ARMENIAN NATIONAL PLATFORM
EASTERN PARTNERSHIP CIVIL SOCIETY FORUM
Funded by the European Union
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Green ways to overcome the challenges of Armenia's energy system development through innovative technologies and in the context of CEPA

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YEREVAN 2024

ՀՏԴ 620.9
ԳՄԴ 31.1

Հեղինակ՝ Արտաշես Սարգսյան, ֆ.մ.գ.թ., Էկոթիմ ՀԿ-ի ղեկավար
«Հայաստանի էներգահամակարգի զարգացման մարտահրավերների հնարավոր հաղթահարման կանաչ ուղիները ինովացիոն տեխնոլոգիաների օգտագործմամբ և ՀԸԳՀ-ի (CEPA) համատեքստում», Երևան, 2024թ. -24էջ

ԱՄՓՈՓՈՒՄ

Սեփական կարիքները էլեկտրաէներգիայով ապահովելու տեսակետից Հայաստանը ինքնաբավ է, նույնիսկ դեպի Իրանի Իսլամական Հանրապետություն արտահանում է էլեկտրական էներգիա, սակայն էներգետիկ անվտանգության և բնակչությանը էլեկտրաէներգիան անդադար մատակարարելու առումով կան բազմաթիվ խնդիրներ, որոնք և քննարկվում են հետազոտության մեջ և նկարագրվում են դրանց հաղթահարելու համար հնարավոր հեռանկարային ուղիներ:

Հետազոտությունը նվիրված է ՀՀ էներգետիկ համակարգի զարգացման օրենսդրական և ծրագրային կարգավորումների, նրանց մեջ փոփոխությունների և լրացումների, ԵՄ-Հայաստան Համապարփակ ևւ ընդլայնված գործընկերության համաձայնագրի (ՀԸԳՀ) ազդեցությանը էներգետիկ համակարգի զարգացման վրա:

Դիտարկվում են ՀՀ վերականգնվող էներգիայի ներուժը, հնարավորությունները և հեռանկարները, Հայաստանի արևային ռեսուրսային քարտեզը և ֆոտովոլտային հզորության ներուժը (Սոլարգիս, ԷՍՄԱՊ):

Անդրադարձ է արվում շրջակա միջավայրի նկատմամբ Հայաստանի միջազգային պարտավորություններին և արտասահմանից «թեթև» վարկերի և դրամաշնորհների տեսքով ֆինանսական աջակցության ստանալու հնարավորություններին:

Բերվում են վերականգնվող էներգետիկ ռեսուրսների օգտագործմամբ արտադրված էլեկտրական էներգիայի մասնաբաժինները էլեկտրական էներգիայի ընդհանուր արտադրության ծավալում և ընդունված թիրախները մինչև 2030թ. և 2040թ.:

Դիտարկվում են հնարավոր նորարարական տեխնոլոգիաների դերը էներգետիկ համակարգում «էներգետիկ անցում» իրականացնելու տեսակետից:



Այս ուսումնասիրությունը պատրաստվել է Եվրամիության ֆինանսական աջակցությամբ: Դրա բովանդակության համար բացառապես պատասխանատու է հեղինակը (հեղինակները) և պարտադիր չէ, որ այն արտացոլի Եվրամիության տեսակետները:

ՀԵՏԱԶՈՏՈՒԹՅՈՒՆԸ ԿԱՏԱՐՎԵԼ Է ԱՐԵՎԵԼՅԱՆ ԳՈՐԾԸՆԿԵՐՈՒԹՅԱՆ ՔԱՂԱՔԱՑԻԱԿԱՆ ՀԱՍԱՐԱԿՈՒԹՅԱՆ ՖՈՐՈՒՄԻ ՀԱՅԱՍՏԱՆԻ ԱԶԳԱՅԻՆ ՊԼԱՏՖՈՐՄԻ ՔԱՐՏՈՒՂԱՐՈՒԹՅԱՆ ԵՆԹԱԴՐԱՄԱՇՆՈՐՀԱՅԻՆ ՀԵՏԱԶՈՏԱԿԱՆ ԾՐԱԳՐԵՐԻ ՇՐՋԱՆԱԿՆԵՐՈՒՄ

UDC 620.9
BBC 31.1

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"Green ways to overcome the challenges of Armenia's energy system development through innovative technologies and in the context of CEPA", Yerevan, 2024 - 23p.

SUMMARY

Armenia is self-sufficient in terms of meeting its own needs with electricity, and even exports electricity to the Islamic Republic of Iran, but there are numerous problems in terms of energy security and uninterrupted supply of electricity to the population, which are discussed in the study as well as possible prospective ways to overcome them.

The study is dedicated to the legislative and program regulations for the development of the RA energy system, amendments and supplements to them, the impact of the EU-Armenia Comprehensive and Enhanced Partnership Agreement (CEPA) on the development of the energy system.

The opportunities of RE in Armenia are considered, the solar resource map of Armenia and the potential of PV power (Solargis, ESMAP) are presented, that allow any interested party to conduct independent assessments of commercial viability of solar project at desired geographical place. This research is a continuation of the previous study devoted to the use of renewable energy sources and hydrogen.

Reference is made to Armenia's international obligations towards the environment and Paris Agreement and the opportunities for obtaining financial assistance in the form of soft loans and grants from abroad.

The shares of electricity generated using renewable energy resources in total electricity generation for 2024 are discussed as well as adopted targets by 2030 and 2040. During 11 months of 2024, 453452.5 thousand kWh electricity was produced at solar PV stations. Their share totals 5.9% of total useful electricity supply (total electricity production minus losses) and around 7.1% of domestic consumption. As it was mentioned in initial Energy strategy (2021), electicity production from solar stations should be 1.8 billion kWh or 15% of total consumption by 2030. So a lot of work should be done to reach this target.

The role of innovative technologies in the energy system from the perspective of implementing the "energy transition" is considered.

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of the author and do not necessarily reflect the views of the European Union.



This research was produced within subgrant research programs of the Eastern Partnership Civil Society Forum Armenian National Platform.

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LIST OF ABBREVIATIONS

EAP	Eastern Partnership (EaP)
ECA	EU-Armenia Comprehensive and Enhanced Partnership Agreement (CEPA)
SDG	United Nations Sustainable Development Goals
USAID	United States Agency for International Development (USAID)
EGD	European Green Deal
UNFCCC	United Nations Framework Convention on Climate Change
PA	Paris Agreement
NDC	Nationally Determined Contributions (NDC)
CET(C)	Caucasus Transmission Network project
CHP	Thermal Power Plant
ANPP	(Armenian) Nuclear Power Plant
HPP	Hydropower Plant
SHPP	Small Hydropower Plant
SHP	Wind Power Plant
RE	Renewable Energy Sources
EE	Energy Efficiency
HE	Electricity Networks of Armenia
CC	Combined Cycle (CC)
PSRC	Public Services Regulatory Commission
CCSU	Carbon Capture, Utilization And Storage
RA	Republic of Armenia
WB	World Bank (WB)
MJ	Megajoule (106J)
MW	Megawatt (106W)
PV	Photovoltaic
IRENA	International Renewable Energy Agency
NREL	National Renewable Energy Laboratory
Toe	The tonne of oil equivalent

Energy Unit Conversion
1 toe = 41.868 GJ = 11.63 MWh
1 GWh = 3.6 TJ = 86 toe

Currency exchange rates
1 USD = 395 AMD (as of December 2024)
1 Euro = 414 AMD (as of December 2024)

1. INTRODUCTION

Armenia is self-sufficient in terms of meeting its own electricity needs, even exporting electricity to the Islamic Republic of Iran, but there are numerous problems in terms of energy security and uninterrupted supply of electricity to the population, which are discussed in the study and possible prospective ways to overcome them are described. In 2023, 8455.2 million kWh of electricity was produced in Armenia, which is 5.3% less than the volume of electricity produced in 2022, which was 8907.9 million kWh, with 44% of electricity produced in natural gas-fired thermal power plants, 32% in nuclear power plants, 24% in large and small hydroelectric power plants and from other renewable sources [PSRC reports, 1].

In 2024, serious problems with energy supply emerged on such a scale that in October of that year, parliamentary hearings were even organized, followed by the dismissals of the heads of the energy system management and regulation sectors (PSRC of the Republic of Armenia, RA State Electricity Regulatory Commission).

The reliability of electricity supply in the republic, including for the population, is under question, which has been manifested in the following way:

- Frequent power outages,
- An outdated energy system, especially in the power grid sector,
- The outflow and shortage of qualified personnel,
- High dependence on imported natural gas and liquid fuels,
- The practical absence of proven reserves of domestic fossil fuels,
- Tariff policy shortcomings,
- Sharp changes in energy strategy in recent years,
- Threats to supply caused by the Russia-Ukraine war,
- Inadequate information provided to the population about the duration of power outages,
- Ownership of power generation plants and distribution networks by foreign companies, etc.

Figure 1 shows the distribution of useful electricity delivery in Armenia in January-November 2024 by type of plant. During the 11 months, a total of 7999.5 million kWh of electricity was produced. 1423.7 million kWh of electricity was exported to Iran (1351.05 million kWh) and Georgia (72.7 million kWh), and 144.3 million kWh of electricity was imported from Georgia. The positive balance of electricity export and import is 1279.40 million kWh. kWh (Source: RA TKEN, [3]): Electricity production from PV plants amounted to 453452.5 thousand kWh, and the share in the

production volume (useful delivery) is 5.9% (see Figure 1), and in the consumption volume it is estimated at about 7.1%.

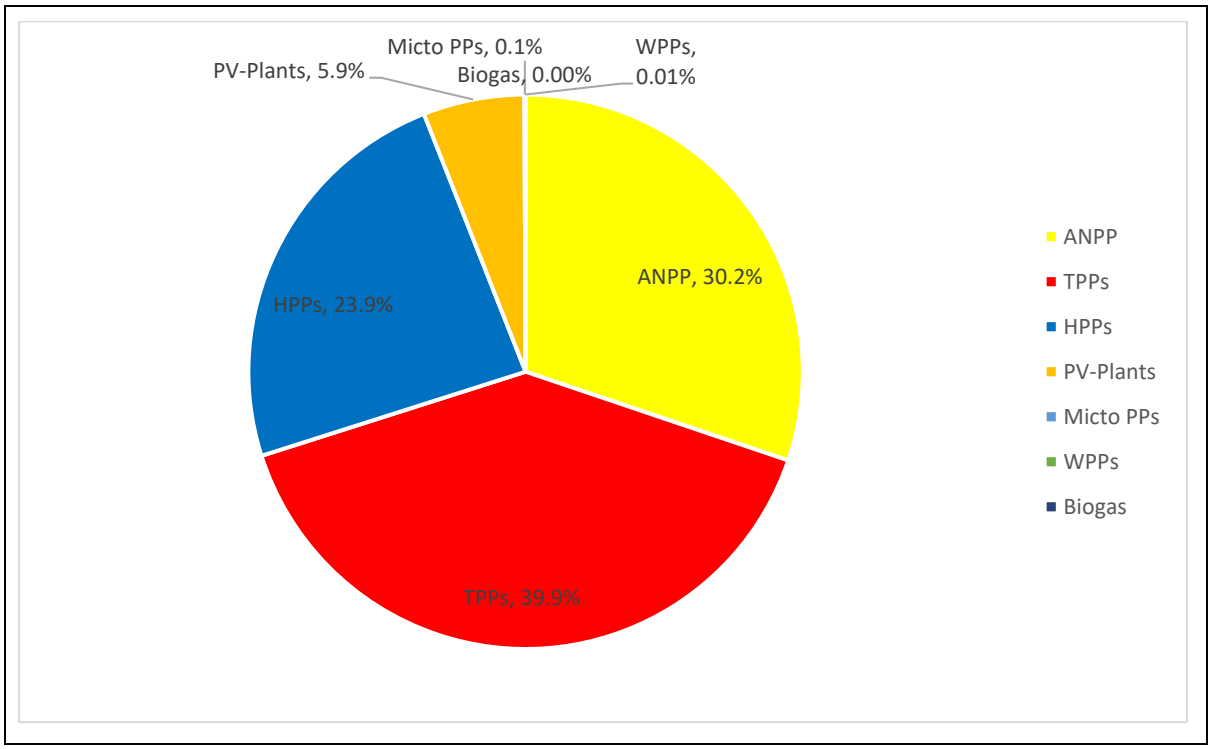


Figure 1. The shares of useful electricity deliveries in Armenia in January-November 2024 by type of plant (only powerplants without autonomous pv producers).

These data and the figure do not include the share of autonomous PV producers in terms of electricity flows. Together with them, the share of useful electricity converted and delivered from solar energy in the total for the first nine months of 2024 will be 9.6%, and in terms of domestic consumption - about 12.3%. Detailed data on annual electricity production will become available in early 2025, after which the shares will be adjusted and will be probably decreased, also taking into account the natural decrease in solar energy flows in the last quarter of the year. It is expected that the Masrik-1 PV plant of about 55 MW capacity will be commissioned by the end of 2024. The future of AYG-1 and AYG-2 is not so deefinite.

Armenia cooperates with the EU under the Comprehensive and Enhanced Partnership Agreement (CEPA), including the approximation of its laws to EU legislation. It is worth noting that in 2021 the EU adopted its first Climate Law[9]. It set out Europe's goals to become climate neutral by 2050, i.e. with net-zero greenhouse gas emissions (in line with the European Green Deal [9] adopted in 2020), and to reduce emissions by 55% by 2030 compared to 1990. As required by the Climate Law, the EU Commission also proposed an additional interim target of 90% by 2040 in February 2024, endorsing the roadmap.

CEPA includes substantial cooperation in the energy sector. This cooperation aims to increase energy security, diversify energy sources, develop competitive energy markets, promote the use of renewable energy and improve energy efficiency. To support this partnership, on 5 April 2024, the EU is proposing a €270 million Resilient Growth and Business Development Programme for Armenia for the period 2024-2027.

2. LEGISLATIVE, STRATEGIC AND PROGRAMMATIC REGULATIONS FOR THE DEVELOPMENT OF THE RA ENERGY

According to Armenia's Strategic Development Program for the Energy Sector (until 2040), approved by the government on January 14, 2021 (N 48-L), it is planned to increase the share of solar energy production in the total energy mix to at least 15% or 1.8 billion kWh by 2030. To achieve this goal, approximately 1000 MW of solar power plants will be built, including those for autonomous power generation, while simultaneously introducing market mechanisms to stimulate the construction of storage facilities. Between 2030 and 2040, an additional 500 MW of solar power plants will be built, combined with storage facilities as needed. It is also planned to build wind power plants with a total capacity of up to 500 MW between 2025 and 2040, bringing the total capacity of solar and wind power plants to at least 2000 MW by 2040. As a result, the share of electricity generated from renewable energy sources in the total final consumption of electricity will reach approximately 50% by 2030 (including large hydropower plants, added in 2023) and around 60% by 2040.

In essence, Armenia is committed to transitioning to a more sustainable energy future by significantly expanding its renewable energy capacity and diversifying its energy sources.

Following the amendments and additions made to the "Strategic Development Program for Armenia's Energy Sector (until 2040)" in 2023, the final sentence of the program was revised to include "including large hydropower plants" in the category of renewable energy sources. This means that large hydropower plants are now classified as renewable energy resources, which aligns with the EU's approach but contradicts Armenia's laws on renewable energy and energy efficiency.

The share of electricity generated from renewable energy sources in the total final consumption of electricity will reach approximately 50% by 2030, including large hydropower plants, and around 60% by 2040.

The amendments also note that: "Regarding the choice of a new nuclear power plant, small modular nuclear reactors will also be considered if economically feasible, which will provide a higher level of energy security and reduce the amount of reserve capacity in the system."

At the same time, the construction of the "Meghri" HPP (on the Araks River), "Shnog" HPP (on the Debed River), and "Lori-berd" HPP (on the Dzoraget River) will remain a state priority project and will be constructed when there is a need for such capacity in the power system."

In March 2022, the Armenian government approved the "Energy Efficiency and Renewable Energy Program for 2022-2030," simultaneously approving the first phase of the program for 2022-2024. The program was developed with technical assistance from the EU-funded EU for Climate Partnership.

The program aims to identify new opportunities to promote energy efficiency and renewable energy development, in line with Armenia's climate change agenda as outlined in the Paris Agreement, as well as to reduce the negative impact of human activities on the environment and human health.

The program sets out the priorities and development directions for the energy efficiency and renewable energy sectors in Armenia until 2030. As a result of the program's implementation, energy efficiency and energy performance indicators in the economy will improve, the production of electricity from renewable energy sources, particularly solar energy, will expand significantly, and the reliability of the energy system will increase.

In 2023, with the support of the US USAID, draft laws "On Electricity" (May 16, 2023) and "On Renewable Energy and Energy Efficiency" (May 31, 2023) were developed and submitted to the Armenian Ministry of High-Tech Industry, but have not yet been subject to public discussion.

3. EU-ARMENIA COMPREHENSIVE AND ENHANCED PARTNERSHIP AGREEMENT (CEPA) EXPECTED ASSISTANCE TO THE DEVELOPMENT OF THE ARMENIAN ENERGY SYSTEM

On November 24, 2017, Armenia signed the Comprehensive and Enhanced Partnership Agreement (CEPA) with the European Union and the European Atomic Energy Community and its member states. The main provisions of the agreement were provisionally applied from June 1, 2018.

The agreement was ratified by all EU member states and entered into force in full on March 1, 2021. In accordance with Article 363 of the agreement, an Armenia-EU Cooperation Committee was established (coordinated by the Ministry of Foreign Affairs of Armenia).

The CEPA Roadmap was approved on June 1, 2019, by the Prime Minister's decision N666-L. Energy issues in the CEPA are reflected in Chapter 2, Articles 42-44: ENERGY COOPERATION, INCLUDING NUCLEAR SAFETY. Chapter 3, Articles 45-50, discusses ENVIRONMENTAL issues, while Chapter 4, Articles 51-56, addresses Climate Action.

Energy cooperation should cover, inter alia, the following areas:

- Energy strategies and policies
- Energy security
- Development of competitive energy markets
- Promotion of renewable energy sources, energy efficiency, and energy saving
- Regional cooperation
- Promotion of a common regulatory framework
- Safety and security in nuclear safety
- The agreement also addresses the closure and safe decommissioning of the Metsamor Nuclear Power Plant and the need for a roadmap or action plan to replace it with new capacity.

At the 5th meeting of the EU-Armenia CEPA Cooperation Committee in Yerevan on June 11-12, 2024, the need to increase energy security, introduce renewable energy sources, and ensure the energy transition was emphasized.

The EU and Armenia discussed how to strengthen cooperation, enhance energy security, and accelerate the energy transition in RA, including through the "Caucasus Interconnector" project and supporting Armenia's participation in regional projects such as the Black Sea Electricity Ring.

The EU encouraged Armenia to make efforts to increase the production of energy from renewable sources, achieve climate neutrality, and improve water management.

On November 29, 2024, on the seventh anniversary of the signing of the EU-Armenia CEPA, a meeting co-chaired by Armenia's Deputy Prime Minister Mher Grigoryan and EU Ambassador to Armenia Vasilis Maragos discussed important investments in the infrastructure sector, including the "Caucasus Interconnector" project, which will connect Armenia's high-voltage transmission network to the Georgian electricity grid.

The Armenian government approved the decision to construct high-voltage transmission lines with Georgia in March 2015 as part of the "Caucasus Interconnector" project, worth a total of 320 million euros. This project will allow the capacity of high-voltage transmission lines to increase from 350 MW to 1050 MW. However, due to various reasons, this project is significantly behind schedule and is at the tender/pre-design stage.

In essence, the CEPA provides a roadmap for Armenia to deepen its cooperation with the EU in the energy sector, promoting sustainable development and energy security.

4. RA'S COMMITMENTS AND EFFORTS UNDER THE PARIS AGREEMENT (2021-2030 -2050)

Armenia's greenhouse gas emissions decreased from 25,855 million tonnes in 1990 to 7,328.6 million tonnes in 1995. By 2017, they had reached 10,624 million tonnes of CO2 equivalent (approximately 3.54 tonnes of CO2 equivalent per person, assuming Armenia's population was 3 million), of which 67% originated from the energy sector, 18.5% from agriculture, 8.9% from industry, and 5.8% from waste.

Under the Nationally Determined Contribution (NDC), Armenia committed to reducing greenhouse gas emissions by 40% compared to 1990 levels, when total emissions were 25,855 million tonnes of CO2 equivalent, and net emissions were 25,118 million tonnes of CO2 equivalent. According to the NDC, the 2030 target is not to exceed 15,047 gigatons of CO2 equivalent of greenhouse gas emissions.

Armenia's long-term low-emission development strategy (until 2050) reaffirms the target of reducing greenhouse gas emissions per capita to 2.07 tonnes of CO2 equivalent by 2050. This was adopted by the government on December 28, 2023.

EU support for energy-efficient renovations in Yerevan

On November 15, 2024, the European Investment Bank (EIB) announced a €10 million EU grant to improve energy efficiency in Yerevan. This EU grant will supplement a €25 million loan agreement signed with the EIB Global in 2023. These funds will be used to renovate more than 100,000 square meters of public buildings. The plan is to renovate 6 polyclinics and 32 kindergartens. The measures include upgrading building facades, replacing windows, installing efficient boilers, solar water heaters, and energy-efficient lighting.

These measures align with the EU's Economic and Investment Plan for the Eastern Partnership and contribute to the priority of "Investments in a Green Yerevan: Energy Efficiency" and are part of the EU's Global Gateway strategy.

In 2024, the EU recorded another significant progress in the construction of new plants using renewable energy sources. In 2024, EU member states installed 77 GW of renewable energy power plants, equivalent to saving about 14 billion cubic meters of natural gas. Specifically, 62 GW of solar

photovoltaic plants and 15 GW of wind power plants were installed (source: EUROSTAT, SolarpowerEurope & WindEurope).

In essence, here are Armenia's efforts to combat climate change, align with international commitments, and benefit from EU support for sustainable development.



So, in 2024 a(t the end of the year), the total capacity of solar photovoltaic plants in the EU was 323 GW, and that of wind power plants was 234 GW.

Figure 2. Source` EUROSTAT, SolarpowerEurope & WindEurope)

5. PROSPECTIVE AND INNOVATIVE SOLUTIONS FOR ENERGY NEEDS

Armenia is recording an overall increase in energy consumption (see Figure 3, which also presents available data for the Eastern Partnership countries according to Eurostat data collection): from 1,085 kg/person in 2015 (the first year for which data is available) to 1,215 kg/person in 2020 (data is not available for 2021).

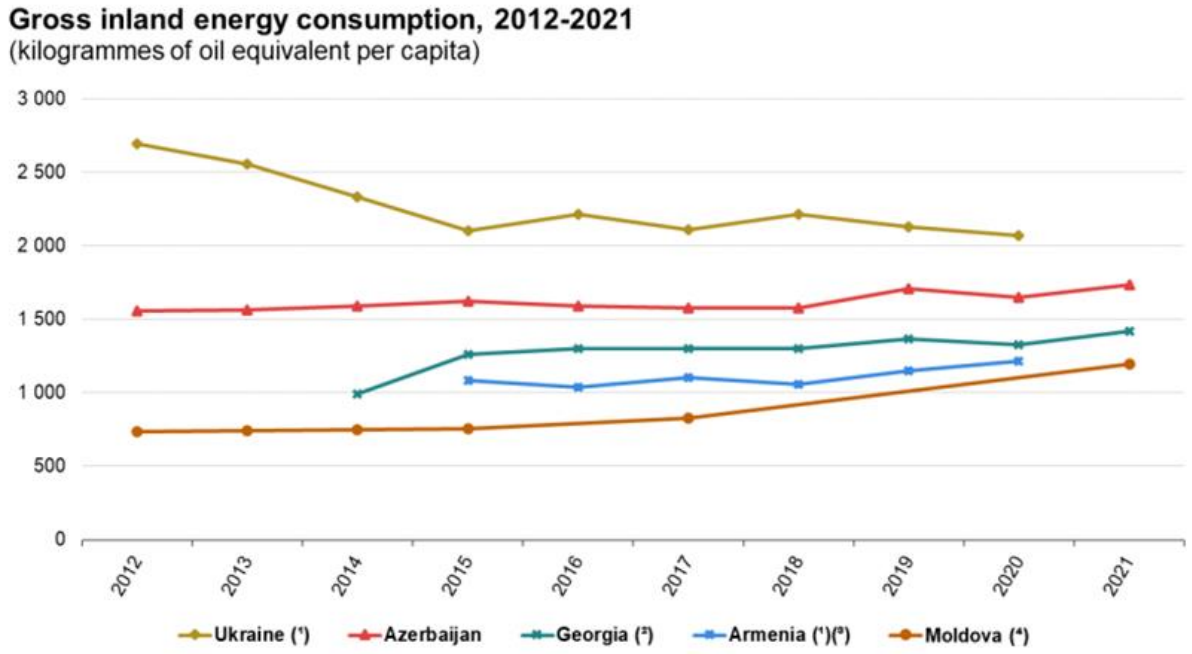


Figure 3: Internal Energy Consumption of 6 Eastern Partnership Countries in 2012-2021 (kg of oil equivalent/person)
For Armenia, a general increase in energy consumption is recorded: from 1,085 kg of oil equivalent/person in 2015 (the first year for which data is available) to 1,215 kg of oil equivalent/person in 2020 (data is not available for 2021), albeit with some fluctuations. Source: Eurostat data collection.



Figure 4. Agrivoltaic system (NREL)



Figure 5. Green hydrogen fuel

The growth in energy consumption necessitates the search for the most efficient energy sources, also contributing to the growth of the republic's energy security and independence.

The installation of highly efficient solar photovoltaic and wind power plants, efficient solar water heaters and energy-saving lighting, while maintaining high technological standards and without harming the environment, construction of hydroelectric power plants, hydrogen production, storage and transportation, the use of fuel cells in vehicles and the introduction of electric motors/batteries in the automotive industry, the expansion of the Yerevan metro, agrovoltaic approaches in agriculture, innovative thermal insulation materials, the creation of storage systems (pumped storage power plants, electric batteries), regional energy interconnection - these are the promising green paths for the development of the energy sector. The design and cost estimation work and comparative analysis of the construction of a pumped storage hydroelectric power plant (HAPS) in Armenia are outlined in the CEPA Roadmap.

Green Hydrogen Production: According to a 2023 study by the German Economic Team, the levelized cost of green hydrogen production in Armenia using newly constructed PV plants in 2025 with preferential interest rates (about 2%) will be $3.4/kg, making it competitive on the international market. With commercial interest rates (about 10%), production costs increase significantly to about $6.1/kg. According to the recommendations of this expert group, to make hydrogen production economically justified, options such as the re-equipment of a copper smelter (Alaverdi), the organization of fertilizer and ammonia production, and joining regional programs for hydrogen production and transportation have been considered.

The data on the conversion of energy carriers to hydrogen is as follows: hydrogen production from coal - 7.6 kg of coal/kg of hydrogen, from natural gas - 4.5 m3 of gas/kg of hydrogen, from nuclear and hydropower plants - 58.8 kWh/kg of hydrogen, for the production of 1 kg of hydrogen, an average of 11.34 liters or 3 gallons of water is required (1 gallon is approximately 3.78 liters), 1 kg of hydrogen can replace 4.35 kg or 1.58 gallons of gasoline.

Agrovoltaic Projects: The vast majority of solar photovoltaic (PV) systems are installed on land used solely for solar energy production. By co-locating solar and agricultural production on the same land, both solar and agricultural industries can benefit. A co-location, also known as agrivoltaics or dual-use solar, is defined as agricultural production, such as crop or livestock production or grazing, under or adjacent to solar panels. As of March 2023, the US National Renewable Energy Laboratory

(NREL) has identified 314 agrivoltaic projects in the United States with 2.8 GW of solar capacity. Most of them are concentrated in grazing and grazing environments with relatively integrated crop production. Agrivoltaic systems help reduce water consumption by providing shade, which reduces soil temperature, reduces evaporation, and helps retain moisture. This is especially beneficial in arid regions where water conservation is important.

To expand the anticipated growth of renewable energy, it is necessary to expand interconnection capabilities with Georgia and Iran. The goal is to increase these capacities from 200 to 350 MW and from 340 to 1200 MW, respectively. In addition, discussions are ongoing on increasing storage capacity through the Vorotan Cascade pumped storage hydroelectric power plant and a battery storage project. A preliminary design for a pumped storage hydroelectric power plant was previously developed in Armenia [12]. Currently, Armenia is at the initial stage of developing a pilot project for a 1200 MW/h battery storage system, the tender for which will be announced in the coming years. The financing of these projects and their exact impact on end-user tariffs remain uncertain.

6. CONCLUSION

The installation of highly efficient solar photovoltaic and wind power plants, adhering to high technological standards while causing no harm to the environment; the construction of hydroelectric power plants (HPPs); hydrogen production, storage, and transportation; the use of fuel cells in vehicles and the introduction of electric motors in the automotive industry; the expansion of the Yerevan metro; agrovoltaic approaches in agriculture; innovative thermal insulation materials; the creation of storage systems (pumped storage power plants, electric batteries); and regional energy interconnection (the "Caucasian power line") - these are promising green avenues for the development of the energy sector.

The EU continues to lead the way in the utilization of renewable energy sources, deploying RES power plants. At the end of 2024, the combined capacity of solar photovoltaic plants in the EU reached 323 GW, while wind power plants accounted for 234 GW.

EU cooperation with Armenia within the Eastern Partnership framework is invaluable for the development of green energy in Armenia. The EU's target of reducing emissions by 55% by 2030 compared to 1990 levels serves as a benchmark and a source of opportunities for Armenia.

The results of monitoring studies on the implementation of tasks in the energy sector according to the EaP Roadmap are not so readily available in the open press. It is advisable to establish and implement programs in this direction. The Comprehensive and Enhanced Partnership Agreement (CEPA) between the EU and Armenia places significant emphasis on energy cooperation. This cooperation aims to enhance energy security, diversify energy sources, develop competitive energy markets, promote renewable energy, and improve energy efficiency.

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Appendix 1. Armenia. Solar energy resource map

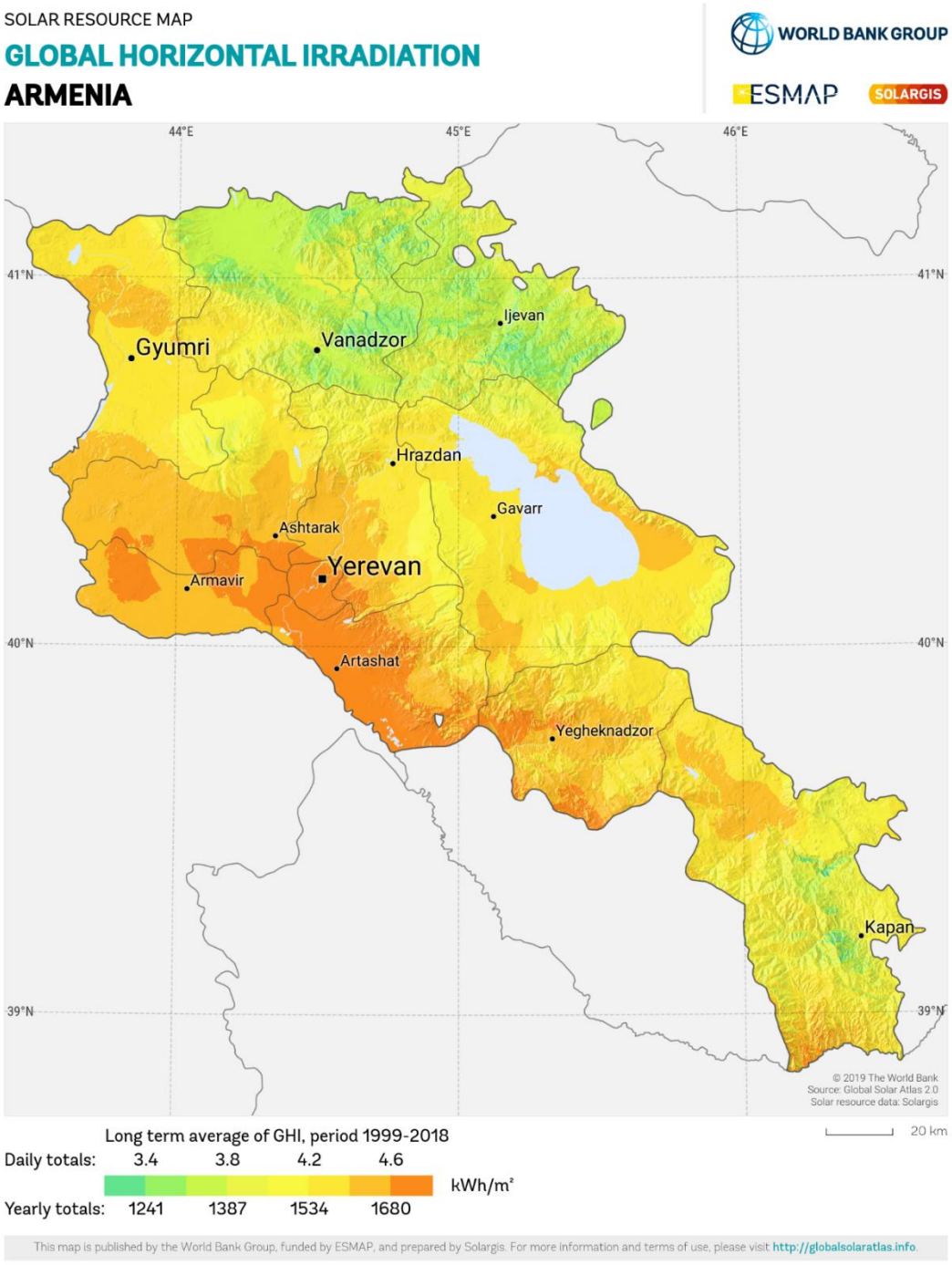


Figure 6. Average daily and annual sums of solar radiation inflow per unit horizontal surface (GHI) in Armenia, kWh/m2 (Source: ESMAP, WB, Solargis). For Armenia, it is 3.68-4.63 kWh/m2 per day.

Appendix 2. Armenia. Solar energy resource map. Photovoltaic power potential

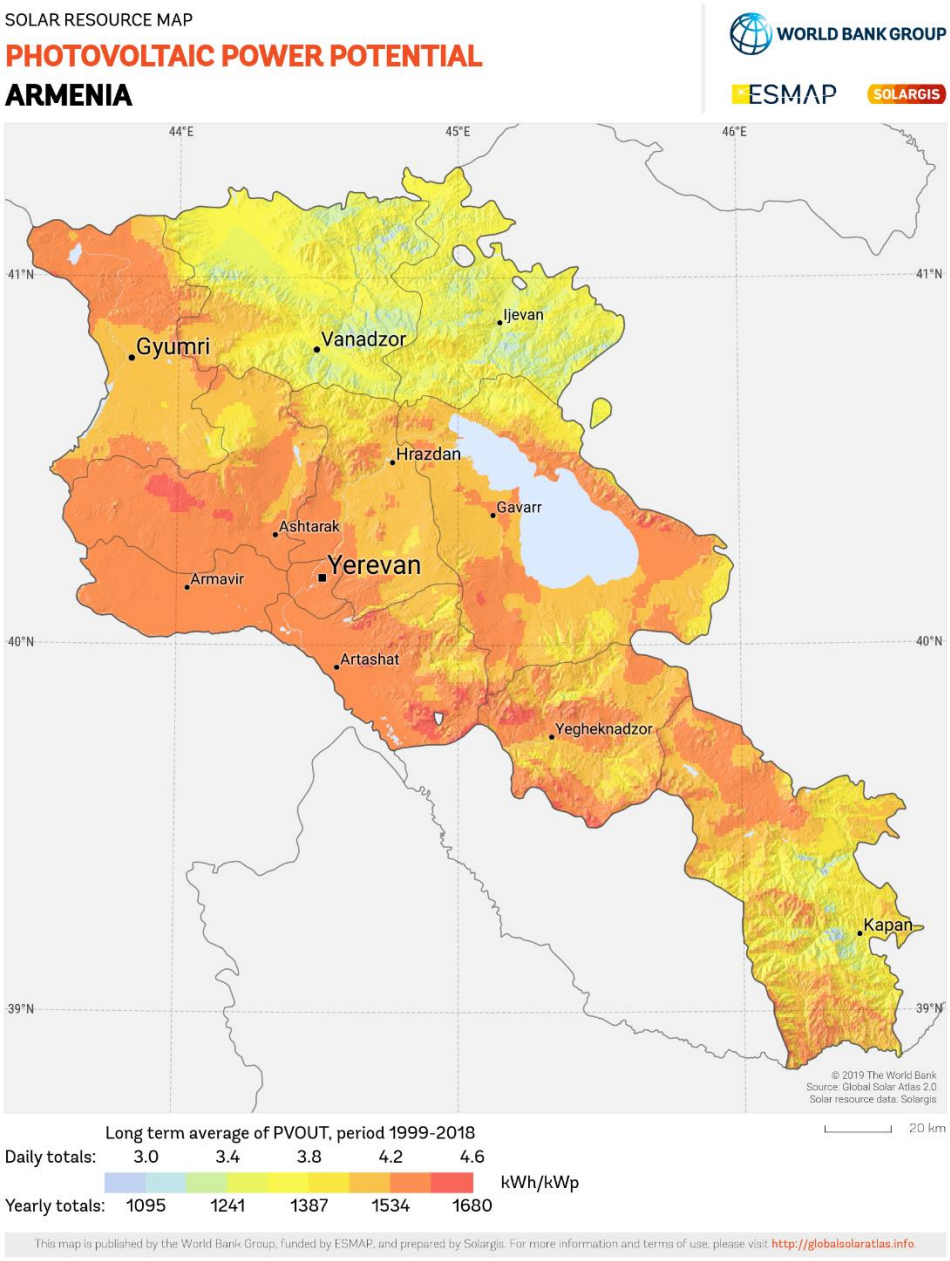
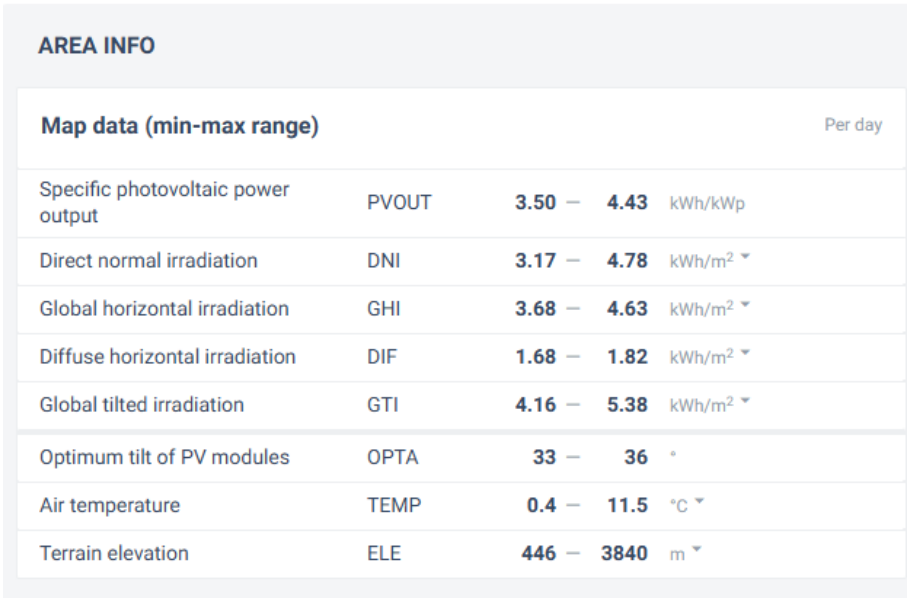


Figure 7. Solar resource map of Armenia's photovoltaic capacity and potential.

Appendix 3. Data on various indicators of solar radiation in Armenia



AREA INFO

Map data (min-max range) — Per day

Specific photovoltaic power output	PVOUT	**3.50** –	**4.43**	kWh/kWp
Direct normal irradiation	DNI	**3.17** –	**4.78**	kWh/m²
Global horizontal irradiation	GHI	**3.68** –	**4.63**	kWh/m²
Diffuse horizontal irradiation	DIF	**1.68** –	**1.82**	kWh/m²
Global tilted irradiation	GTI	**4.16** –	**5.38**	kWh/m²
Optimum tilt of PV modules	OPTA	**33** –	**36**	°
Air temperature	TEMP	**0.4** –	**11.5**	°C
Terrain elevation	ELE	**446** –	**3840**	m

Figure 8. Data obtained by the ENERGIS program for Armenia (preliminary) are based on monitoring stations and satellite measurements and reflect the resource maps provided in the Appendixes 1, 2.

Appendix 4. Georgia-Romania Black Sea submarine cable project

Georgia-Romania Black Sea Submarine Cable Project

Georgia-Romania Black Sea Submarine Cable Project Feasibility Study Summary 1 BACKGROUND The proposed Black Sea Submarine Cable (BSSC) project aims to develop electricity and digital fiber-optic interconnections between the South Caucasus and the European Union (EU), with landing points in Georgia and Romania [https://www.cesi.it/news/2024/regional-growth-cesi-reveals-black-sea-cable-plan/].

It would include a high-voltage direct current (HVDC) line with an envisaged capacity of 1,000 or 1,300 MW and a separate fiber-optic cable. The interconnection would stretch for an estimated 1,155 km, of which about 1,115 km would be via a submarine cable system at a depth of up to 2,200 m crossing the Exclusive Economic Zones (EEZ) of Georgia, Türkiye, Bulgaria, and Romania. While the BSSC project focuses on electricity interconnection, laying a separate fiber-optic cable in the same corridor would enable routing and project preparation synergies.

According to preliminary estimates of the feasibility study, the preferred option would be a 1,300 MW power cable system with an estimated cost of US$3.1–3.6 billion for a 1,300 MW and approximately US$70–90 million for the fiber-optic cable.