Policy Recommendation Series

SOLVING THE ENERGY TRILEMMA: ARMENIA'S TRANSITION TO ENERGY ABUNDANCE

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May 2025

ABSTRACT

Armenia stands at a pivotal moment in its energy trajectory, confronted by acute dependence on imported fuels and the pressing need for long-term sustainability. This paper examines Armenia's energy security challenges through a detailed analysis of its current energy mix, infrastructure vulnerabilities, and geopolitical dependencies, particularly closed borders due to the conflict with Azerbaijan, dependence on Russian capital for domestic energy infrastructure, and reliance on Russian imports for gas and nuclear fuel.

The paper presents two complementary strategies to chart a more secure energy future: import diversification and reduction. The former advocates leveraging underused capacities and regional gas swaps to reduce reliance on a single supplier. The latter centers on scaling renewable energy deployment, improving energy efficiency, and electrifying transport and heating systems. Drawing on empirical data, the paper reviews the cost-effectiveness of solar energy generation supported by policy frameworks and public-private investment models.

In addition to recommended pathways towards clean energy transition, the paper discusses the broader socio-economic implications of energy insecurity, from industrial productivity losses to affordability gaps in household energy consumption. It calls for systemic reforms—including the establishment of a project preparation facility for private partnerships (PPPs), upgrades in energy governance, implementation of government incentive mechanisms and standards for clean energy projects and energy efficient technologies—to boost investment in energy infrastructure, unlock climate finance for clean energy transition and improve energy efficiency. Finally, this study is a foundational guide for policymakers, investors, and international partners committed to building a resilient, diversified, and sustainable energy system in Armenia.

INTRODUCTION

Armenia faces a critical juncture in its energy policy, shaped by the dual pressures of heavy dependence on imported energy and the imperative for sustainable development. This paper explores strategic interventions to enhance Armenia's energy security and reduce its vulnerability to geopolitical and market fluctuations. This paper provides actionable insights for transforming Armenia's energy sector through a detailed analysis of the current energy landscape and strategic recommendations.

The paper's first section delves into the existing energy structure in Armenia, highlighting the significant reliance on imported energy, with 73.3% of electricity generation fueled by imports, predominantly from Russia. This section explores the composition of Armenia's energy mix, the dynamics of energy consumption across various sectors, and the challenges posed by the monopolistic control of critical energy infrastructures by foreign entities such as Gazprom.

The second section addresses the specific challenges Armenia faces in achieving energy independence and stability. It examines the geopolitical risks, market dependencies, and the impacts of foreign control over Armenia's energy assets. This section sets the stage for discussing the strategic recommendations by identifying the key vulnerabilities in Armenia's current energy model and the potential areas for intervention.

The third section outlines a series of strategic recommendations to mitigate the identified challenges:

- Import Diversification: Enhancing pipeline capacity from multiple sources and exploring gas swap agreements to reduce reliance on Russian gas.
- Renewable Energy Development: Significantly increasing the share of renewables in the energy mix through solar, wind, and geothermal projects. Notably, solar energy initiatives are supported by Armenia's favorable solar irradiation levels, with projects like Masrik-1 and Ayg-1 photovoltaic (PV) plants serving as prime examples.
- Electrification and Energy Efficiency Improvements: Promoting electric vehicles and heat pump technologies, complemented by policy incentives and regulatory reforms to boost energy efficiency across various sectors.

The paper concludes by emphasizing the necessity of Armenia's transition towards a diversified and sustainable energy portfolio to achieve greater energy independence and economic resilience. The recommendations are a blueprint for policy-making and strategic planning, guiding Armenia toward a more secure and sustainable energy future aligned with global environmental and energy efficiency standards. This strategic approach will enhance Armenia's energy security and contribute to sustainable economic growth and environmental sustainability.

BACKGROUND: ENERGY LANDSCAPE

Armenia significantly depends on imported fuels, presenting an acute challenge for energy security, affordability, and sustainability. Despite the diverse energy sources, the predominant share of imports highlights a vulnerability that impacts national energy security and economic autonomy. This section shows how Armenia's energy mix relies heavily on external sources, particularly natural gas and nuclear power.

Our insights are drawn from analyzing Armenia's current energy framework and its performance on a global scale. These serve as a basis for discussing strategic measures to enhance Armenian energy independence through increased use of renewable resources and diversification of energy sources.

Energy Mix

While Armenia's energy landscape is diverse, its energy dependence on imports presents a pressing challenge for the country's future. In 2022, the total energy supply (net of imports and exports) comprised 0.3% coal, 14% oil, 59% natural gas, 18% nuclear, 4% hydro, 2% geothermal/solar/wind, and 3% biofuels and waste. Of this, 73% comes from outside the country's borders. Over the past two decades, the reliance on external sources has only increased, with natural gas usage - which is principally imported - increasing by 116% while other sources have remained relatively stable.

Nuclear energy remains the primary generation source for Armenia's electricity, while reliance on imported energy highlights the dependence of its regional energy market. Despite its limited domestic energy resources, Armenia primarily generates its electricity from nuclear power, accounting for 69% of domestic production. This is followed by hydroelectric power at 15.4%, biofuels and waste at 10.2%, and geothermal/solar/wind at 5.7%. The country's heavy reliance on imported energy has grown by 124% since 2000, making Armenia the fourth biggest importer in its region, preceded by Russia, Georgia, and Uzbekistan[1].

The distribution of energy consumption across residential, transport, and industry reflects the critical role of energy in economic activities and the potential impact of supply shifts. The electricity generation profile shows that 42% is derived from natural gas, 31% from nuclear power, 21% from hydro sources, and a growing but still modest 6% from solar photovoltaic systems. This includes a 42% increase in nuclear energy generation since 2000, positioning Armenia as the sole country in its region operating and substantially utilizing a nuclear power plant for electricity generation.

Energy Trilemma

Armenia suffers from the "Energy Trilemma" balancing Energy Security, Energy Affordability, and Environmental Sustainability of Energy Systems. In 2023, Armenia's

[1] These values are for total energy import. Armenia imports 134462 TJ, Uzbekistan 203256 TJ, Georgia 208052 TJ, and Russia 839437 TJ.

overall score in the World Energy Trilemma Index was 60.4, ranking 58th globally. This reflects the complexity of achieving energy independence, providing affordable energy access, and advancing towards environmental sustainability.

Armenia's energy security is endangered by its heavy reliance on energy imports from geopolitically sensitive sources, impacting national stability and independence. Armenia's energy security has seen fluctuations and a general downward trend over the past two decades, largely due to its heavy reliance on imported energy sources. With over 87% of its total gas supply,[2] being imported from Russia and 12% from Iran via energy barter agreements, Armenia's energy security is tightly linked to its geopolitical relationships (IEA, 2023)[3]. As a result, import independence has seen a declining trend, defined as the country's reliance on net imports for total energy consumption and the diversity of suppliers[4]. This high import dependence, particularly from sensitive geopolitical sources, exacerbates the country's vulnerability to external market dynamics and political shifts, disrupting its energy supply and affecting national security.

Regarding energy affordability, despite universal electricity access, Armenia faces challenges with fluctuating fuel and electricity prices that affect its energy affordability within the Trilemma framework. Armenia has shown remarkable progress in energy affordability, as evidenced by its universal electricity access for its 2.8 million population (World Bank)[5]. Despite this success, challenges persist in fluctuating fuel and electricity prices, crucial components defining energy affordability within the Trilemma framework. In 2023, electricity prices for all consumer types increased by an average of 14%, with no changes recorded in 2024[6]. Meanwhile, gasoline prices decreased between 2022 and 2023, but diesel prices climbed from an average of 490 drams in January 2022 to 527 drams by January 2023 (World Bank)[7]. These trends highlight the ongoing need for policies that manage the volatility of energy costs to ensure social and economic stability.

Environmental sustainability in Armenia is characterized by modest gains in renewable integration and a decline in energy intensity, highlighting the need for continued improvement in renewable energy adoption. The environmental sustainability score has steadily declined but shows modest gains in integrating renewable energy sources into the energy mix. This is partially attributed to improvements in key performance metrics: final energy intensity, which measures the ratio of final energy consumption over GDP, has decreased, suggesting more efficient energy use in relation to economic output. Concurrently, CO_2 emissions per capita, which account for CO_2 emissions from fuel combustion per capita, have also decreased.

[2] Armenia's Statistical Committee - https://armstat.am/file/doc/99535988.pdf
[3] IEA (2023), Armenia energy profile, IEA, Paris https://www.iea.org/reports/armenia-energy-profile, Licence: CC BY 4.0
[4] Chambers, T. (2024). WORLD ENERGY TRILEMMA INDEX 2024.
[5] World Bank, World Development Indicators, 2022.
[6] Electricity tariff in Armenia to not change on February 1, 2024. (n.d.). Retrieved February 4, 2025, from https://news.am/eng/news/799791.html
[7] World Bank, Development Data Group, 2025.

This paper will primarily focus on proposing and detailing measures to increase Armenia's energy independence through a transition to renewable energy— aimed at a more secure, sustainable, and equitable energy landscape for the country. Given Armenia's high reliance on energy imports, which creates significant volatility in fuel prices and affects overall affordability and reliability, there is a pressing need for a shift towards greater energy independence. This dependency impacts economic stability and constrains Armenia's ability to control its energy future. The vulnerabilities associated with geopolitical dependencies and the resultant fluctuations in energy costs underscore the critical importance of enhancing the nation's energy security through diversification and increased use of renewable resources.

ANALYSIS: ENERGY SECURITY

Our analysis of Armenia's energy security reveals significant challenges stemming from foreign control and monopolistic practices in the energy sector. This section delves into how privatization and strategic foreign investments have led to a dependency on imported energy, particularly natural gas and nuclear power, which compromises Armenia's energy sovereignty.

The gas sector remains monopolized by Russian control over key energy infrastructure and policies that prevent supplier diversification. Price adjustments used as geopolitical leverage further highlight such dependency's economic and political implications.

Despite these challenges, Armenia is trying to liberalize its energy market, foster competition, and reduce reliance on foreign energy. These actions are crucial as Armenia seeks to secure a more balanced and resilient energy sector that supports sustainable economic growth and reduces geopolitical risks.

Monopolizing the Gas Sector

Over the last two decades, Armenia's energy sector has undergone extensive changes through privatization initiatives. These changes have also led to significant foreign control over critical energy assets. The pivotal moment came in 2001 when Armenia entered an assets-for-debt agreement that transferred control of six hydroelectric plants and the Medzamor nuclear power plant to Russian Authorities[8]. As a result, approximately 70% of Armenia's electricity production and 90% of its power-generating capacities fell under Russian control[9].

Armenia's energy affordability is undermined by reliance on expensive imports, with most of its electricity generated via natural gas and uranium sourced from Russia and Iran. While Armenia claims 100% access to electricity-fired thermal power plants generated 42% of Armenia's total electricity, while the Metsamor nuclear power plant

[8] Terzyan, A. (2018). *The anatomy of Russia's grip on Armenia: Bound to persist?*
[9] Armenia's Energy Security Faces Frosty Relations with Russia | Institute for War and Peace Reporting. (n.d.). Retrieved February 6, 2025, from https://iwpr.net/global-voices/armenias-energy-security-faces-frosty-relations-russia

generated 31%[10]. Since Russia and Iran supply natural gas, and Russia supplies uranium, about 73.3% of the total electricity generated was heavily dependent on imports— particularly from Russia and, to some extent, Iran. Moreover, Armenia imports 2.7 billion cubic meters of gas from Russia, while Iran's supply is close to 365 million cubic meters— creating a monopoly of Russian gas in Armenia's energy mix.

Preventing Supplier Diversification

The influence of foreign control is also evident in the operation of Armenia's energy infrastructure, specifically through Gazprom Armenia. Gazprom Armenia was initially established in 1997 as ArmRosGazprom, a subsidiary of the Russian company Gazprom. The company was created as a joint Russian-Armenian venture to manage natural gas pipeline projects and the domestic gas supply in Armenia. At its inception, the ownership was split between Gazprom and the Energy Ministry of Armenia, each holding 45% of the shares and the remaining 10% held by the ITERA company[11]. Over the years, Gazprom's stake in the company increased[12]. By 2014, Gazprom acquired the remaining shares to become the sole owner, rebranding the company as Gazprom Armenia. This move solidified Russian influence over Armenia's energy infrastructure. Currently, Gazprom Armenia continues to play a dominant role by fully owning and operating the gas distribution network in Armenia.

While energy imports from Iran do not prevent a viable medium-term alternative to Russia given the political situation, Russian strategies have effectively hindered all diversification given the geopolitical context. In 2006, amidst a significant contract for cooperation on gas and energy projects, Gazprom exerted greater control over strategic assets like the Iran-Armenia Natural Gas Pipeline and the Hrazdan Thermal Power Station[13]. Many analysts believe that Gazprom's influence significantly reduced the Iran-Armenia pipeline's diameter[14]. Originally planned to be 1,420 millimeters, it was narrowed down to 700 millimeters— a technical fix to limit the pipeline's capacity to a third of its original 1.1 billion cubic meters per year, further blocking Iran's supply of natural gas to third countries via Armenia and challenge Russia's monopoly over gas supplies[15]. Furthermore, the final acquisition of a major portion of the pipeline by Gazprom Armenia effectively allowed Russia to manage the key energy supply routes into Armenia.

Using Price Adjustments as Leverage

[10] Armenia Energy Factsheet 2022 - https://armstat.am/file/doc/99544448.pdf
[11] *Rubles for Resources: Top Russian Investments Exploit Armenia and Energy | AGBU*. (n.d.). Retrieved February 6, 2025, from https://agbu.org/moscow-connection/rubles-resources-top-russian-investments-exploit-armenia-energy
[12] Ռ/Կ«Ազատություն». (09:49:28Z). More Details Of Russian-Armenian Gas Deal Released. «Ազատ Եվրոպա/Ազատություն» ռադիոկայան. https://www.azatutyun.am/a/1584863.html
[13] A Post-Sanctions Iran and the Eurasian Energy Architecture Challenges and Opportunities for the Euro-Atlantic Community. (n.d.). [Dataset]. https://doi.org/10.1163/2210-7975_HRD-0128-2015019
[14] Armenia, Iran eye warming ties despite divergent interests | Eurasianet. (n.d.). Retrieved February 6, 2025, from https://eurasianet.org/armenia-iran-eye-warming-ties-despite-divergent-interests
[15] Socor, V. (n.d.). RUSSIA CEMENTS CONTROL OF ARMENIA'S ENERGY SYSTEM. Retrieved February 7, 2025, from https://jamestown.org/program/russia-cements-control-of-armenias-energy-system/

Russia has employed pricing strategies as geopolitical tools, manipulating gas prices to influence Armenia's foreign policy decisions and underline its dependency. Moscow has traditionally used its gas deliveries as a lever in bilateral relations[16]. In 2005, Gazprom announced a drastic price increase (from $56 per thousand cubic meters to $110 per thousand cubic meters) to express Russia's sour sentiments over ex-Soviet states becoming more pro-Western in their foreign policy, affecting several nations, including Armenia and Georgia[17]. Again, in 2013, Russia doubled the gas price to strongarm Armenian authorities to abandon the EU association agreement and join the Eurasian Economic Union, after which the prices were returned to their original value[18]. In the recent past also, Russia unexpectedly shut down the gas pipeline via Georgia to serve as a fresh reminder of its dominance over Armenia[19].

Despite Gazprom's control, Armenia has sought to negotiate lower rates, citing high consumer costs and discrepancies between prices charged to Armenia and those in European markets. For example, as of the fourth quarter of 2019, the average price of Russian gas delivered to Europe was about 139 USD (at the border), while on the Armenian border, it was 165 USD, which is 19% more than the price set for Europe[20]. While natural gas is delivered to Armenia by Gazprom at $165 per one thousand cubic meters, Gazprom Armenia sells it to Armenian households at almost $284 per thousand cubic meters[21]— a significant concern for Armenian households.

As a result of gas monopolies, trade restrictions, and price controls, electricity prices in Armenia have been impacted more significantly than those of its neighboring countries. In 2024, the average electricity cost in Armenia was $0.112 per kWh[22], reflecting a 13% increase from $0.099 per kWh in 2021[23]. This rate is the highest recorded among its neighbors; Georgia's electricity cost was $0.062 per kWh in 2024, decreasing from $0.076 in 2023. Azerbaijan maintained a steady rate of $0.047 per kWh over four years. Iran, experiencing fluctuation, recorded rates of $0.002 in 2024 and $0.005 in 2023. Turkiye's rate in 2024 was $0.048 per kWh, up from $0.052 in 2021. Amid regional

[16] Konarzewska, N. (2019, April 29). Armenia's Gas Dispute with Russia. The Central Asia-Caucasus Analyst. https://www.cacianalyst.org/publications/analytical-articles/item/13570-armenias-gas-dispute-with-russia.html
[17] Ռ/Կ«Ազատություն». (09:49:28Z). Armenian Speaker Warns Russia Over Gas Price Hike. «Ազատ Եվրոպա/Ազատություն» ռադիոկայան. https://www.azatutyun.am/a/1579831.html
[18] Armenia Navigates a Path Away From Russia. (n.d.). Carnegie Endowment for International Peace. Retrieved January 24, 2025, from https://carnegieendowment.org/research/2024/07/armenia-navigates-a-path-away-from-russia?lang=en
[19] *Armenia Navigates a Path Away From Russia*. (n.d.). Carnegie Endowment for International Peace. Retrieved January 24, 2025, from https://carnegieendowment.org/research/2024/07/armenia-navigates-a-path-away-from-russia?lang=en
[20] Ioannisyan, D. (2020, January 23). History of gas pricing and the reasons for the rise in prices—Union of Informed Citizens. Union of Informed Citizens -. https://uic.am/en/21489
[21] ARKA.am. (n.d.). Armenian government expects Russian Gazprom to cut natural gas price. Retrieved February 6, 2025, from https://arka.am/en/news/business/armenian_government_expects_russian_gazprom_to_cut_natural_gas_price/
[22] Cost of Electricity by Country 2024. World Population Review. Retrieved February 7, 2025, from https://worldpopulationreview.com/country-rankings/cost-of-electricity-by-country
[23] Abdolahinia, H., Heidarizadeh, M., & Rahmati, I. (2024). Assessing Iran and its neighbors for prospects and challenges: The case of the electrical sector. Renewable and Sustainable Energy Reviews, 193, 114190. https://doi.org/10.1016/j.rser.2023.114190

dynamics, these comparisons showcase a unique challenge faced by Armenia in managing its electricity pricing.

Future Risks

Amidst the backdrop of significant foreign control and geopolitical leverage exerted through energy dependencies, Armenia faces formidable challenges. However, concerted efforts are underway to mitigate these vulnerabilities and foster a more balanced energy sector. The USAID's Market Liberalization and Electricity Trade (MLET) program exemplifies such initiatives[24]. Implemented by Tetra Tech ES, Inc., this five-year program has completed tasks in energy supply diversification and facilitated cross-border trade. Key outcomes include introducing wholesale electricity market structures, such as day-ahead and real-time balancing markets, which, by 2023, enabled industrial customers, representing about 20% of demand, to transition to competitive procurement methods.

Further legislative reforms underscore Armenia's commitment to energy sector liberalization. The 2017 amendments to the Law on Energy have catalyzed substantial market transformations, including the breaking up of monopolistic control previously held by Electric Networks of Armenia (ENA) over distribution[25]. These changes enable consumers to purchase electricity from multiple suppliers, enhancing competition and consumer choice. Moreover, large wholesale consumers now have the option to procure electricity from external sources, marking a significant shift towards market liberalization initiated on February 1, 2022.

Armenia's strategic governmental actions are supported by comprehensive frameworks such as the 20-year Energy Sector Development Program adopted in January 2021[26]. This program aims to establish a transparent, diversified, and efficient energy system, preparing Armenia for future challenges and growth in electricity demand, which is projected to increase by up to three percent annually. The government's proactive stance is further evidenced by international collaborations, including the 2022 Memorandum of Understanding with the United States concerning civil nuclear cooperation and ongoing engagements with the European Union and Eurasian Economic Union to align energy policies and market mechanisms[27].

The initiatives and reforms discussed set the stage for the forthcoming recommendations on renewable energy transition, import diversification, and climate finance. These recommendations aim to further Armenia’s agenda of reducing dependency, enhancing energy security, and promoting economic resilience through

[24] Tetra Tech ES, Inc. (2022). Armenia Least Cost Energy Development Plan: 2024–2050. United States Agency for International Development Armenia Mission.
[25] Armenia—Energy. (2023, November 29). International Trade Administration. https://www.trade.gov/country-commercial-guides/armenia-energy
[26] Republic of Armenia Energy Sector Development Strategic Program to 2040. (2021). Asia Pacific Energy Portal.
[27] Armenia, U. S. M. (2022, May 3). The United States of America and the Republic of Armenia Sign a Memorandum of Understanding Concerning Strategic Civil Nuclear Cooperation. U.S. Embassy in Armenia. https://am.usembassy.gov/memorandum-of-understanding-2/

sustainable development practices. As the analysis transitions into actionable strategies, it is crucial to focus on integrating these systemic reforms into Armenia's broader energy policy framework, ensuring that the strides made toward liberalization and market competitiveness translate into tangible benefits for all stakeholders involved.

KEY CONSIDERATIONS

This section outlines key strategic recommendations for enhancing Armenia's energy security through two primary pathways: Import Diversification and Import Reduction, each encompassing specific measures like renewable development, electrification, and energy efficiency improvement. Given Armenia's heavy dependency on Russian energy imports and the geopolitical strains accompanying this reliance, these strategies aim to reduce vulnerability and foster a more resilient and autonomous energy landscape.

Import diversification seeks to mitigate risks associated with single-source dependency by potentially expanding partnerships with Iran and other regional players while challenging Russian dominance. Import reduction focuses on increasing the share of renewables in the energy mix, highlighting the cost-effectiveness and sustainability of solar, wind, and geothermal sources compared to traditional fossil fuels. Both pathways are framed within Armenia's broader commitment to decarbonize its economy by 2050, aligning with global environmental goals and enhancing national energy security through strategic, sustainable development practices. These recommendations set the stage for Armenia to transition towards a more diversified, efficient, and sustainable energy system, promoting economic resilience and reducing external dependencies.

Strategy	Key Challenge	Opportunity
Import Diversification	Armenia's landlocked geography and current energy infrastructure orientation towards Russia complicate diversification efforts, risking dependency on another dominant exporter.	Can enhance energy resilience by reducing reliance on Russian imports and mitigating supply disruptions and price volatility through partnerships with Iran and other countries.
Increasing Renewable Energy Share	Intermittency of renewables and advanced grid management needs, coupled with high capital costs and underdeveloped financial markets.	Substantial increase in renewable deployment can secure energy independence and is cost-effective compared to modernizing outdated fossil fuel infrastructures.
Solar Energy	High CAPEX for solar projects and logistical challenges in importing technology components.	Armenia's high solar irradiation levels make it an ideal candidate for solar projects, which can reduce reliance on imported gas and enhance local energy security.
Wind Energy	Limited and hard-to-access installation sites, higher installation costs, and logistical challenges due to Armenia's topography.	Potential for doubling existing capacity with new developments like the Gavar wind farm, enhancing Armenia's renewable energy portfolio.
Geothermal Energy	Some potential sites are not economically viable; high initial exploration and verification costs.	Development of identified feasible sites like Jermaghbyur could establish

		significant geothermal capacity, contributing to energy diversification.
Electrification	Current heavy reliance on fossil fuels in transport and heating; need for substantial policy support for transition.	Electrification can drastically cut carbon emissions and reduce energy costs, particularly through the adoption of EVs and heat pumps.
Energy Efficiency Improvement	Need to strengthen legislative frameworks and enforcement; requires initial investments and cultural shift towards energy efficiency.	Improving energy efficiency can reduce overall energy consumption, decrease environmental impact, and foster sustainable economic growth[28].

Import Diversification

Import diversification is a vital strategy for countries like Armenia that depend heavily on gas imports for heating. This approach aims to enhance the energy system's resilience by reducing reliance on a single source or a single country, particularly when geopolitical or economic instability can disrupt supply. Research on optimal decarbonization pathways, similar to studies conducted in the UK, indicates that diversification can significantly enhance energy system resilience without incurring prohibitive costs. These studies suggest achieving 50% to 100% import diversification could increase energy supply costs by only 3% to 9%, respectively. Diversification is particularly relevant for Armenia due to its heavy reliance on Russian gas, which poses risks of supply disruption and price volatility.

To effectively implement import diversification, Armenia should strategize a phased reduction of Gazprom's dominance in its gas infrastructure and decrease Russian ownership in its energy sector. However, there are significant challenges and limitations to import diversification for Armenia. The country's landlocked geography and closed borders complicate the logistics of diversifying imports. Moreover, the current orientation of Armenia's energy infrastructure towards Russia, where Russian entities own a large portion, makes significant diversification challenging and potentially costly. There is also the risk of replacing one dominant gas exporter with another, which could lead to similar vulnerabilities in the future. Thus, any moves towards diversification must be carefully balanced with Armenia's commitment to decarbonizing its economy by 2050, ensuring that investments in gas infrastructure do not conflict with sustainable energy goals.

Eventually, one route to diversification could be for Armenia to increase its utilization of the existing pipeline from Iran, which remains underutilized with a capacity of 1.1 billion m³ per year compared to the 365 million m³ currently imported. Enhancing this capacity could be further supported by establishing gas swap agreements with countries like Turkmenistan. Additionally, These steps could potentially position Armenia as a transit country for Iranian gas to Europe, an initiative in the making since 2004. This option, however, remains politically unviable in the medium term.

Import Reduction

[28] Energy Efficiency Finance: Task 1 – Energy Efficiency Potential, Country Report: Armenia. Vienna: Oesterreichische Entwicklungsbank (OeEB), 2013.

Increasing Renewable Energy Share in the Generation Mix

Renewable energy development is increasingly viewed as a strategic necessity for Armenia, which lacks indigenous fossil fuel resources and relies heavily on imports from Russia. The need for this transition is further underscored by the aging nature of Armenia's fossil fuel power infrastructure, which will require costly modernization or replacement by 2050. In this context, investing in renewable energy becomes more cost-effective than refurbishing old gas-based power plants, particularly if gas import prices remain unfavorable. However, renewable energy introduces challenges, including intermittency and the requirement for advanced grid management solutions. The Least Cost Energy Development Plan (LCEDP) for 2024–2050[29] highlights that the most economical path for Armenia involves a substantial increase in renewable energy deployment to ensure energy security and meet future demand under various scenarios.

According to research[30], an energy shortfall could result in significant economic and sectoral losses across critical areas of development. In the industrial sector, inconsistent electricity supply disrupts manufacturing operations, delays production timelines, and discourages both local expansion and foreign direct investment—particularly in energy-intensive industries. Small and medium-sized enterprises (SMEs), especially in rural areas, face increased operating costs due to reliance on backup diesel generators, reducing competitiveness and profit margins. In agriculture, unreliable power impacts irrigation systems, cold storage, and food processing facilities, leading to post-harvest losses and lower productivity. The education sector is similarly affected, as schools and universities experience interruptions in digital learning and classroom instruction due to outages, disproportionately harming students in remote regions. Healthcare services in under-electrified areas become vulnerable, with power disruptions threatening the operation of life-saving equipment and cold chains for medicines. The tourism industry also suffers as insufficient infrastructure undermines visitor experiences, especially in eco-tourism and winter resort regions. These sectoral disruptions can translate into hundreds of millions of dollars in lost GDP annually, widening inequality and slowing Armenia's long-term economic development.

According to the LCEDP's baseline scenario, even if gas prices follow EU trends, Armenia is projected to increase its renewable share from the current 7% to only 14% by 2050. Under this scenario, to adequately meet its energy needs and maintain reliability, Armenia would need to invest approximately $68 billion. However, a more cost-effective strategy outlined by the LCEDP suggests a $13 billion investment focusing on substantially enhancing renewable and storage technologies. This includes installing an additional 2,630 MW of solar PV, 375 MW of wind power, 439 MW of small hydropower plants (HPPs), and 141 MW of large HPPs, such as Loriberd and Shnokh, by 2050 (see **Table 1**). This strategy also proposes the construction of a new 600 MW nuclear power

[29] Tetra Tech ES, Inc. (2022). *Armenia Least Cost Energy Development Plan: 2024–2050*. United States Agency for International Development Armenia Mission.
[30] *Ou, Peng, Ruting Huang, and Xin Yao. "Economic Impacts of Power Shortage."* Sustainability *8, no. 7 (2016).*

plant by 2033 as a part of the least-cost solution. The LCEDP further proposes advancing the construction of geothermal, hydro, and additional wind and solar capacities to reduce costs. For example, developing a 25-MW geothermal plant starting in 2033 and pushing the construction of both Loriberd and Shnokh HPPs to 2023 (originally planned for 2045) is part of this cost-effective approach. Delaying the new nuclear power plant to 2045 and adding 210 MW more solar PV than initially planned by 2050 are also recommended. These initiatives align with Armenia's goal to ensure sustainable energy while achieving energy sufficiency and meeting its Nationally Determined Contributions (NDCs).

However, developing these renewable resources and lowering the levelized cost of electricity (LCOE) will require addressing high capital costs driven by Armenia's country risk and underdeveloped financial markets. Enhancing National Sustainable Finance and Green Taxonomy frameworks could facilitate this by promoting Environmental, Social, and Governance (ESG) investment practices among local businesses and financial institutions. The government could support these initiatives through technical assistance, capacity building, and subsidizing capital costs for green investments. Establishing carbon financing mechanisms and engaging with international financial bodies could also attract necessary climate finance and lower-cost funds for renewable projects in Armenia. Based on the World Bank's targeted analysis, several potential energy financing mechanisms exist for the clean energy transition in Armenia (**Table 2**). Particularly, Armenia has a growing track record in public-private partnerships (PPPs)[31], with increasing reliance on private capital for large-scale solar projects such as Masrik-1 solar PV plant. Also, the government's 2019 Law on Public-Private Partnerships (PPP) provides a clear legal framework for mechanisms like PPAs and Government Support Agreements that have already been implemented for several renewable projects. However, some issues in this area remain, including the absence of a project development facility and overreliance on unsolicited proposals, which have slowed PPP development[32].

According to World Bank experts, to enhance public-private engagement, a centralized project preparation fund needs to be established that will roll out standardized PPP templates and build institutional capacity across the PPP lifecycle. These measures would lower transaction costs, enhance predictability for private investors, and facilitate the development of a robust PPP pipeline aligned with the country's generation and transmission planning needs. Furthermore, well-governed SOEs like HVEN and YTPC could leverage corporate financing through improved governance, tariff predictability, and credit ratings—thereby reducing reliance on sovereign guarantees while attracting long-term private investment[33]. Additionally, the government could consider offering import subsidies and customs duty exemptions to address the capital expenditure (CAPEX) challenges, particularly those related to high import costs of renewable technology components due to complex logistics. These measures would support the cost-effective

[31] Most PPP projects in Armenia so far have been financed by multilateral institutions—such as the IFC, EBRD, and ADB—as well as by bilateral development agencies, including Germany's DEG and the Netherlands' FMO.

[32] World Bank Group. (2021). Maximizing Finance for Development in the Power Sector – Armenia: MFD Country Diagnostics.

[33] (ibid)

development of renewable energy projects, ensuring that Armenia effectively progresses towards its energy independence and sustainability goals.

Finally, while promising to reduce reliance on imported gas, the shift towards renewables is associated with increased energy supply costs[34]. Initial estimates suggest that substituting 50% of fuel imports with renewables could lead to a 34% rise in energy costs, assuming stable technology costs. With expected reductions in renewable technology costs, this could decrease to a 30% increase. Moreover, with substantial subsidies for technologies like heat pumps, these costs could be further reduced to as low as 15%[35]. Thus, transitioning to renewable energy will necessitate significant governmental support through subsidies or other policy mechanisms initially.

Solar Energy

Armenia boasts considerable solar energy potential, higher than the European average. The country receives an average annual solar irradiation of 1,720 kWh per square meter on a horizontal surface, with one-quarter of the territory enjoying even higher levels of 1,850 kWh/m^2 per year[36]. This robust solar resource base supports large-scale solar installations, such as the Masrik-1[37] and Ayg-1[38] photovoltaic (PV) plants, and distributed energy solutions, including residential solar systems that enhance local energy affordability and security. The declining cost and improving efficiency of battery storage technologies make renewable-plus-storage solutions increasingly viable. These systems are essential for managing peak loads and providing continuous, base-load power, critical for reducing reliance on thermal power plants and enhancing energy security with diversified, sustainable sources.

Costs for generating electricity from various sources show a wide range due to differing technologies, project scales, and economic conditions[39]. The Levelized Cost of Electricity (LCOE)[40] for utility-scale PV power plants can range from $14 to $157 per MWh. In contrast, concentrated solar power costs range from $79 to $222 per MWh. Wind, both onshore and offshore, geothermal, hydropower, coal, nuclear, and biomass power generation exhibit their respective costs, influenced by both inherent factors like technology costs and policy-dependent factors such as capital expenditure (CAPEX) and

[34] Mersch, M., Caton, P., Markides, C. N., & Mac Dowell, N. (2024). Energy import security in optimal decarbonization pathways for the UK energy system. Cell Reports Sustainability, 1(10), 100236. https://doi.org/10.1016/j.crsus.2024.100236
[35] ibid
[36] *Armenia Energy Profile*. (2023). International Energy Agency.
[37] The construction started in 2023
[38] The project was approved in 2024 but the construction hasn't started yet
[39] Timilsina, Govinda R. (2020). "Demystifying the Costs of Electricity Generation Technologies". World Bank Policy Research Working Paper, WPS 9303. World Bank Washington, DC.
[40] This is the average cost to generate one unit of electricity (measured in megawatt-hours, or MWh) over the lifetime of a power plant, including the cost to build, operate, and finance it.

discount rate (equivalent to the cost of capital in the market)[41,42]. In Armenia, two recent solar projects—Ayg-1[43] and Masrik-1[44]—have construction costs (CAPEX) of about $908 and $994 per kilowatt (kW). These projects were mostly funded through a mix of investor money (equity), long-term loans, and project-specific financing where lenders get repaid from the project's profits. Only a small part of the funding came from low-interest loans or grants. Assuming the plants run at 22% of their full capacity, have a 25-year lifespan, and use a 5% discount rate[45,46], the average cost to generate electricity from these Armenian solar plants is between $28.2 and $35.1 per MWh[47,48,49]. That's very affordable—cheaper than the global average of $44 per MWh[50], and even within the typical U.S. range of $27 to $50 per MWh[51].

Given the competitive costs of solar power in Armenia, which are more favorable than those for any fossil fuel-based power generation in the country, there is a compelling case for accelerating the pace of electricity market liberalization. This would allow solar power plants to compete more directly with fossil fuel plants, likely attracting further investment into solar energy and increasing its share in Armenia's energy mix. Given solar technology's declining price trend and potential gas price increases[52], it is advisable for Armenia to set more ambitious goals for solar energy development than those currently in place by the government. The promising outlook for solar energy in Armenia, highlighted by its competitive LCOE and the potential for further reductions through government policy interventions, positions solar energy as a key component in Armenia's strategy for a secure and sustainable energy future.

Wind Energy

[41] Capital expenditure (CAPEX) is the cost to build the plant, and the discount rate is how expensive it is to borrow money for the project.
[42] For a business project, weighted average cost of capital (WACC) depends on the proportion of different sources of financing (debt, equity, grants, transfers, etc.) and their corresponding costs (paid interest rate, dividends that investors require to invest, etc.)
[43] *Ayg-1 Solar Power Plant*. (n.d.). Retrieved February 7, 2025, from https://www.ebrd.com/work-with-us/projects/psd/53283.html
[44] *Masrik-1 Solar Power Plant*. (n.d.). Retrieved February 7, 2025, from https://www.ebrd.com/work-with-us/projects/psd/masrik1-solar-power-plant.html
[45] Given that an average credit market interest rate in Armenia is 12% but most of the funding for solar projects comes from equity and EBRD loans which is typically essentially cheaper than local market loans, as well as taking into account concessional loans and grants 5% discount rate is a reasonable assumption.
[46] *Armenia Mortgage credit interest rate, percent, December, 2024—Data, chart*. (n.d.). TheGlobalEconomy.Com. Retrieved February 7, 2025, from https://www.theglobaleconomy.com/Armenia/mortgage_interest_rate/
[47] *Private Sector Utility-Scale Solar Power Support Project*. (2018, March 8). The World Bank.
[48] *Solar Power Offers Armenia Greater Energy Security*. (n.d.). [Text/HTML]. IFC. Retrieved February 7, 2025, from https://www.ifc.org/en/stories/2020/masrik-solar-armenia
[49] Given the electricity price bids provided for Masrik-1 and Ayg-1 PV plants, $41/MWh and $29/MWh, we can assume that these estimates are very close to the actual LCOE.
[50] *Global average solar LCOE stood at $0.044/kWh in 2023, says IRENA*. (2024, September 27). Pv Magazine International. https://www.pv-magazine.com/2024/09/27/global-average-solar-lcoe-stood-at-0-044-kwh-in-2023-says-irena/
[51] Lazard's Levelized Cost of Energy Analysis—Version 17.0
[52] Currently, Russia sells natural gas to Armenia at $165/1000 m3, which is one of the lowest export prices set by Moscow. Before Russia's gas export to Europe stopped, Romania was paying €510/1000 m3, while other EU members were paying even higher prices until 2025. Gas price for Georgia is $235/1000 m3. Given this, as well as the loss of the EU market by Russia due to the war in Ukraine, deteriorating Russia-Armenia relations and Armenia's movement toward the EU and US, the prices are expected to increase.

Upon completion, the proposed 4 MW wind farm in Gavar is expected to double Armenia's existing wind energy capacity and is projected to produce 10 GWh of electricity annually.

The cessation of operations at a key wind farm due to territorial conflicts and delays in the Gavar wind farm's construction underscores the challenges faced. Armenia's actual use of wind energy is minimal, with only a small number of operational wind farms and a modest amount of new construction underway[53]. Yet these areas are limited and hard to access and are mainly located in mountainous regions at elevations above 2000 meters, which escalates the costs of turbine transport and installation, as well as reduces generation potential due to low air density[54]. According to estimates from the Ministry of Energy Infrastructures and Natural Resources of the Republic of Armenia, the wind potential is economically feasible at 450 MW capacity[55], while some independent experts estimate it to be equal to 300 MW at present costs[56]. The most feasible sites for wind farms fall within the good to excellent range regarding wind power potential[57].

The higher installation costs in Armenia, approximately 20% more than in Europe, are mainly attributed to the remoteness of sites, lack of construction expertise, inadequate infrastructure, and reduced generation potential due to high elevation and low air density[58]. The Konrad Adenauer Foundation's study points out the logistical challenges in Armenia due to its topographical features, which hinder the transportation of large wind turbines, typically ranging from 1.5 to 3 MW, and blades extending up to 52 meters in length. To circumvent these obstacles, an initiative has been initiated to start local production of smaller-scale turbines within the country[59].

Geothermal Energy

[53] Nazaretyan, H. (2023, April 20). Renewable Energy: Armenia's Opportunities and Limits. *EVN Report*. https://evnreport.com/raw-unfiltered/renewable-energy-armenias-opportunities-and-limits/
[54] Market Liberalization and Electricity Trade Program, Yerevan, Armenia, December 2022: Final Draft of Armenia Least Cost Energy Development Plan: 2024 – 2050; url: https://pdf.usaid.gov/pdf_docs/PA0211F2.pdf
[55] *Wind Energy—Power system—Www.minenergy.am*. (n.d.). Retrieved February 7, 2025, from http://www.minenergy.am/en/page/545#%3A~%3Atext%3DWind%20Energy%20Program%20in%20Armenia%26text%3DAccording%20to%20it%2C%20economically%20reasonable%2Cof%201.26%20billion%20kWh%2Fy
[56] Armenia Renewable Resources and Energy Efficiency Fund; Tamara Babayan - Report: Renewable Energy Potential in Armenia; url: https://unece.org/DAM/hlm/prgm/hmm/sustainable_housing/armenia/presentations/day_1/session3_3_EE_Tamara_Babayan.pdf
[57] Armenia Renewable Resources and Energy Efficiency Fund; Tamara Babayan - Report: Renewable Energy Potential in Armenia; url: https://unece.org/DAM/hlm/prgm/hmm/sustainable_housing/armenia/presentations/day_1/session3_3_EE_Tamara_Babayan.pdf
[58] *Wind Energy—Power system—Www.minenergy.am*. (n.d.). Retrieved February 7, 2025, from http://www.minenergy.am/en/page/545#%3A~%3Atext%3DWind%20Energy%20Program%20in%20Armenia%26text%3DAccording%20to%20it%2C%20economically%20reasonable%2Cof%201.26%20billion%20kWh%2Fy
[59] Vahe Davtyan, Konrad Adenauer Stiftung (2021): ARMENIA'S PRECARIOUS BALANCE: THE EUROPEAN UNION (EU) AND THE EURASIAN ECONOMIC UNION (EAEU); url: https://www.jstor.org/stable/pdf/resrep30729.6.pdf

Geothermal energy has an estimated potential of approximately 150 MW[60]. While some of this potential still needs to be examined regarding economic feasibility, some sites have undergone technical and economic explorations in the past and proved to be economically unfeasible. For instance, the feasibility study of the Karkar site by the World Bank indicated that the geothermal resources at Karkar are not economically viable for power generation[61]. On the other hand, investigations have pinpointed locations for potential geothermal power plants based on geological and geophysical studies[62]. At the Jermaghbyur site, it was discovered that high-pressure hot water (20-25 atmospheres, reaching temperatures of up to 250°C) exists between depths of 2,500 and 3,000 meters. Should further verification uphold these findings, it could lead to the development of Armenia's first 25-MW geothermal power plant.

Electrification

Parallel to renewable integration, Armenia should boost the energy sector's electrification to substitute its fuel import with renewable sources. The main two areas heavily dependent on fuels are transport and heating. Although the share of EVs in the transport sector is growing, Armenia still predominantly uses gasoline and natural gas for transportation, with the share of the latest reaching 80%[63]. Hence, there is a significant need for policy support to facilitate the transition towards EVs in the transport sector, reducing dependence on gas imports. Our analysis of the suggested policy[64] provides several options that can be efficiently adapted to Armenia's specific context. Recommended policies include fiscal incentives like purchase subsidies and tax rebates to reduce the cost gap between EVs and conventional vehicles and enhanced charging infrastructure through government support and building code updates. Additionally, implementing stringent emissions and fuel economy standards, preferential access, and low-emission zones can further boost EV adoption.

For the heating sector, which predominantly uses natural gas, transitioning to efficient and renewable technologies like heat pumps is becoming viable. Policies to support this transition should include substantial subsidies for heat pump installation, public awareness campaigns to educate on the benefits, and enhanced building codes to require energy-efficient technologies in new constructions. Financial incentives such as tax credits, rebates, and low-interest loans could help offset the upfront costs of adopting new heating technologies.

The benefits of electrification are manifold, including significant reductions in carbon emissions as Armenia shifts away from fossil fuels in favor of renewable sources. Heat pumps offer much higher energy efficiency than traditional heating systems and

[60] Nazaretyan, H. (2023, April 20). Renewable Energy: Armenia's Opportunities and Limits. EVN Report. https://evnreport.com/raw-unfiltered/renewable-energy-armenias-opportunities-and-limits/
[61] https://www.cif.org/sites/cif_enc/files/2022-09/SREP_Update_IP_Armenia_06.12.2019.pdf
[62] *Armenia Energy Profile*. (2023). International Energy Agency.
[63] Armenia Energy Profile. (2023). International Energy Agency.
[64] Policies to promote electric vehicle deployment – Global EV Outlook 2021 – Analysis. (n.d.). IEA. Retrieved February 7, 2025, from https://www.iea.org/reports/global-ev-outlook-2021/policies-to-promote-electric-vehicle-deployment

could reduce overall energy consumption and costs[65]. The transition also promises enhanced energy security by reducing dependence on imported fuels and fostering economic growth through job creation in new technology sectors, including EVs and heat pump systems. Additionally, improved air quality from reduced fossil fuel combustion could improve public health outcomes[66]. Armenia can position itself as a leader in the region's renewable heating and transportation technologies by aligning with global energy efficiency movements.

Energy Efficiency Improvements

Energy efficiency (EE) is critical for decreasing dependence on imported energy, reducing environmental impacts, and fostering sustainable economic growth[67].

Armenia's energy use is currently inefficient in several key sectors, with substantial potential for cost savings and improved energy security through conservation and efficiency measures, particularly in buildings and industry. The country's energy intensity—energy use per unit of GDP—is below international standards. Armenia's industrial sector is one of the least energy-efficient in the region, and the absence of strong energy efficiency obligations for public buildings or incentives for private sector retrofits, poor data collection, and limited professional capacity to conduct audits compounds the issue[68,69]. Buildings account for nearly 40% of Armenia's total energy demand, and most structures—especially those built before 1990—are not compliant with modern energy efficiency standards. Low-income households can spend up to 50% of their income on heating and cooking, largely due to inefficient gas-based systems[70]. The government has acknowledged these challenges and has included improved efficiency as a pillar of its 2021 Energy Sector Development Strategy. However, implementation has been slow due to fragmented governance, limited funding, and lack of enforcement capacity[71].

One of the potential solutions with high feasibility is conducting conservation programs, which demonstrate high success in their pilot stages, particularly for Yerevan's public buildings heating retrofitting project. For instance, energy efficiency retrofits in kindergartens resulted in savings of 1.2 GWh per year, with broader plans to retrofit over 140 public buildings supported by blended financing from the EIB, GCF, and other donors [72]. Additionally, deploying energy-saving technologies like heat pumps—up to five times more efficient than gas boilers—has significant potential to lower household energy bills

[65] Mersch, M., Caton, P., Markides, C. N., & Mac Dowell, N. (2024). Energy import security in optimal decarbonization pathways for the UK energy system. Cell Reports Sustainability, 1(10), 100236.
[66] Aldy, J., M. Kotchen, M. Evans, M. Fowlie, A. Levinson, & K. Palmer. CO-BENEFITS AND REGULATORY IMPACT ANALYSIS: THEORY AND EVIDENCE FROM FEDERAL AIR QUALITY REGULATIONS (No.w27603) NATIONAL BUREAU OF ECONOMIC RESEARCH
[67] USAID. (2022). *Armenia Energy Efficiency*
[68] World Bank. Charged Decisions: Difficult Choices in Armenia's Energy Sector. October 2011.
[69] International Energy Agency (IEA). Armenia 2022 Energy Policy Review. Paris: IEA, 2022. [ISBN: 978-92-64-32810-7]
[70] EU4Energy. Home Heating Technology Guide: Armenia. European Union, 2023.
[71] World Bank. Charged Decisions: Difficult Choices in Armenia's Energy Sector. October 2011.
[72] Third Biennial Update Report (BUR3) of Armenia to the UNFCCC from 2021

and emissions[73]. However, scaling these efforts will require better governance, streamlined financing mechanisms, and stronger incentives for adoption in both residential and industrial sectors.

Armenia should strengthen legislative and regulatory frameworks to enhance EE across various sectors effectively, align with international standards, and ensure rigorous enforcement. This approach will facilitate the incorporation of stringent energy efficiency measures, particularly in new constructions and major renovations within the building sector, and encourage compliance through energy audits and performance certifications. Additionally, the public sector can play a pivotal role by setting an example in energy efficiency, adhering to higher standards in public buildings, and procuring only high-efficiency products and services. Developing and expanding financial mechanisms and incentives are essential to support these regulatory measures. This could include establishing a national energy efficiency fund, providing subsidies or tax rebates for energy-efficient technologies, and stimulating private investment in energy efficiency projects. Increasing awareness and capacity among all stakeholders is crucial to building a culture that supports energy efficiency. This can be achieved through targeted training programs, public awareness campaigns, and educational initiatives emphasizing the benefits and practicalities of adopting energy-efficient practices and technologies. Furthermore, fostering innovation and adopting advanced technologies will be key in upgrading the energy sector's infrastructure, integrating smart energy systems, and deploying renewable energy solutions that improve overall energy performance.

Finally, fostering partnerships between the government, private sector, and international bodies can leverage additional expertise, funding, and innovative technologies necessary for impactful energy efficiency projects. This collaborative effort is vital for scaling up energy efficiency solutions and ensuring they are integrated across different sectors of the economy, thus supporting Armenia's broader goals for reducing energy costs, enhancing environmental sustainability, and bolstering energy security

[73] EU4Energy. Home Heating Technology Guide: Armenia. European Union, 2023.

RECOMMENDATIONS

To assist Armenia in navigating its energy trilemma—balancing affordability, sustainability, and security—the U.S. government has a unique opportunity to provide critical support and strategic partnership. Armenia's democratic orientation and geopolitical vulnerability make it a natural ally for advancing regional stability, reducing Russian influence, and promoting resilient, sustainable development. The following recommendations outline how the U.S. can play a constructive and catalytic role in Armenia's energy transformation:

- **Support Armenia's Diversification of Energy Imports.** The U.S. can aid Armenia in reducing its dependence on Russian energy by facilitating diplomatic and technical support for alternative regional energy partnerships. Specifically, the U.S. should back Armenia-Iran and Armenia-Turkmenistan energy swap arrangements through regional diplomacy and sanctions waivers where applicable; provide expertise in optimizing underutilized gas infrastructure, including the Iran-Armenia gas pipeline, and encourage trilateral cooperation between Armenia, Georgia, and European partners to establish a reliable and transparent energy corridor.

- **Promote Large-Scale Renewable Energy Development.** The U.S. can lead efforts to scale Armenia's renewable energy capacity by offering development finance and credit guarantees for large-scale solar and wind projects, such as Masrik-1 and Ayg-1; encouraging U.S.-Armenian public-private partnerships (PPPs) in clean energy technology and grid modernization, and suupporting feasibility studies and regulatory alignment with international renewable energy standards.

- **Advance Electrification and Energy Efficiency.** The U.S. should assist Armenia in transitioning its residential heating and transportation sectors to electricity through technical assistance to upgrade grid infrastructure and enable distributed energy systems; support for pilot programs and urban planning models focused on electric heating, vehicle electrification, and smart metering; and collaboration with Armenian municipalities to enhance building energy codes and deploy low-emission heating alternatives.

- **Facilitate Access to Climate Finance.** The U.S. can play a pivotal role in helping Armenia unlock global green funding sources by supporting Armenia's integration into U.S.-backed climate initiatives such as USAID's Clean EDGE Asia and the Just Energy Transition Partnership framework; assisting Armenian agencies in developing transparent project pipelines eligible for funding from institutions like the Green Climate Fund (GCF), Global Environment Facility (GEF), and the World Bank; and leveraging U.S. leadership in multilateral banks to prioritize Armenia's access to concessional financing and technical grants.

- **Foster Regulatory and Institutional Reform.** The U.S. can provide Armenia with policy guidance and capacity-building support to ensure sound energy governance through technical exchange programs with U.S. energy regulators and independent system operators; support for anti-corruption safeguards and competitive bidding frameworks in Armenia's energy sector; and assistance in establishing an independent energy regulator and building local capacity for long-term planning and risk management.

By supporting Armenia's energy transformation, the U.S. strengthens a frontline democracy, undermines Russian energy leverage, and unlocks regional opportunities for clean energy leadership. American engagement will help ensure Armenia's long-term resilience and promote stability in the South Caucasus while aligning with U.S. interests in democracy promotion, climate action, and regional integration.

CONCLUSION

In conclusion, the challenges identified— ranging from logistical and infrastructural issues to the need for substantial financial and policy support— highlight the complexity of Armenia's energy transition. However, the strategic approaches recommended herein provide a roadmap to guide policy decisions, attract investment, and foster international cooperation. As Armenia stands at a crossroads in its energy strategy, the choices made today will determine its future energy landscape. By embracing these recommendations, Armenia can foster a robust, diversified, and sustainable energy system that supports economic growth, enhances energy security, and meets the environmental benchmarks outlined in its national and international commitments. This strategic shift requires concerted efforts from all stakeholders, including government bodies, private sector participants, and international partners, to ensure a cohesive and effective implementation of these transformative initiatives.

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ABOUT THE INSTITUTE

The Aram Manoukian Institute for Strategic Planning has been formed to work with experts in various fields to develop plans for the future of the Armenian nation in Armenia, Artsakh, and the Diaspora. The overarching vision of the Institute is to work towards the creation of a prosperous and just society in Armenia, Artsakh, and the Armenian diaspora, where the rights and dignity of all individuals are respected and where peace, democracy, and sustainable development are achieved.

The Institute will identify appropriate target audiences, including government officials, civil society organizations, academia, businesses, and the public, to ensure its work reaches various stakeholders. It will also build a diverse team with expertise from various fields, including academics, practitioners, individuals from the Armenian diaspora, and youth, to provide a holistic perspective in addressing the nation's challenges. Additionally, it underscores the significance of developing partnerships and collaborations with government agencies, NGOs, research institutions, businesses, international organizations, and diaspora organizations to leverage resources and knowledge effectively. The Institute's agenda will focus on pressing issues such as national security, economic development, education, good governance, health care, diaspora engagement, and environmental sustainability. By addressing these challenges through research-based insights and policy recommendations, the Institute will contribute toward the betterment of the Armenian nation.

ABOUT THE INSTITUTE'S NAMESAKE

Aram Manoukian, born in 1879, was a prominent Armenian revolutionary who played a pivotal role in the formation of the First Armenian Republic in 1918. His educational journey began in local Armenian schools, followed by studies at the St. Petersburg Polytechnic Institute in Russia.

While still a student in St. Petersburg, Manoukian became deeply involved in the Armenian national liberation movement. In 1902, he formally joined the Armenian Revolutionary Federation (ARF) and actively participated in various ARF activities, including armed struggles against oppressive regimes in the Caucasus and the Middle East, notably the Ottoman Empire. He successfully led the self-defense of Van, saving the lives of tens of thousands of Armenian civilians from deportation massacre by the Turkish government.

In 1917, after the Russian Revolution, Manoukian returned to Armenia and assumed a central role in establishing the First Armenian Republic in 1918. He served as the commander-in-chief of Armenian forces during intense battles against Ottoman forces in the Caucasus, ultimately securing Armenia's independence.

Beyond his military leadership, Manoukian's contributions extended to politics and economics in the nascent republic. As the prime minister, he championed social justice,

equality, and progressive policies, focusing on land reform, education, and other measures to improve the lives of ordinary Armenians.

Today, Aram Manoukian's legacy endures, serving as a timeless source of inspiration for Armenians, commemorating his unwavering dedication to his nation and his role as a patriotic statesman.

APPENDIX

Table 1. Armenia's Energy Use, Generation, Imports, and Needs (2023–2050)[74]

Category	Description
Total Electricity Generation (2024)	9,381.4 million kWh (↑6.5% from 2023) - Thermal: 3,516.4 million kWh (↓5.4%) – 37.5% share - Nuclear: 2,830 million kWh (↑4.5%) – 30.2% share - Hydro: 1,868.4 million kWh (↑25.1%) – 21.9% share - Solar: 974.6 million kWh (↑32.9%) – 10.4% share - Wind: 1.2 million kWh (↓47.4%) – 0.02% share
Electricity Demand (2022)	~6.7 TWh (industry: 27%, households: 32%, services: 37%)
Installed Power Capacity (2023)	~4,089 MW - Available capacity: ~3,155 MW - Peak demand: ~1,300 MW
Primary Energy Mix (2022)	- Natural Gas: 60.6%, Nuclear: 18.5%, Oil: 14.9%, Renewables: 9%
Electricity Trade (2023)	- Net exporter (mainly to Iran: ~1.1 TWh/year via 3kWh:1m³ gas barter deal)
Fuel Imports	- 100% of natural gas, oil, and uranium imported (mostly from Russia; some gas from Iran) - 2023 gas imports: ~2.7 bcm (86% from Russia)
Final Energy Consumption (2022)	2,937 ktoe - Households: 34%, Transport: 30%, Industry: 14%, Services: 16% - By source: Natural gas (55%), Oil (20%), Electricity (20%), Biofuels (4%)
Projected Final Energy Consumption	Will increase by >50% by 2050 (under baseline scenario of current trends expansion) - Highest growth in industrial & commercial sectors - 24% of 2050 demand to be met by high-efficiency tech

[74] Tetra Tech ES, Inc. (2022). *Armenia Least Cost Energy Development Plan: 2024–2050*. United States Agency for International Development Armenia Mission.
National Statistical Committee of Armenia. (2025, February). *Electricity generation and trade: 2024 data*. As reported by Turan News.
Ministry of Territorial Administration and Infrastructure of the Republic of Armenia. (2021). *Energy Sector Development Strategic Program to 2040*. Government of Armenia.
Ministry of Environment of the Republic of Armenia. (2021). *Third Biennial Update Report under the United Nations Framework Convention on Climate Change (BUR3)*. UNDP Armenia.
Scientific Research Institute of Energy. (2023). *Energy Balance of the Republic of Armenia for 2022*. Yerevan: Ministry of Territorial Administration and Infrastructure.

Projected Electricity Demand (2050)	>15.6 TWh *(under baseline scenario of current trends expansion)*[1]
Planned Generation Additions (by 2050)	- Solar PV: 2,630 MW, Wind: 375 MW, Hydro: 580 MW, Storage: 130 MW, New NPP: 600 MW
Energy Independence Forecast	Drops to 12.9% after ANPP decommissioning (2027), recovers to ~38.3% by 2050[1]
Renewable Energy Plans	- 66% of power generation from renewables by 2036[1] - Solar: 1,000 MW target by 2030 - Wind: 500 MW by 2040 - Hydro (incl. SHPPs): ~1,425 MW by 2030

Table 2. Armenia Energy Sector Financing Mechanisms and Potential[75]

Category	Type	Mechanism/Approach	Examples/Details
Current Financing Mechanisms	Private Capital via Project Finance	Private equity and commercial debt supported by PPAs, GSAs, and risk mitigation instruments (e.g., MIGA guarantees)	Masrik-1 ($49.3M, FRV, IFC, EBRD), Yerevan CCGT-2 ($272M, Renco, Siemens, ADB/IFC)
Current Financing Mechanisms	Small Renewable Energy (RE) Financing	Loans from local banks using project assets as collateral, enabled by FiTs, stable offtaker (ENA), and regulatory clarity	USD/EUR loans at 6–9% interest, 4–5 year terms; small hydro/solar via commercial banks
Current Financing Mechanisms	Distribution Investment (ENA)	ENA raised $530M via commercial banks, parent company funding, and IFI private arms (IFC, EBRD)	Privatized distribution grid; ENA attracted $530M (2007–2020) in investment
Potential for Energy Financing	Project Finance for Large-Scale RE	Scaling PPPs with project preparation facilities, model contracts, and competitive tenders	Masrik-1 and Yerevan CCGT-2 as viable models; future projects need better prep pipeline
Potential for Energy Financing	Corporate Finance for SOEs	SOEs to raise commercial debt via improved governance, fixed ROA/O&M in tariffs, and credit ratings	Up to $400M in sovereign debt could be refinanced; frees ~$300M fiscal space
Potential for Energy Financing	Pension Funds	Enable long-term investment by pension funds through credit-enhancement and bankable project pipeline	Projected to reach $4.9B by 2030; alignment with infrastructure finance goals needed

[75] World Bank Group. (2021). Maximizing Finance for Development in the Power Sector – Armenia: MFD Country Diagnostics.

Potential for Energy Financing	Crowdfunding & Fintech	Enable legal and regulatory frameworks for crowdfunding platforms to support small RE/efficiency projects	Inspired by global examples like Mosaic, CitizenEnergy; reforms needed to permit activity
Potential for Energy Financing	Capital Markets	Develop capital markets through SOE bond issuance, project aggregation, and risk-sharing instruments (e.g., IBRD guarantees)	Corporate bonds currently issued mainly by banks; insurance/mutual funds still nascent

Table 3. Required Energy Infrastructure Finance in Armenia (2021–2035[76]

Investment Category	Description	Estimated Cost (USD million)	Timeline	Financing Model
Solar PV (1,050 MW)	Gradual commissioning to replace nuclear & meet growing demand	750	2021–2035	Private (IPP, Project Finance)
Wind (500 MW)	For energy security and supply diversification	750	By 2035	Private (IPP, Project Finance)
New Nuclear Power Plant (600 MW)	Replacement of ANPP post-decommissioning	3,500+	2030–2040 (est.)	TBD (Public/PPP)
ANPP Decommissioning	Safe decommissioning of Armenia's nuclear plant	200+	2027–2035	Public
Transmission Upgrades	387 km of lines, 3 supply transformers	70	2021–2025	Public
Substation Rehabilitation	4 key substations	60	2021–2025	Public
Regional Interconnection	Georgia-Romania power/digital corridor	100	2030–2040	TBD
Distribution Network (ENA)	Improving supply reliability, reducing losses	445	2021–2027	Private (ENA, commercial loans)

[76] World Bank Group. (2021). Maximizing Finance for Development in the Power Sector – Armenia: MFD Country Diagnostics.