for clean technologies;
- **The Statistics Committee (ArmStat):** main provider of energy-related data and statistics, adopting international standards since 2015.

There is no separate parliamentary committee specifically dedicated to the energy sector in Armenia. Instead, energy-related legislative oversight, along with other aspects of economic development, is managed by the Standing Committee on Economic Affairs.

1.4.2 Key Energy Companies

Armenia's electricity market includes six major generation companies (both private and state-owned), over 200 small electricity producers, one power system operator, one power transmission company, and one primary power distribution company. Generation and transmission activities are distinctly separated (IEA, 2022; Shatvoryan et al., 2024)[xi]. Private companies, predominantly linked with Russia, dominate the electricity production and distribution sectors.

The key companies in the sector include:

1. **Electric Power Systems Operator CJSC (EPSO)** – a public legal entity responsible for managing Armenia's power system. EPSO oversees the strategic management of the national transmission grid, including interconnections with Iran and Georgia, grid configuration, and regulation set points. Operations are carried out by other entities, while EPSO issues orders for generation adjustments and switching, with local teams performing the on-site work.

2. **High Voltage Electric Networks CJSC (HVEN)** – established by the Armenian government in 1998, HVEN operates the country's 220/110 kV transmission network, providing both domestic and cross-border electricity transmission services. The company manages substations, transmission lines, and is responsible for the maintenance and construction of energy infrastructure[xii]. Although privatization or transfer of management was considered in 2017-2018, HVEN remains state-owned as of 2024.

3. **Settlement Center CJSC** – the state operator responsible for electricity and capacity settlement on the wholesale electricity market[xiii].

4. **Armenian Nuclear Power Plant CJSC (ANPP)** – a state-owned entity operating the Metsamor Nuclear Power Plant[xiv].

5. **Razdan Energy Company CJSC** – the largest private company in the sector, owned by the Tashir industrial-construction group owned by Armenian entrepreneur Samvel Karapetyan. The Tashir group's origins and primary business are based in Russia[xv]. Razdan Energy Company CJSC owns key assets in Armenia's energy sector, including:
    - **The Razdan Thermal Power Plant**, with an installed capacity of approximately 800 MW.
    - **Electric Networks of Armenia (ENA) CJSC** – a power distribution company with a network spanning about 36,000 km, serving over 1 million consumers[xvi].
    - **International Power Corporation CJSC** – manages the Sevan-Hrazdan cascade of hydropower plants, which includes seven stations with a total capacity of approximately 540 MW[xvii].

6. **ContourGlobal Hydro Cascade CJSC** – Manages the Vardenis Cascade of hydropower plants, consisting of three plants with a total capacity of around 400 MW[xviii]. This asset belongs to ContourGlobal, an international company headquartered in London, which manages a global portfolio of 6.2 GW of power plants[xix].

7. **Gazprom Armenia CJSC** – a wholly-owned subsidiary of Russian Gazprom, owned the Hrazdan-5 CCGT power unit with a capacity of approximately 480 MW, as well as the transportation and distribution of natural gas throughout Armenia.

1.4.3 Other Market Stakeholders

In Armenia, various scientific and educational institutions, international development banks, international cooperation organizations, and local engineering firms are actively involved in both the strategic discussion of the energy sector's development and the implementation of specific renewable energy projects. Among these stakeholders are:

- **The Armenia Renewable Resources and Energy Efficiency Fund (R2E2)** (established in 2005) is a state entity focused on promoting renewables and energy efficiency. R2E2 provides technical and advisory services to the government, contributes to legislation and regulations, and organizes training and public awareness programs in the sector. The Fund also evaluates investment projects, conducts energy audits, and collaborates with international partners to promote clean energy technologies[xx].
- **Scientific Research Institute of Energy CJSC** – established in the mid-20th century, this research institute is actively engaged in strategic planning for the energy sector. In 1998, with support from TACIS, the institute established the "Energy Strategy Center," which specializes in energy strategy and policy development[xxi].
- **The National Polytechnic University of Armenia (NPUA)** – a leading institution in technical education in Armenia, NPUA conducts research and development in power engineering, energy technologies, and automation systems. The Institute of Energetics and Electrical Engineering, a key component of the university, supports the advancement and modernization of Armenia's energy infrastructure[xxii].
- **Foundation for Armenian Science and Technology (FAST)** – founded in 2016 by Armenian entrepreneurs Nubar Afeyan and Ruben Vardanyan, FAST aims to foster technological breakthroughs in Armenia. The foundation focuses on areas such as IT and computer science, artificial intelligence, high-tech materials, robotics, biotechnology, advanced engineering, and manufacturing technologies. Among its initiatives is grant support for the development of Armenia's Energy Independence Roadmap[xxiii].
- International development banks, such as the **European Bank for Reconstruction and Development (EBRD)**[xxiv] and the **World Bank**[xxv], are actively implementing projects in Armenia aimed at strengthening the country's power grid and promoting the expansion of renewables
- **The German-Armenian Fund**, established in 1998 by the Central Bank of Armenia, aims to support Armenia's financial sector and economic development through targeted investments. The programme for the promotion of renewables (with a support from KfW) has evolved through multiple phases, with recent agreements totaling €20 million to enhance access to loans for renewable energy projects, including solar PV and solar thermal heating. The latest phase, launched in May 2021, continues to build on the successful outcomes of previous phases by financing small-scale renewable energy technologies[xxvi].
- **USAID, the U.S. Agency for International Development**, is implementing the Market Liberalization and Electricity Trade (MLET) project in Armenia[xxvii]. The project aims to enhance competition in the electricity market, accelerate legal and regulatory reforms in line with European standards, and support cross-border electricity trade with Georgia. **Tetratech** is involved in the project as the main consultant[xxviii].
- **German Federal Ministry for Economic Cooperation and Development (BMZ)**, which includes projects such as Sustainable Energies for Climate Resilient Municipal

Development in Armenia (SE4Resilience), being implemented in collaboration with the Ministry for Territorial Administration and Infrastructure of Armenia[xxix].

- **The Agence Française de Développement (AFD)** is implementing projects focused on the deployment of clean energy and the promotion of efficient agriculture in rural areas of Armenia[xxx].

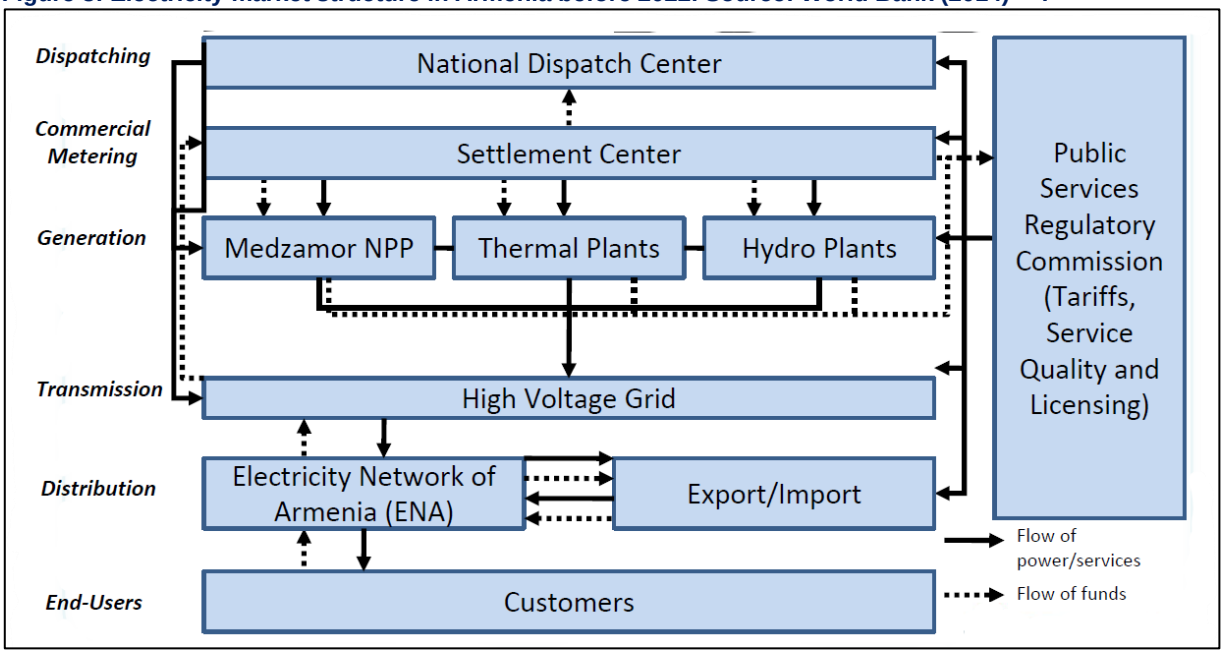
A list of local engineering companies, developers, and solution providers specializing in PV, along with their contact details, is provided in the following chapter of the report.

1.5 Electricity Market, Tariffs, and Costs

1.5.1 Overview of the Electricity Market

As of 2021, Armenia's electricity market operated under a single-buyer model, where the distribution company, Electric Networks of Armenia, entered into direct power purchase agreements with generating companies. Electricity tariffs were regulated by the Public Services Regulatory Commission (PSRC) (Figure 3).

Figure 3: Electricity market structure in Armenia before 2022. Source: World Bank (2014)[xxxi].



In 2021, a new energy strategy was adopted, outlining the roadmap to 2040 and setting goals for gradual market liberalization, renewable energy development, and the expansion of free electricity trade, including cross-border operations (ARLIS, 2024)[xxxii].

In February 2022, a new wholesale market model was introduced, incorporating direct contracts between market participants, a balancing mechanism, and long-term power purchase agreements. This model was based on recommendations from the USAID Market Liberalization and Electricity Trade (MLET) project. The target model foresees the following developments (Shatvoryan et al, 2024):

1. implementation of retail market trading rules and contracts,
2. an updated distribution network code,
3. revised wholesale market trading rules and contracts,
4. an updated transmission network code and reliability indicators,
5. development of an annual energy adequacy forecast,

6. advancement of a market management system,
7. enabling renewable energy plants to sell electricity on the new market under competitive conditions, without power purchase guarantees or public-private partnership agreements, and facilitating generation and consumption across different metering points in the energy system,
8. the deployment of an automated platform—the Armenian Energy Exchange (AEX)—which will enable the wholesale electricity market operator and system operator, along with market participants, to interact and facilitate electronic communications, energy transactions, settlements, and market data visualization across various market segments.

Since 2022, not only Electric Networks of Armenia (ENA), but also other suppliers are able to operate in the market, paying ENA a fixed fee for the physical distribution of electricity. The role of alternative traders is to compete by reducing administrative costs and offering more favorable terms to power plants, including operational modes aligned with electricity load profiles. According to the Public Services Regulatory Commission, by February 1, 2025, all commercial and industrial consumers must transition to the liberalized electricity market, starting with large consumers at 110 kV, followed by medium and small consumers. Households can remain with ENA after 2025, with the option to switch to market rates voluntarily. As of November 2023, 7-8 alternative electricity suppliers were registered, with 2-3 actively operating, accounting for approximately 17% of Armenia's total electricity consumption on the open market (Sputnik Armenia, 2023)[xxxiii].

1.5.2 Tariffs for Regulated Consumers, Power Plants, and Electricity Distribution in 2024

Electricity tariffs in Armenia are regulated by the Public Services Regulatory Commission (PSRC) using a cost-plus method, which ensures a predetermined level of profit for operators after accounting for both fixed and variable costs. While the government has historically followed a cost-recovery policy for tariffs, recent increases in electricity service costs and concerns about affordability have led to a shift away from cost-reflective tariffs, resulting in higher subsidies and below-cost pricing. The tariff-setting process is transparent and is supported by the official PSRC website and consultations with consumers and other stakeholders. For electricity generators participating in the balancing market managed by the system operator, the tariff structure may include one or two components (electricity only or both electricity and capacity); other generators are subject to a single-component tariff. At the retail level, electricity tariffs for residential consumers have increased by 77% from 2009 to 2021 (IEA, 2023)[xxxiv].

In 2024, among regulated consumer groups, the lowest tariffs apply to businesses consuming electricity at a voltage of 110 kV: 41.98 AMD (0.098 EUR) per kWh during the day and 37.98 AMD (0.088 EUR) per kWh at night. For those consuming electricity at 220 kV, the tariffs are 53.48 AMD (0.12 EUR) and 43.48 AMD (0.1 EUR) per kWh, respectively (Aysor.am, 2023)[xxxv].

For low-income households, the tariffs in 2024 are set at 29.99 AMD and 19.99 AMD per kWh. For households consuming up to 200 kWh, the rates are 46.48 AMD and 36.48 AMD per kWh, while for those consuming 200-400 kWh, the tariff is 48.48 AMD per kWh. For households consuming over 400 kWh, the rate is 38.48 AMD per kWh. (Aysor.am, 2023). More detailed information on tariffs for consumers is provided in the regulator's decision from 2022 (ARLIS, 2022)[xxxvi].

Until June 2025, the following tariffs are set for regulated renewable energy plants in Armenia (ARLIS, 2024b)[xxxvii]:

- **solar**: from 16.651 to 42.148 AMD/kWh, depending on the year of commissioning and the completion of all necessary procedures and documentation submission.
- **hydro**: from 10.432 to 23.476 AMD/kWh, depending on the type of water source (natural watercourses, irrigation, or water supply systems).
- **wind**: from 16.651 to 42.148 AMD/kWh, depending on the year of commissioning and operational conditions.

Starting February 1, 2024, the tariffs for electricity distribution services provided by Electric Networks of Armenia will range from 1.581 AMD/kWh for connections at 110 kV to 19.232 AMD/kWh for connections at 0.38 kV (ENA, 2023)[xxxviii].

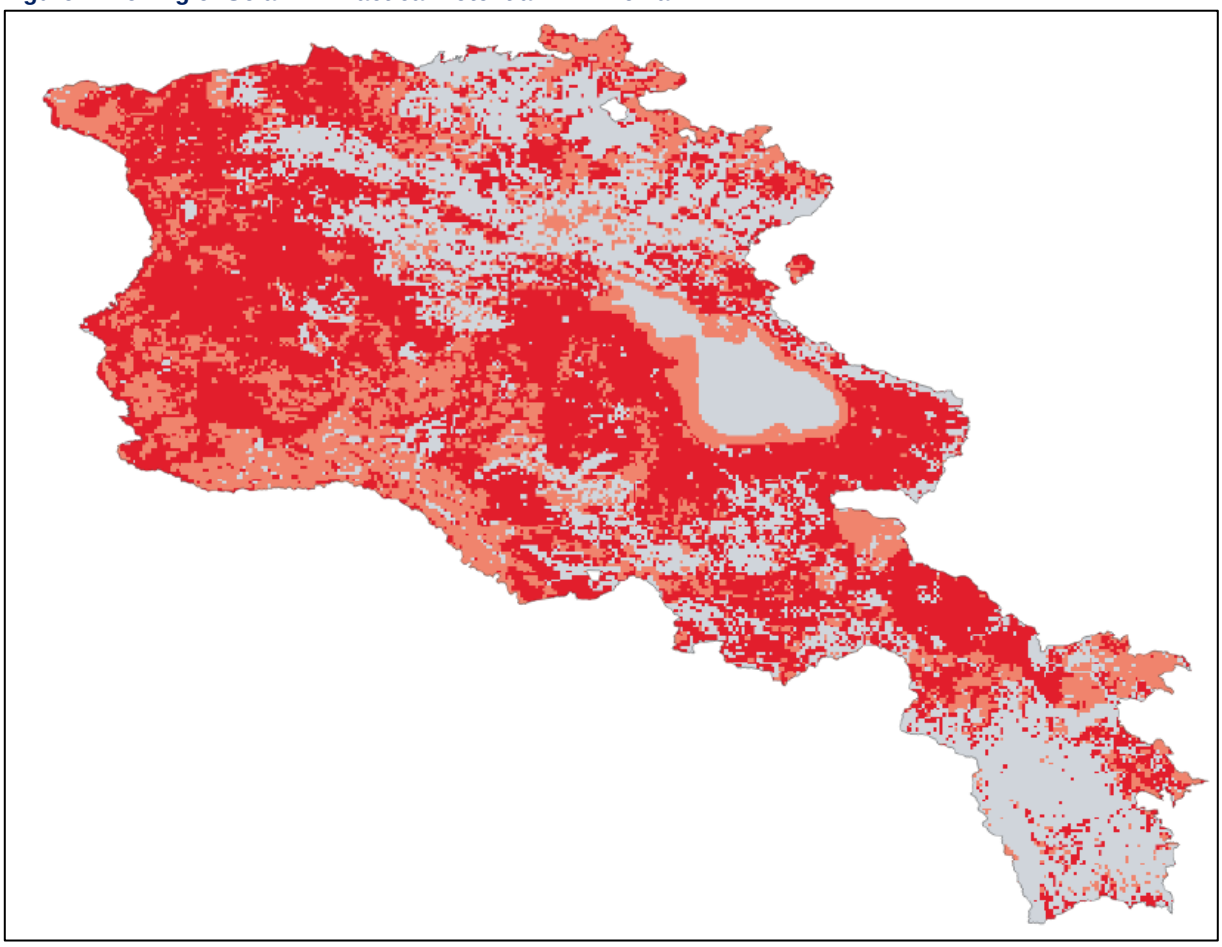
2. Factors for PV Development: Potential and National Strategies

The development of the PV sector in Armenia is at a relatively early stage but is already showing impressive growth. The share of solar PV in electricity generation increased nearly eightfold between 2020 and 2022, making it the fastest-growing segment in Armenia's power generation. In terms of growth rate and absolute volume of electricity produced from PV in 2022, Armenia leads among the South Caucasus countries (IRENA, 2024).

2.1 Solar Energy Potential

Armenia's average solar PV potential is around 4.2 kWh/m², which is 1.5 times higher than that of Germany. It is estimated that approximately 0.17% of the country's total area would need to be utilized for PV installations to meet annual electricity consumption. The specific PV power output per day ranges from 3.25 to 4.48 kWh/kWp, with an average of 4.05 kWh/kWp. About two-thirds of this potential lies in the 4.0–4.4 kWh/kWp range (1460–1600 and even more full load hours per year), similar to Spain (ESMAP, 2020; IEA, 2022)[xxxix].

Figure 4: Zoning of Solar PV Practical Potential in Armenia



Red color in Figure 4 is used to indicate locations suitable for utility-scale PV plants without significant land-use constraints, orange is for areas suitable with some constraints, and gray is for regions where utility-scale PV plants would be impractical due to identifiable physical obstacles (ESMAP 2020).

The potential for residential rooftop solar PV alone on existing buildings in Armenia reaches

around 1,600 MW (Shatvoryan et al., 2024). The country's energy strategy aims to achieve 1 GW of installed solar PV capacity by 2030 and 1.5 GW by 2040, with a target of 15% of electricity generation from solar PV by 2030, equating to approximately 1.8 TWh annually (ARLIS, 2024). In an aggressive energy independence scenario, Armenia could reach solar PV electricity production of up to 6.5 TWh annually by 2040, accounting for 38% of total electricity generation (Shatvoryan et al., 2024). Armenia could potentially achieve a fully carbon-neutral power system by 2050 with 2.63 GW of solar PV capacity, making solar PV the dominant source of electricity (Tetratech, 2022)[xl].

Thus, the total potential for new solar PV installations by 2040–2050 is comparable to the existing available capacity of all power plants in Armenia, which is currently 2.9 GW.

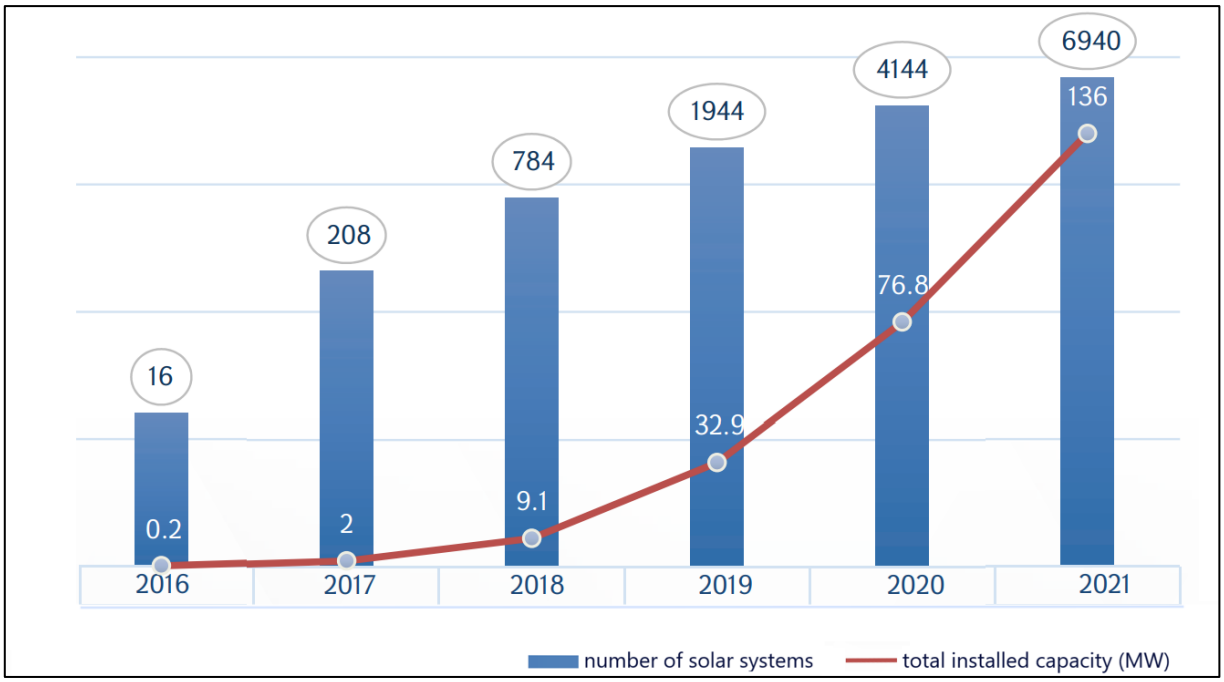
2.2 Current Market Status: Installed Capacity and Upcoming Projects

A notable feature of solar PV deployment in Armenia is the relatively significant role of rooftop solar PV. As of January 1, 2024, the country had 471 MW of installed PV capacity, consisting of 61 utility-scale plants with a total capacity of 205.5 MW, and 16,920 small-scale (primarily rooftop) installations, amounting to 265.7 MW (Keshihsyan, 2024)[xli].

Over the next two years, the construction of utility-scale PV plants "Masrik-1" (55 MW) and "Ayg-1" (200 MW) is anticipated under public-private partnerships (Keshihsyan, 2024), though the status of Ayg-1 remains uncertain due to ongoing discussions between investor (Masdar, UAE) and the regulator[xlii]. Meanwhile, the rooftop sector, operating within a different regulatory framework, is expected to continue its organic growth annually.

From 2016 to 2021, distributed solar PV generation grew at an impressive rate (Figure 5).

Figure 5: Distributed solar power generation in Armenia in 2016-2021. Source: PSRC, 2022[xliii].



2.3 Local Ecosystem of Developers and Solution Providers in the PV Sector

The rapid growth of Armenia's solar PV sector is supported by a well-established ecosystem of companies capable of driving project implementation. Throughout the 2010s, a competitive environment emerged in Armenia's solar PV development and engineering market, formed by numerous local specialized companies, including:

- **Shtigen Energy Systems** – a developer of PV plants and solar water heaters, established in 2011. The company has reportedly implemented over 50 MW of PV plants, including a 1.26 MW rooftop PV station, the largest in Armenia[xliv].
- **ApriSolar** – founded in 2012, the company has completed around 2,000 projects across the residential, commercial, industrial, and municipal sectors[xlv].
- **Rubinar** – a PV plant developer and solution provider, founded in 2013[xlvi]
- **Ecoville** – a PV plant developer focused on the rooftop segment, established in 2015[xlvii].
- **GSS Solar** – a developer of PV plants specializing in rooftop installations, founded in 2016. The company claims to have assisted hundreds of electricity consumers in becoming autonomous energy producers[xlviii].
- **Solaron** – recognized as Armenia's first domestic manufacturer of solar PV panels, starting production in 2016 with an annual capacity of 60 MW. Solaron offers a range of PV modules, including monofacial, bifacial, half-cut, colored, semi-transparent, and semi-flexible panels. The company has provided turnkey solutions for industrial facilities, public spaces, private residences, and government installations, delivering over 1,400 solar panels since its inception[xlix].
- **OHM Energy** – a solar PV plant developer operating since 2016[l].
- **Ecostep** – a developer of solar PV plants, active since 2017[li].
- **Solara** – a PV plant developer and solution provider founded in 2019, a partner of the US-based La Solar Group[lii].
- **Manana Technology**[liii], **Optimum Energy**[liv], **R-Fab**[lv], **Solar ESS**[lvi] – PV plant developers and solution providers with a focus on the rooftop segment.

Notably, many of these companies have leveraged their expertise gained from the rapidly growing Armenian market to expand into neighboring countries, such as Georgia and Uzbekistan.

3. Legal and Regulatory Framework for Solar PV: Incentives, Barriers, and Standards

3.1 Strategic Regulatory Environment: Key Documents

Armenia has consistently developed key documents critical for the growth and reform of its energy sector, regularly updating them to reflect new reforms, market liberalization, and the country's increasing renewable energy ambitions. This section provides an overview of key strategic documents, including references to primary sources, to help track future developments.

3.1.1 Energy Law

The Energy Law (ARLIS, 2024c)[lvii], adopted in 2001 with the latest amendments in May 2024, serves as the fundamental legislative framework governing Armenia's energy sector. The law defines the relationships between government authorities, energy market participants, and consumers of electricity, heat, and natural gas. It outlines the key principles of state energy policy, including the promotion of competition, consumer rights protection, and ensuring energy security. A key aspect of the law is the licensing of energy sector activities and tariff setting for energy services. The law also addresses nuclear energy and renewable energy development.

One of the central principles established by the law is the efficient use of local energy resources and renewables, supported by economic and legal mechanisms to encourage their development. It grants the Public Services Regulatory Commission the authority to issue licenses for power generation, including from renewable sources. Tariffs for electricity take into account the costs associated with renewable energy use, and the Public Services Regulatory Commission can apply special tariff mechanisms to encourage renewable energy development.

While the law does not have a dedicated chapter on renewables, its general provisions on licensing, tariffs, contracts, and other regulatory aspects are fully applicable to renewable energy activities.

3.1.2 Strategic Program for Energy Sector Development Until 2040

The Strategic Program for the Development of the Energy Sector of Armenia until 2040, adopted in 2021 and updated in late 2023, forms the foundation of Armenia's long-term energy policy (ARLIS, 2024). The program outlines key goals, priorities, and directions for the sector's development until 2040. It includes an analysis of the current state of the energy sector, forecasts for its growth, and specific measures and projects aimed at achieving these goals.

Key topics covered in the document include:

- **Expansion of electricity generation**, with a focus on increasing the share of renewables (especially solar) and nuclear energy.
- **Modernization and expansion of electricity grid infrastructure**, including the construction of new high-voltage lines and substations.
- **Market liberalization and regional cooperation**, transitioning to a demand-and-supply-balanced, liberalized market model to enhance efficiency and foster competition. This also includes improvements in tariff policies and protection for vulnerable consumers.
- **Enhancing energy efficiency and the development of digital technologies** in the energy sector.

Renewable energy, particularly solar energy, plays a central role in the program. The maximization of renewable energy potential is identified as a key priority, aimed at reducing the country's dependence on imported energy resources and strengthening its energy security. The share of renewables in total electricity consumption is expected to reach 50% by 2030 and 60% by 2040 (including large hydropower plants). By 2030, around 1,000 MW of solar power plants are to be built, including self-consumption installations, raising solar energy's share in total electricity generation to at least 15%. Between 2030 and 2040, an additional 500 MW of solar plants are planned, possibly in conjunction with energy storage systems.

The program emphasizes that the government plans to implement market mechanisms to encourage the construction of energy storage systems alongside solar plants. Maximizing the development of solar and wind energy is projected to achieve the lowest system costs, especially given potential increases in natural gas prices.

3.1.3 Energy Efficiency and Renewable Energy Program 2022-2030

The Energy Efficiency and Renewable Energy Program for 2022-2030 (ARLIS, 2022b)[lviii], adopted in 2022 and updated at the end of 2023, is designed in alignment with the Strategic Program for Energy Sector Development until 2040. The program governs energy efficiency and renewable energy policies through 2030, focusing on the development of solar and wind energy as well as energy efficiency improvements.

The program is being implemented in three stages: 2022-2024, 2025-2027, and 2028-2030. Various measures are planned to achieve the program's goals:

- **In renewables**: development of solar and wind energy, deployment of energy storage systems, exploration of geothermal potential, and support for renewable energy research.
- **In energy efficiency**: improvements in households (e.g., replacing gas heating with electric systems, installing solar panels), transport (expanding public transport and electric vehicles), schools (insulation and upgrading heating and lighting systems), industry, and agriculture.
- **In regulation**: tariff reforms, incentives for electric vehicles and appliances, and the development of business models for energy storage systems.

The program assigns a crucial role to solar energy in reaching renewable energy and emission reduction targets. By 2030, solar energy is expected to account for 15% of total electricity generation, with energy storage capacity reaching 300 MW (1,200 MWh). Business models for energy storage, combined with large solar power plants or developed as standalone systems, are planned. Additionally, the program includes measures to reform tariffs and foster the adoption of energy storage systems, alongside research into wind potential and R&D in renewable energy technologies.

The program specifically highlights the installation of solar systems on the rooftops of public schools as a means to reduce electricity consumption from the grid. It is estimated that solar installations on Armenian school rooftops could save between 14.7 to 24.5 thousand tonnes of oil equivalent per year. The program envisions the installation of solar panels with a capacity of at least 10 kW on the rooftops of schools that have undergone energy efficiency upgrades. This would lead to additional energy savings of approximately 5.2 million kWh, or 0.45 thousand tonnes of oil equivalent annually. The installation of solar panels is part of a broader set of energy efficiency measures, which includes improving insulation, upgrading heating and lighting systems, and implementing educational programs for staff and students aimed at fostering energy conservation awareness.

3.2 Incentives for Renewables

3.2.1 Feed-in tariff

Under the Law on Energy, feed-in tariffs are available from 2007 for small hydropower plants and other renewables for a duration of 15-20 years from the date of their license issuance. These tariffs are adjusted annually to reflect fluctuations in the exchange rate between the Armenian dram and foreign currencies (USD or EUR). Introduced in 2007, feed-in tariffs have supported the development of 389 MW of small hydropower, 4.23 MW of wind power, and 56 MW of solar PV capacity by January 2022 (IEA, 2023). This approach was particularly prevalent in the years leading up to the 2010s.

3.2.2 Long-term PPA based on PPP

In practice, the advancement of large-scale renewable energy projects has been primarily driven by competitive tenders leading to long-term power purchase agreements (PPAs). The central component of these tenders is the tariff, which is guaranteed for a specified duration (e.g., 20 years for the Masrik-1 project) and formalized through a public-private partnership with the Ministry of Territorial Administration and Infrastructure (MTAI) and a power purchase agreement with Electric Networks of Armenia (ENA). These tariffs are adjusted annually to reflect inflation and exchange rate fluctuations. Public-private partnerships and corresponding PPAs are accessible solely through competitive bidding processes.

The initial competitive tender for solar PV in Armenia, supported by the World Bank, took place in 2017 for the 55 MW Masrik-1 solar PV project. The tender attracted around 70 international participants through a two-stage process. The winning bid came from a consortium led by Fotowatio Renewable Ventures, part of Abdul Latif Jameel Energy (Saudi Arabia), which offered the lowest tariff of USD 4.19 cents per kWh. This tariff was secured through a 20-year PPA with ENA and supported by a public-private partnership agreement signed with MTAI in 2018. The agreement included additional forms of support, such as purchase and payment guarantees. The winner also received financial backing from the International Finance Corporation (IFC), EBRD, and the EU, with total funding reaching up to USD 38.4 million (IEA, 2022b). The Masrik-1 project is currently under construction and expected to become operational by October 2024[lix].

A second tender for the 200 MW AYG-1 solar PV project was concluded in 2021, with the winning bid from Masdar (UAE) offering an even lower tariff of USD 2.9 cents per kWh. The project was initially expected to begin operations in 2025 (IEA, 2022b), but its status remains uncertain due to a review of the agreement between the regulator and the investor.

3.2.3 Net-metering

In 2015, Armenia introduced net-metering for autonomous energy producers (“self-generators’), i.e., those producing electricity primarily for their own use. Since 2017, the maximum capacity for such producers has been set at 500 kW, and as of August 2024, this limit has been reduced to 150 kW. Under this scheme, self-generators can "store" excess electricity in the grid and consume an equivalent amount later. At the end of the year, autonomous energy producers settle with ENA for the difference between their production and consumption based on regulated tariffs set by the PSRC. Additionally, those with capacities up to 150 kW are exempt from income tax on excess generation. The cost for connecting to the net-metering system includes the installation of a bi-directional meter, currently costing less than USD 100 (IEA, 2022b)[lx].

New regulations, effective from 2022 with the introduction of a new electricity market model, will enable "virtual" net-metering. This means that autonomous energy producers will not be required to locate their renewable energy installations at the same point in the grid where they consume electricity. This will facilitate the placement of renewable energy systems in more technically advantageous locations and allow payment of only the regulated transmission or distribution fee. However, such users will need to provide the Market Operator with preliminary schedules (on an hourly basis) of their consumption and generation at relevant metering points. The new rules will also allow group net-metering, where groups of consumers located at different points in the grid can share a single self-generating facility. These changes aim to bring Armenia closer to EU electricity directives and international best practices (IEA, 2022b).

3.2.4 Other incentives

Additional support measures for renewable energy projects include assistance with obtaining land use permits, ensuring non-discriminatory access to and conditions for electricity grid connections, providing investment incentives and loans, as well as offering tax and duty exemptions for imported equipment (IEA, 2022b).

3.3 Barriers to PV Development

While the balance of incentives and barriers for PV energy in Armenia currently favors rapid project development, certain obstacles typical of other markets are likely to emerge in Armenia as well.

3.3.1 Power Grid Bottlenecks

PV currently constitutes about 5-6% of Armenia's electricity generation. As this share grows to 10-20%, the need for flexibility in grid regulation will become more pronounced. This requires a combination of modern management and automation tools for the system operator, along with access to flexible dispatchable power plants, such as hydro or gas-fired plants, to offset the variability of PV generation. Without adequate flexibility, the system operator may need to implement curtailments, limiting the output from solar plants. This can reduce the efficiency of these installations and negatively impact the return on investment for PV projects.

In Armenia, this issue may be exacerbated by the fact that, as of 2022, the Electric Power System Operator (EPSO) did not use an Automatic Energy Management System, relying instead on a statistical approach to network regulation. With the current infrastructure, EPSO may struggle to manage the grid with increased variable generation, necessitating significant investment in modernization (Shatvoryan, 2024). The Armenian government plans to address this issue in strategic documents, potentially through the development of energy storage systems. PV developers are advised to monitor this situation closely to mitigate the risk of curtailments affecting their projects.

3.3.2 Land Competition

Armenia, being the smallest country in the region with a significant portion of mountainous terrain, has limited suitable land for large-scale utility PV projects. Optimal sites for these projects are likely to be scarce and will face competition from other land uses, such as agriculture. For instance, in 2022, the Armenian NGO Energy Saving Foundation attempted to propose legislation that would prohibit the promotion of PV power plants on agricultural land and offer incentives for land unsuitable for agricultural purposes[lxi].

3.3.3 Barriers to Electricity Market Liberalization

The liberalization of Armenia's electricity market, initiated with a new model in 2022, aimed to introduce additional players into what was previously a single-buyer market, thereby enhancing opportunities for PV project developers in terms of grid connectivity and electricity trading.

However, as of February 2024, Electric Networks of Armenia (ENA) continues to hold a monopoly in the sector, according to research by the Competition Protection Commission of Armenia (CPCA). As the largest electricity buyer and sole distributor, ENA maintains substantial market control, which allows it to influence competitive conditions. The CPCA notes that ENA's dominant position enables it to affect consumer behavior, with the potential to create artificial shortages or manipulate market prices. ENA is also required to implement an automatic electricity metering system for all consumers by 2027, though specific penalties for non-compliance have not been defined. This raise concerns that ENA, as a monopolist, might delay the system's implementation to maintain its customer base (Ecolur, 2024) [lxii]. The slow pace of market liberalization could present barriers to the accelerated development of PV projects.

3.4 Regulation of PV Project Development

3.4.1 General Procedure Overview

To develop a utility-scale PV project in Armenia, investors generally follow steps typical of other markets. These include selecting a site, acquiring land use rights and changing land use designations if necessary, drafting a project business plan, obtaining an electricity generation license if required, and requesting grid connection conditions from the grid company. The project must then be constructed in compliance with the obtained permits. Utility-scale projects in Armenia typically involve international tenders and the signing of PPAs with winners for pre-determined sites, such as the upcoming Ayg-2 project tender with a capacity of 200 MW. Project developers can seek free consultations and the most current information from the state-owned Renewable Resources and Energy Efficiency Fund (R2E2), as mentioned earlier.

For rooftop PV projects intended primarily for self-consumption, licensing may not be required for capacities up to 150 kW, depending on the conditions. Investors should apply to the grid company for a network connection and install bidirectional meters. Electricity payments for excess energy fed into the grid are generally based on existing net metering rules, typically calculated on an annual basis. Producers with capacities up to 150 kW are exempt from income tax on surplus electricity.

3.4.2 Grid Connection Procedures

The procedure for connecting renewable energy projects to the grid is governed by the "Rules for Connection to the Distribution Networks," first approved in 2019 with the latest amendments as of mid-2024 (ARLIS, 2019)[lxiii]. These rules cover a broad range of issues related to the operation of distribution networks in Armenia, including network development planning, operational management, dispatching, and the connection of electricity producers and consumers, as well as commercial electricity accounting.

The document places particular emphasis on the connection of renewable energy systems, including standalone producers. To connect utility-scale producers to the distribution network, a contract must be signed. The producer submits an application to the distribution company, including technical specifications of the plant (type, capacity, location, etc.), a copy of the electricity generation license (if required), and documents proving land ownership or use. The

distribution company reviews the application within 15 business days. The producer must ensure that the plant meets technical and safety standards. If the application is approved, the distribution company issues technical connection conditions detailing the requirements for the plant and its connection to the grid. For plants of 10 MW or more, technical conditions are also coordinated with the system operator. Connection fees may apply, based on the costs of necessary infrastructure construction. For licensed producers, the validity of technical conditions aligns with the electricity generation license, while for others, it is two years. Upon completion of construction and connection, the producer and distribution company sign a connection agreement.

For autonomous energy producers, such as rooftop PV projects, a request must be submitted to replace the standard meter with a bidirectional multi-tariff meter. The distribution company reviews the request and, if approved, installs the bidirectional meter within three business days after payment for the service. Autonomous producers generally must not exceed 150 kW in capacity, primarily use the electricity for their own needs, and may sell surplus electricity to the grid under a separate agreement with a guaranteed supplier (IEA, 2022b).

3.4.3 Tariff Calculation Methodology

The methodology for tariff calculation, determination, and revision in the electricity sector (ARLIS, 2024d)[lxiv] was approved in 2022, with the latest changes as of mid-2024.

The tariff calculation methodology is based on ensuring that licensed entities engaged in regulated activities within the electricity system receive necessary revenues. These revenues must cover justified operating, maintenance, and depreciation costs, as well as provide a reasonable return on invested capital. The methodology specifies categories of licensed entities subject to tariff regulation, including electricity producers (thermal, nuclear, hydro, and renewable), system operators, market operators, transmission organizations, distribution organizations, and guaranteed suppliers. It outlines the process for tariff application submissions and revisions, including deadlines, required documents, and review procedures. The document also defines the tariff structure for wholesale and retail electricity markets, including tariffs for system operator services, market operator services, transmission organizations, and guaranteed suppliers.

Special attention is given to tariffs for electricity generated from renewables. Fixed tariffs with annual adjustment mechanisms, accounting for inflation and currency fluctuations, are set for renewables. The document also specifies exceptions to general tariff regulations for certain categories of renewables, such as small hydropower plants on natural waterways and biomass or biogas stations. Unique licensing and tariff conditions apply to these categories.

The methodology establishes differences in tariff determination for renewables facilities commissioned in different years. This is particularly notable for solar and wind power plants, as well as small hydropower plants built on irrigation and drinking water systems. For solar power plants:

- For capacities up to 1 MW licensed before November 1, 2018, the initial tariff is set at AMD 42.845 per kWh (excluding VAT), with subsequent adjustments for inflation and exchange rate fluctuations.
- For capacities up to 5 MW licensed from November 2, 2018, to December 31, 2020, the initial tariff is based on the tariff for small hydropower plants on natural waterways, adjusted for inflation.
- For capacities up to 5 MW licensed after December 31, 2020 (excluding some specific-

owned plants), the initial tariff is based on the base tariff for large solar PV plants commissioned after January 1, 2021, with adjustments for inflation and currency fluctuations.

- For all solar PV plants: if the capacity, land area, or connection voltage changes after licensing, the tariff is revised with a reduction factor of 0.9.

4. Economic and Financial Analysis

This section is dedicated to the profitability analysis of residential PV projects in Armenia. Sample calculations of typical projects include: cash-flow modelling and sensitivity analyses to provide an outlook of profitability changes related to changes in system prices, energy yield and remuneration.

For the business case we have used the solar radiation values of Yerevan in the central part of the country. According to data taken from the global solar atlas, the solar radiation in the region corresponds to 1,960 kWh/m2 (global tilted irradiation (GTI) at optimum angle). After applying a performance ratio of 0.80 to this irradiation, the specific yield used (and shown in the graphs and figures) is 1,568 kWh/kWp/a. Please note, that the specific annual PV yield in Armenia depends heavily on the location of the project. The solar irradiation (again GTI at optimum angles) varies in Armenia between approx. 1,400 kWh/kWp/a in the north to 2,000 kWh/kWp/a in the south.

4.1 Methodology of the profitability analysis

An excel based discounted cash flow analysis (DCF) was used for the profitability analysis. The DCF methodology evaluates a project using the concept of the time value of money. All future cash flows are estimated and discounted to their present values. The net present value (NPV) is the sum of all positive and negative cash flows including the initial investment. The NPV allows for the comparison of investments with different durations and cash flow profiles over their lifetime at the present point in time. Besides NPV, the internal rate of return (IRR) for the equity was calculated as well as the amortization period (payback time) for the invested capital.

These parameters give an indication of the attractiveness of a PV investment for residential and therefore, enable decision makers of solution providers. Please note that we have used discounted cashflows for the calculation of the amortization period and that we also show an undiscounted payback period in the project overview charts. By definition, these undiscounted payback periods are always shorter than the discounted payback periods because the time value of money concept is ignored which basically means that 1 AMD today will still be worth 1 AMD at any time in the future.

4.2 PV Net-Metering

A grid connected residential solar PV system combines the power output of PV arrays with a grid connection. The legislation in Armenia allows private households to connect their PV installation to the grid with the option to credit 100 % of produced solar energy to the annual electricity consumption. Therefore, this calculation is focused on net-metering with a residential rooftop system. Input values have been discussed with regional energy experts.

Profitability analysis for a residential net-metering PV system is presented below.

Figure 6: Project Overview – Residential PV

PV System		
Project Duration	Years	25
PV System Size	kWp	5,0
Nominal storage capacity	kWh	-
Total PV system costs /kWp	AMD/kWp	400.000
Total PV System Cost	AMD	2.000.000
Performance Factor	%	80%
Degradation	% p.a.	0,70%
Applied Solar Yield	kWh/kWp/a	1.568
Average Yearly Generation	kWh/a	7.143
Fixed Operation Costs PV	% p.a.	1,50%

System Operation - Savings		
Net-Metering	%	100%
Grid electricity replaced p.a.	kWh	7.143
Grid electricity price at start	AMD/kWh	38,5
Grid electricity annual escalation	%	5%
Average electricity price over the lifetime	AMD/kWh	77,1
Applied Battery PV Consumption	%	-

Financing			
Debt (Gearing)	-	AMD	-
Loan Tenor		Years	6
Debt Interest Rate		%	-
Initial Equity		AMD	2.000.000
Additional Equity		AMD	-
Discount Rate		%	8,0%
Longterm Inflation Rate		%	4,0%

Results		
Net-Present Value	AMD	2.441.140
Equity IRR	%	18%
Amortization - discounted payback period	Years	8,81
Undiscounted payback period	Years	6,36
LCOE (no subsidy)	AMD/kWh	31,77
Min DSCR**	x	-
Min LLCR***	x	-
* LCOE: Levelized Cost of Electricity ** DSCR: Debt Service Coverage Ratio *** LLCR: Loan Life Coverage Ratio		
Project IRR	%	18%

Source: eclareon, 2024

About the assumptions for this PV Business Case

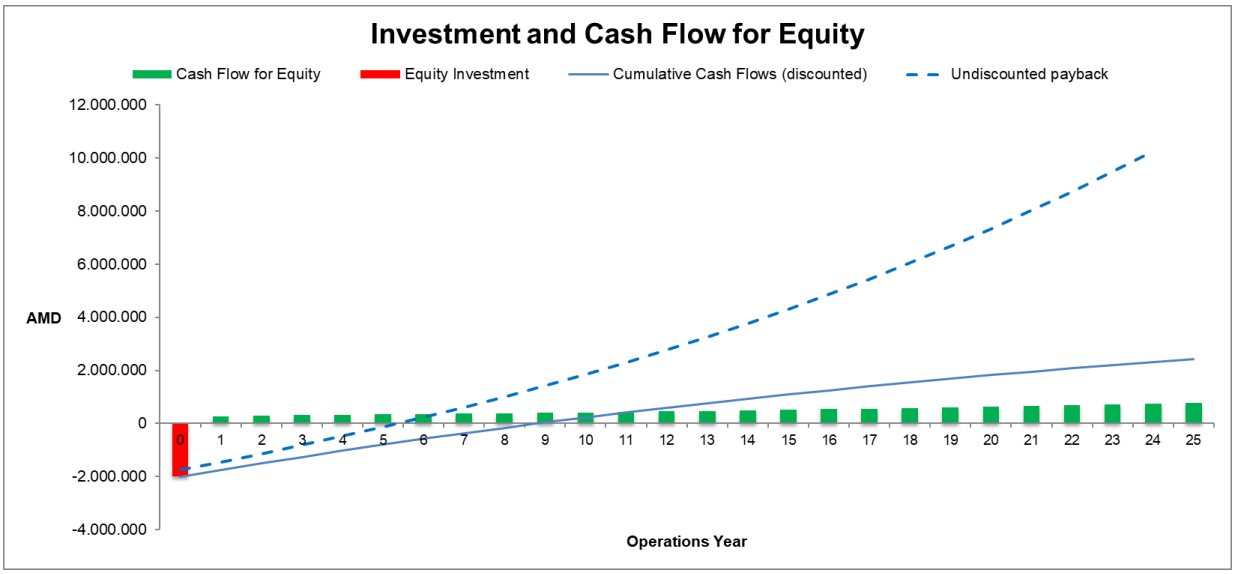
Electricity savings based on reduced grid electricity consumption were evaluated with a residential tariff of 38.5 AMD/kWh (retail market price) for the start of the period (beginning of 2024). This tariff is typical for households in Yerevan with an annual consumption of above 400 kWh. The annual increase of electricity prices is estimated to 5 %. There was no differentiation between self-consumption and electricity fed to the grid, as the Armenian net-metering scheme enables consumers to credit 100 % of the produced energy to the annual bill.

Regarding financing it was assumed that these installations attract rather wealthy individuals who can afford the investment in a 5 kWp system and will buy the system based on their own funds alone. The internal interest rate was set at 8% which is 4% higher than the estimated long-term inflation rate of 4%. The internal interest rate is rather ambitious and shall indicate, that in this calculation purely economic interests have been taken into account. It is possible, that more environmentally conscious consumers use a lower internal interest rate.
The investment costs at 400.000 AMD/kWp are in the range of offers in Yerevan, but looking at the global market, even lower prices could be possible, which would have a positive impact on the IRR and shorten the payback period. This effect is shown in the sensitivity analysis pertaining to system prices. The lifetime of the system is set to 25 years and is based on the lifetime of the PV modules.

Financial results for the PV Business Case

As can be seen from figure 7, with best possible solar irradiation conditions in Yerevan the discounted payback period is 8.8 years and the equity IRR is 18%. The equity cash flow for the case is as follows:

Figure 7: Equity Cash Flows - Residential PV



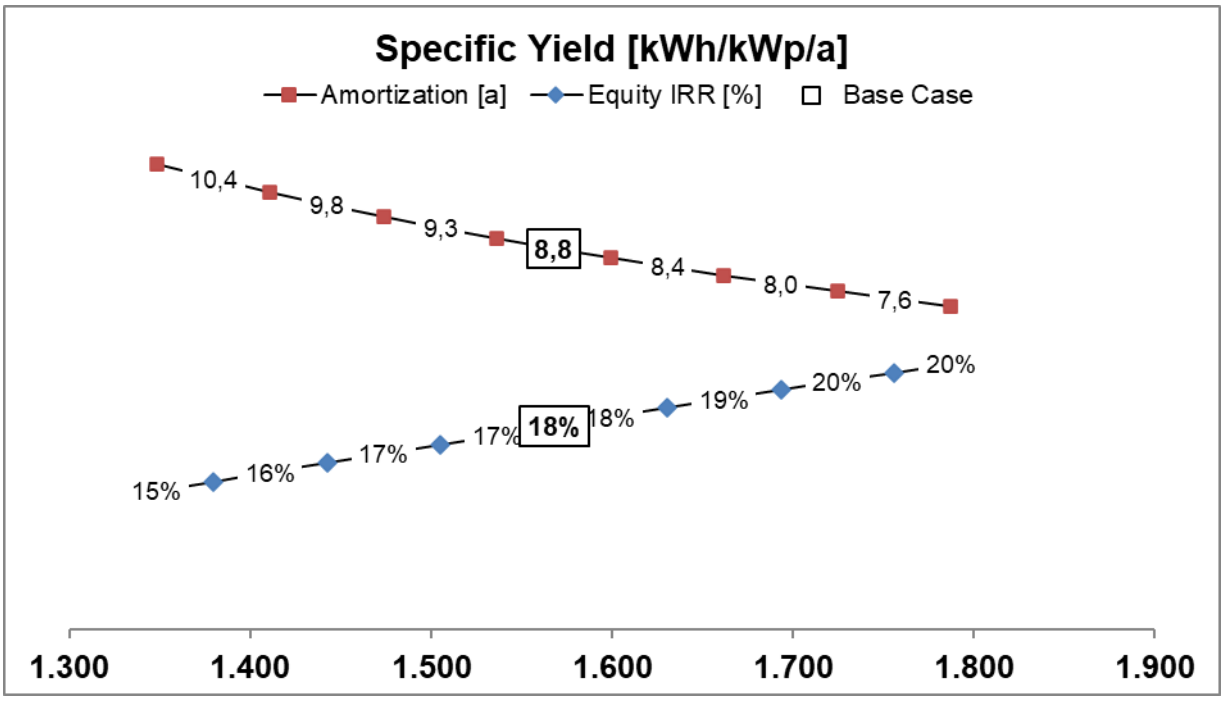
Source: eclareon, 2024

A discounted payback period of 8.8 years is a strong value for the residential segment, the undiscounted (equaling an internal interest rate of 0 %, as there was no dept gearing) payback period would be around 6 years. These good payback periods can be credited to low installation costs in the residential net-metering segment. With higher grid electricity prices, or a growth rate above 5 % (which is below the internal interest rate) payback periods would be even shorter. When both are set to 5 %, the discounted payback period would be around one year shorter, as can be seen in figure 10. Nevertheless, the LCOE of the solar system is 31.7 AMD/kWh and therefor far lower than the average 77.1 AMD/kWh average grid electricity tariff over 25 years.

Sensitivity of results for this PV Business Case

The following figures show how the two key economic performance indicators for the investment, payback period (amortization) and return on equity (equity IRR) change when certain assumptions of the business case are modified. The figures show which alterations of the individual assumptions influence the profitability of the investment particularly strongly (→ high sensitivity). This needs to be carefully observed when making the investment.

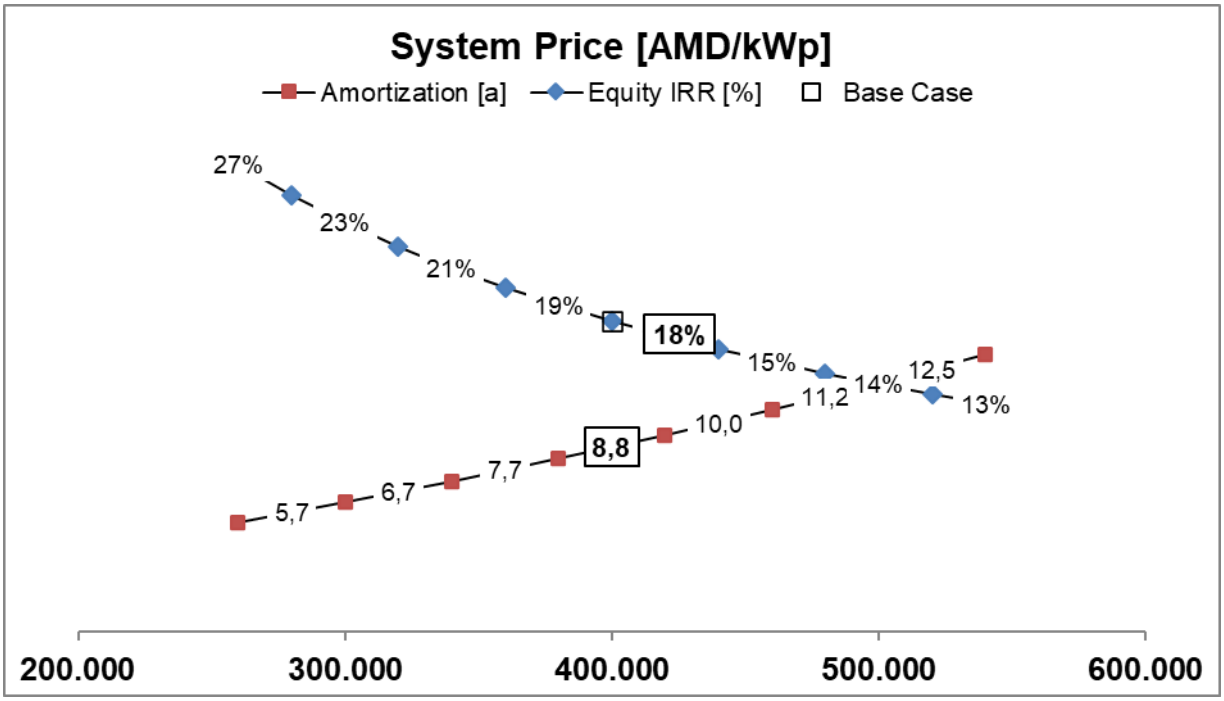
Figure 8 Specific Yield Sensitivity - Residential PV



Source: eclareon, 2024

The effects of lower (but also higher) overall system prices can be seen in figure 9.

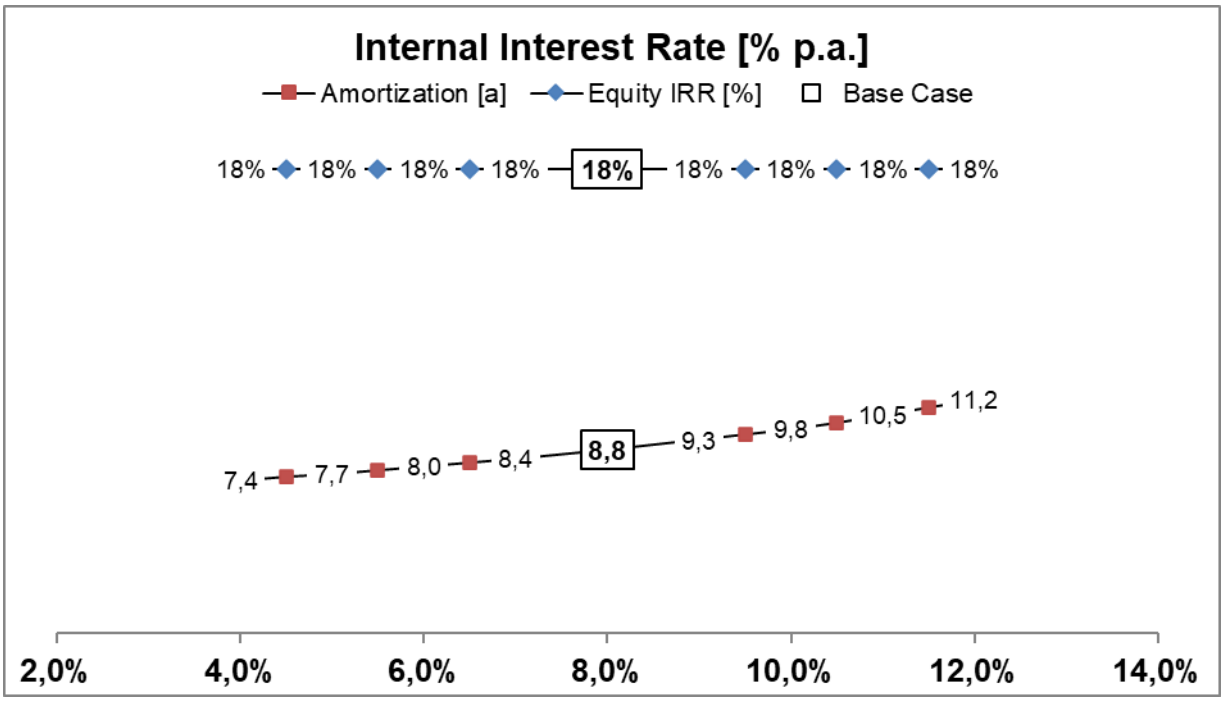
Figure 9: System Price Sensitivity - Residential PV



Source: eclareon, 2024

Another important parameter for this business case is above-described internal interest rate. With 8 % annually, it is very ambitious for residential households but shall provide an economic evaluation comparable to other investment options. At 4 %, the discounted payback period would already be one year lower.

Figure 10: Internal Interest Rate - Residential PV



Source: eclareon, 2024

4.3 Conclusions

Overall, the analysis supports the conclusion that net-metering PV systems in Armenia is economically viable, mostly based on very low installation costs. A discounted payback period of around 9 years is very reasonable and shows a strong business case for residential net-metering.

5. Recommendations for policymakers and developers

Based on the brief analysis of Armenia's energy strategy, policies, long-term goals, the status of the PV sector, and the model assessment of the net-metering business case, the following recommendations can be proposed for stakeholders in Armenia:

Recommendations for policymakers:

1. **Accelerate electricity market liberalization:** Reduce barriers for new entrants to ensure transparency and create a level playing field for all participants. This will foster competition and attract investments in the solar energy sector.
2. **Modernize the grid infrastructure** with a focus on strengthening interconnections with neighboring countries. Upgrading the grid is a key step to increasing the share of variable renewables like PV in the energy mix, addressing network congestion, and minimizing curtailments.
3. **Streamline permitting processes** for land allocation and grid connection. Simplifying bureaucratic procedures, reducing approval times for PV projects, and digitizing the application processes will speed up project development and reduce risks and costs for investors.
4. **Support energy storage systems:** Promote the development of energy storage solutions integrated with solar PV or as standalone systems to enhance grid flexibility and better utilize solar energy, especially during periods of low solar irradiance. One potential avenue is to encourage electric mobility and vehicle-to-grid (V2G) services, where EVs can be charged from home solar systems, absorbing renewable energy during peak production. In turn, EV batteries could supply energy back to the grid during peak demand hours, provided the necessary technical and regulatory framework is in place. Expanding EV infrastructure aligns with Armenia's energy strategy by reducing demand for imported natural gas, the primary fuel for transportation.
5. **Raise public awareness** through information campaigns and education programs that highlight the benefits of solar energy and energy efficiency. Training professionals in the solar sector will help create a more supportive environment for investment and market growth.

Recommendations for PV project developers:

1. **Carefully assess grid connection risks,** considering the current grid status and future network modernization projects, particularly for utility-scale PV developments. In some cases, integrating energy storage systems with PV projects may reduce the impact of grid constraints and mitigate curtailment risks.
2. **Monitor changes in land-use regulations.** Priority may be given to land not suitable for agricultural use, as regulatory adjustments could influence site selection.
3. **Leverage international collaboration** by engaging with international financial institutions, technology providers, and other stakeholders. This will help attract investments and gain access to cutting-edge technologies and expertise.
4. **Develop local competencies** by investing in the training and development of local professionals in the solar energy field. This will reduce reliance on foreign contractors and improve the efficiency of project execution.

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