Scenario Highlights for the Republic of Armenia

1. Introduction

The Government of the Republic of Armenia (shortened as Armenia in this document forward) has been endorsed to be included in the NEXSTEP initiative to develop an SDG7 Road Map for Armenia. The inception workshop to kick off this initiative was held on 25 November 2022. Subsequently, several consultations have taken place between the UNESCAP and UNECE teams, the national consultant, and the Ministry of Territorial Administration and Infrastructure of the Republic of Armenia. Energy and emissions modelling, multiple scenario development, and economic analysis have been completed after intensive data collection. Key results and findings from the analysis will be discussed with stakeholders in the workshop scheduled for 13 May 2024 to seek comments, suggestions, and expert opinions to ensure that these findings are meaningful and aligned with Armenia's specific context. Once agreed upon, these scenarios will form the basis for the development of the SDG 7 Road Map report.

1.1. Purpose of this document

This document provides an overview of key data and assumptions used to perform energy modelling, energy transition scenarios, key results and findings, and policy recommendations for the SDG7 roadmap for Armenia, developed using the National Expert SDG7 Tool for Energy Planning (NEXSTEP). NEXSTEP uses the Low Emission Analysis Platform (LEAP)[1] for modelling energy transition scenarios. LEAP is a widely used tool developed by the Stockholm Environment Institute (SEI), which is utilized to develop scenarios for the energy sector policy analysis and Nationally Determined Contribution (NDC).

NEXSTEP modelling utilizes data collected from the national level that includes bottom-up energy demand and intensity data for the demand sectors (i.e., residential, commercial, transport, and industry), macroeconomic and demographic data such as the country's GDP, projected GDP growth rate, population data, and projected population growth rate.

2. Introduction to energy scenario modelling and scenarios

The base year for the modelling analysis is 2021 (based on the year of most data availability), whereby simulation for the different scenarios is made between the period of 2022-2030, except for one of the ambitious scenarios where a timeframe has been extended to 2050. Four scenarios have been developed for Armenia using the bottom-up approach, as depicted in Figure 1. These are as follows:

[1] https://leap.sei.org/

- **The Business as Usual (BAU)** scenario hypothetically projects the energy demand and emissions trajectory based on historical improvement and in the absence of any new actions or policies. Whilst this scenario is not a practically true scenario, since there will be policies and plans implemented along the way, it is helpful in comparing the emissions trajectories.
- **The Current Policy (CP)** scenario considers the existing policies and plans implemented or scheduled for implementation during the analysis period, with reference to the SDG 7 and national NDC targets, as well as national targets for energy efficiency improvement and renewable energy share. This scenario does not consider policies and plans that are unlikely to be implemented.
- **The Sustainable Development Goal (SDG)** scenario has been developed to help achieve the SDG 7 targets as well as the NDC unconditional target by 2030. Essentially, it ensures the following:
    - Universal (100%) access to electricity;
    - Universal (100%) access to clean cooking fuels and technologies;
    - Substantial increase of RE share in total final energy consumption (TFEC);
    - Doubling the rate of improvement of energy efficiency. In other words, halving the energy intensity between now and 2030, compared to the rate between 1990 and 2010; and
    - Achieving the NDC unconditional target by 2030.
- **Towards Net Zero by 2050 scenario** explores technological interventions, the timeframe of implementation of different measures and technologies, and the policy framework that would be needed if Armenia would like to plan for Net Zero Emissions by 2050

Figure 1: Example of bottom-up approach modelling using LEAP

3. Overview of Armenia's energy sector

3.1. Demographic and macroeconomic data in 2021

Population: The total population of Armenia was around 2.96 million in 2021[2] with an annual growth rate of -0.52 per cent between 2020 and 2021. Over the ten-year period between 2011 and 2021, the annual population growth rate averaged -0.48 per cent, showing a reduction in population. The percentage of the urban population was estimated to be 67.3[3] per cent. Yerevan, the capital city, is the most populated city in Armenia, with a population of around 1.1 million.

Economy: Armenia's GDP in 2021 was estimated at US$13.88 billion, a significant growth of 5.8 per cent from the value in 2020. Over the ten-year period between 2011 and 2021, the GDP growth rate averaged 3.6 per cent. The GDP per capita has been increasing from just US$ 3,043 in 2011 to US$ 4,685 in 2021. The country's GDP relies heavily on the service sector (54.8 per cent), the industry sector (28.2 per cent), and the agricultural sector (16.7 per cent). The remaining goes to the other sectors.

3.2. Baseline energy situation in 2021

Energy demand: In 2021, the total final energy consumption (TFEC) was 2.84 Mtoe (Figure 2). Most of the demand came from the residential sector (33.8 per cent), followed by transport sector (31.7 per cent), commercial sector (15.3 per cent) and the industry sector (13.1 per cent). Agriculture and non-energy use accounted for 3.6 per cent and 2.6 per cent.

[2] According to the data collection provided by the national consultant. The value is slightly higher compared to the data presented in The World Bank (2024)
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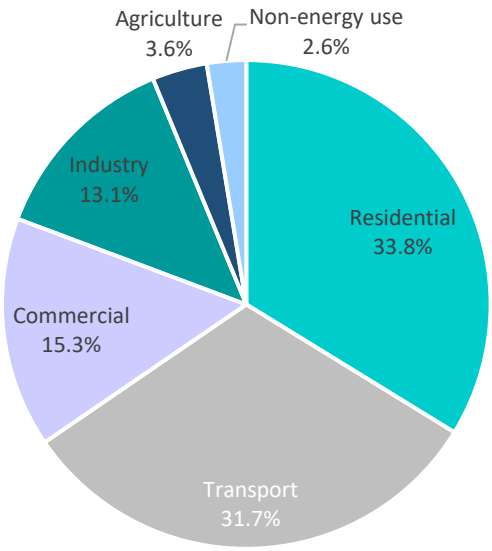
Figure 2: Total final energy consumption by sector in 2021

2.84 Mtoe



In the residential sector, around 62.7 per cent of energy was consumed for heating purposes (0.6 Mtoe). Heating demand in Armenia is quite high as the country experiences a long and very cold winter season. Such a high share of residential heating demand was supplied mainly by fuelwood (34.6 per cent), gas boiler (27.9 per cent), gas heater (24.1 per cent), electric heater (10.1 per cent), and coal boiler (1.6 per cent). Homemade biogas accounted for one per cent, while district heating accounted for 0.7 per cent only. Cooking activities consumed around 21.1 per cent of residential energy demand. The distribution of cooking technology will be discussed later. Apart from cooking and heating, refrigeration consumed 34.5 per cent of electrical demand, television 22 per cent, lighting 19.8 per cent, air conditioners 18.8 per cent, and the remaining 4.9 per cent was used for ironing, washing machines, and other appliances.

Within the transport sector, 99.2 per cent of energy was consumed by road transport and 0.7 per cent by rail transport. The remaining went to the aviation sector. Within the road transport category, 41.7 per cent of energy was used by passenger cars. Trucks accounted for 36.2 per cent, vans accounted for 10 per cent, and buses accounted for 9.8 per cent of energy demand. The remaining went for taxis, minibuses, and motorcycles.

The commercial sector analysis is usually based on floor space occupied by the sector and the energy intensity per square metre. However, due to the limited amount of information, only the total energy demand by fuel type could be obtained. In the commercial sector, natural gas accounted for 49.9 per cent of the energy demand, electricity at 43.7 per cent, and diesel at 4.1 per cent. The remaining 2.3 per cent was allocated for district heating and biomass demand.

There are two energy-intensive industries in Armenia, which are (1) cement and non-ferrous metal and (2) food and beverages. These industries together consumed 53.5 per cent of industrial energy demand.

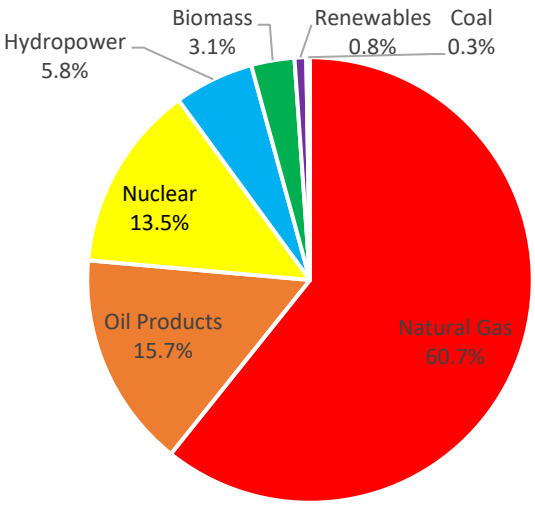
The remaining was consumed in iron and steel, pulp and paper, machinery and transport equipment, fertiliser and chemical products, textile and leather, and other processing industries.

Energy supply: The total primary energy supply (TPES) in 2021 was 3.75 Mtoe. The energy supply mix was as follows: natural gas 60.7 per cent, oil products 15.7 per cent, nuclear 13.5 per cent, hydropower was 5.8 per cent, biomass 3.1 per cent, and renewables was 0.8 per cent. Figure 3 presents distribution of TPES by fuel.

Total installed power generation capacity in 2021 was 4,052.3 MW. In terms of capacity mix, natural gas accounted for 51.5 per cent of the capacity while nuclear accounted for 11.1 per cent. Renewables[4] accounted for 37.4 per cent of capacity of which large hydropower was 33.2 per cent, solar was 4.2 per cent, and wind was 0.1 per cent. Total electricity generation in 2021 was 7.9 TWh. Thermal power plants accounted for 78.4 per cent of power generation of which 25.4 per cent coming from nuclear. The remainder came from renewable energy (large hydropower 27.9 percent, solar 3.7 per cent, and wind ~0.02 per cent). Total heat generation in 2021 was 15.7 ktoe coming from gas CHP. Figure 4 shows the Sankey Diagram with energy flows and sources.

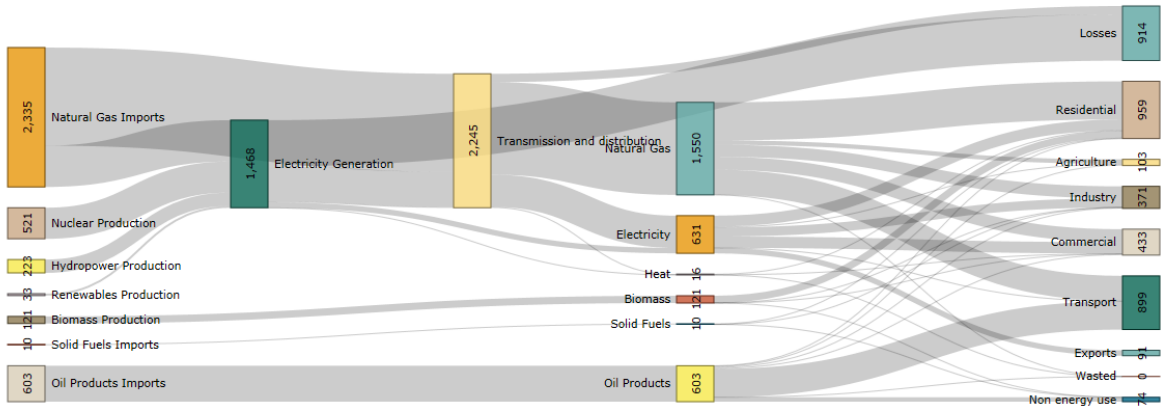
Figure 3: Total primary energy supply by fuel in 2021

3.75 Mtoe



[4] Large hydropower is considered as renewables under the SDG 7.2 definition.

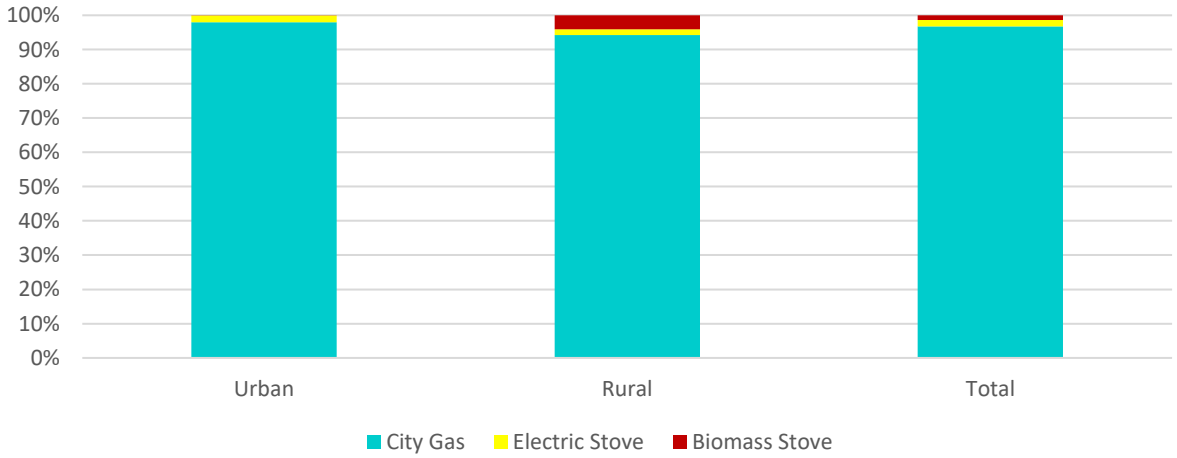
Figure 4: Sankey diagrams.



3.3. Status of SDG 7 targets in the base year 2021

Access to modern energy: Armenia has progressed well in providing energy access to its citizens. The electrification rate in Armenia was already 100 per cent in 2021. The clean cooking access rate was estimated at 98.6 per cent[5]. The remaining 1.4 per cent of the population, which corresponds to 10,706 households, still relied on unclean and polluting biomass stoves as their primary cooking technology. City gas stoves were the most dominant primary clean cooking technology, with an estimated 96.8 per cent share. This was followed by electric cook stoves, which were estimated at 1.8 per cent.

Figure 5: Clean Cooking Access Share



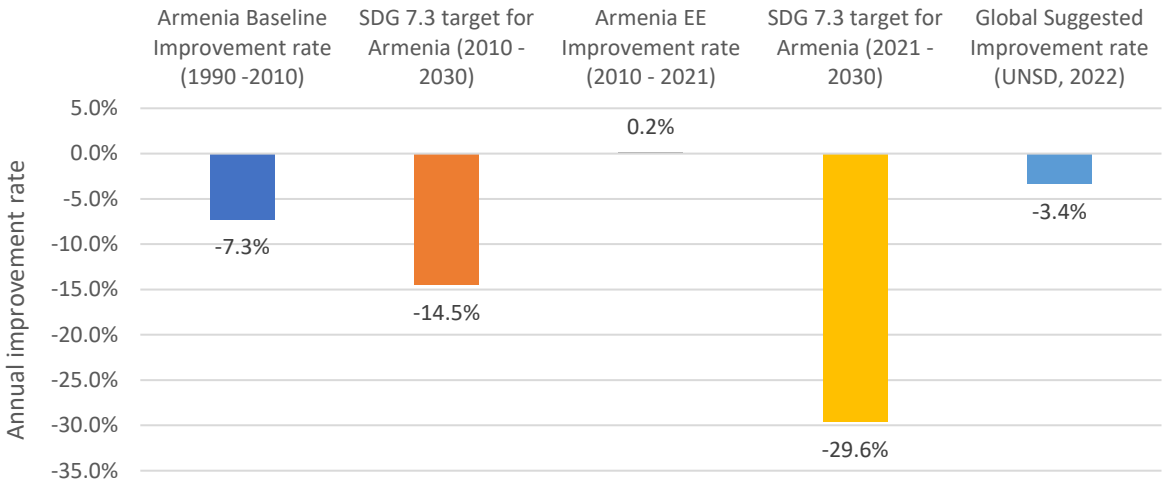
Renewable energy share in the total final energy consumption (TFEC): Renewable energy (solar, wind, large and mini hydropower, as well as traditional biomass usage) delivered approximately 10.4 per cent of TFEC in 2021, which is equivalent to 9.7 per cent of TPES. If the traditional biomass usage in residential sector was excluded, the renewable share was 6 per cent of TFEC. While endowed with

[5] Estimated based on the cooking distribution data provided for urban and rural sectors in accordance with WHO (2023).

an abundance of renewable potential, Armenia has a high reliance on fossil fuels (i.e., natural gas and oil products) to meet its stationary and mobile energy demands.

Energy intensity: Energy intensity under SDG 7.2 is defined as the ***total primary energy supply*** (TPES) in megajoules per US$ of gross domestic product in terms of power purchase parity in 2017. Armenia's energy intensity in 2021 is estimated to have been 5.6 MJ/USD_{2017}. Energy intensity in Armenia has declined at an average annual rate of 7.3 per cent between 1990 and 2010 from 17.6 MJ/USD_{2017} to 3.9 MJ/USD_{2017}.

Figure 6: Armenia energy efficiency target.



A doubling of the 1990-2010 improvement rate is required to achieve the SDG 7.3 target, which requires an average annual rate increase of 14.6 per cent between 2010 and 2030, reaching 0.2 MJ/USD_{2017} in 2030. However, between 2010 and 2021, the energy intensity increased to 4 MJ/USD_{2017}. To reach the expected 2030 intensity, the annual improvement rate between 2021 and 2030 must be around 28.7 per cent, which is quite challenging. Therefore, NEXSTEP analysis suggests Armenia's energy intensity target to be aligned with the global target of 3.4 per cent annual improvement (UNSD, 2022). This corresponds to a 2030 energy intensity target of 2.6 MJ/USD_{2017}.

GHG emissions: The energy sector emissions, from the combustion of fossil fuel, were calculated based on IPCC Tier 1 emission factors assigned in the LEAP model and expressed in terms of 100-year global warming potential (GWP) values. GHG emissions from the energy sector were estimated at 6.9 $MtCO_{2\text{-}e}$ in 2021. Emissions from the transport sector were the largest at 2.4 $MtCO_{2\text{-}e}$ rising from direct fuel combustions in internal combustion engines. It is followed by the power generation sector at 1.6 $MtCO_{2\text{-}e}$. The emissions from residential sector were 1.6 $MtCO_{2\text{-}e}$ coming from natural gas and biomass combustions for cooking and space heating. The emissions attributable to the commercial sector were estimated at 0.6 $MtCO_{2\text{-}e}$. Industrial and agriculture sector emission was around 0.7 $MtCO_{2\text{-}e}$ altogether.

3.4. Energy policies and targets

Armenia's energy sector development is guided by several national policies and legislations. These policies have been used as guiding references for the NEXSTEP modelling, to better understand the country's context and to provide recommendations in adherence to the national government's overarching direction. Where applicable, the currently implemented and adopted policies or regulations are considered in the current policy scenario, to identify gaps in achieving the SDG 7 targets. The following policies or strategic documents have been consulted.

- **Armenia Development Strategy (ADS) for 2014-2025** (Government of the Republic of Armenia, 2014) sets out national development objectives for 2014-2025. The country's main socioeconomic development strategy is the basis for medium‑term, sectoral and other program documents. Priorities include: 1) Priority 1. Growth of employment; 2) Priority 2. Development of human capital; 3) Priority 3. Improvement of social protection system; and 4) Priority 4. Institutional modernization of the public administration and governance. The strategy prioritizes the maximization of RE use, promoting EE in all sectors, and diversifying energy supply and regional integration. The Armenia Development Strategy further attempts to improve the level of safety and reliability of the power supply and promotes the development of nuclear energy.
- **Republic of Armenia Energy Sector Development Strategic Program to 2040** (Government of the Republic of Armenia, 2020) is a long-term development strategy covering the main directions of the development of the energy sector of the Republic of Armenia and the measures ensuring its implementation till 2040. Particularly, after realizing small hydro potential, mostly after 2000, the focus is shifted to solar energy and wind. Armenia is developing solar energy capacity from current 59.57 MW to 1000 MW before 2030, to increase both, green energy share and energy security (at least 15 per cent in 2030 in power generation mix).
- **Programme of the Government of Armenia 2021-2026** (Government of the Republic of Armenia, 2021) aims to continuously minimise the role of natural gas in the structure of electricity production by replacing it with sources of renewable and alternative electric energy and to prepare the transition of infrastructures to alternative transportation.
- **Energy Law No. ZR-148 of 2001** (Office of the President of the Republic of Armenia, 2001) established a regulatory framework for the energy sector management, including licensing rules, setting regulated tariffs and payments for services. The power market of Armenia has no elements of competition or explicit or implicit subsidies, and it is fully regulated by the independent regulatory agency – the Public Services Regulatory Commission (PSRC). In 2017, amendments were introduced to the 2001 Energy Law to liberalize the energy market, including introducing competition among electricity suppliers.
- **Law No. LA-122 of 2004 on Energy Saving and Renewable Energy** (Office of the President of the Republic of Armenia, 2004) aims to support the implementation of programs on energy efficiency and the introduction of renewable sources of energy in the Republic of Armenia. The sustainable energy sector is an important driver of sustainable economic growth.

- **Scaling Up Renewable Energy Program (SREP): Investment Plan for Armenia** (Government of the Republic of Armenia, 2014) contains the Investment Plan (IP) for the Republic of Armenia. The government's target for renewable energy generation is set at 21 per cent of total generation by 2020 and at 26 per cent by 2025 with respect to the benchmark of 6 per cent in 2012. Renewable generation capacity targets for both geothermal and wind energy aim to reach 50 MW by 2020 and 100 MW by 2025, respectively. Armenia is also targeting 40 MW of solar (PV) by 2020 and 80 MW by 2025.
- T**he European Union-Armenia Comprehensive and Enhanced Partnership Agreement (CEPA)** (European Union and the Government of the Republic of Armenia, 2021) includes the promotion of the use of renewable energy sources, energy efficiency and energy savings.
- **Second National Energy Efficiency Action Plan (NEEAP)** (Armenia Renewable Resources and Energy Efficiency Fund (R2E2), 2015) sets out generally expected energy intensity savings, achievable through energy efficiency (EE) measures, ranging from 14 per cent to 23 per cent across the residential, industry, transport, commercial services and water sectors by 2020. Under the Second NEEAP, Armenia will seek improvements in energy efficiency, including building audits and certification, energy efficiency projects in public buildings, street lighting, energy management, and energy efficiency in tendering procedures for public procurement. The government is developing a National Programme on Energy Saving and Renewable Energy for 2021-2030.
- **Nationally Determined Contribution 2021-2030 of The Republic of Armenia To The Paris Agreement** (Government of The Republic Of Armenia, 2022) sets a mitigation target for Armenia's NDC, which will be a 40 per cent reduction in total national greenhouse gas (GHG) emissions by 2030, compared to the 1990 emissions. The strategy includes increased efficiency of public transport, use of renewable energy, stimulation and support in the uptake of electric vehicles.

4. Key Assumptions, Demand Analysis and Growth Projections

The energy demand is estimated using the activity level and energy intensity in the LEAP model. The demand outlook throughout the NEXSTEP analysis period (2022-2030) is influenced by factors such as annual population growth, annual GDP growth and per capita GDP. The assumptions used in the NEXSTEP modelling are further detailed in the later sub-sections, while Table 1 provides a summary of the key modelling assumptions for the three main scenarios (i.e., BAU, CPS and SDG scenarios).

Table 1. Important factors, targets and assumptions used in NEXSTEP modelling

Parameters	Business as usual scenario	Current policy scenario	Sustainable Development Goal scenario
Economic growth	12.6 per cent between 2021 and 2022,8.7 per cent between 2022 and 2023, 5.7 per cent between 2023 and 2024, and 6 per cent per annum from 2024[6]		

[6] Historical data and estimation from Asian Development Bank

Population growth	-.0.48 per cent per annum*		
Urbanization rate	67 per cent in 2021, growing to 68 per cent in 2030[7]		
Commercial floor space	Assumed annual energy consumption increasing at the same growth as GDP		
Industrial activity	Assumed annual energy consumption increasing at the same growth as GDP		
Transport activity	Passenger transport activities and freight transport activities are assumed growing at a rate like the growth in GDP per capita		
Residential activity	The appliance ownership for electrical appliances is projected to grow at a rate like the growth in GDP per capita.		
Access to electricity	The universal (100 per cent) access to electricity has been achieved.		
Access to clean cooking fuels	Projected based on the historical penetration rate between the 2000-2020 period. 100 per cent clean cooking access rate is expected to be achieved by 2026		
Energy efficiency	Additional energy efficiency measures not applied	Improvement based on current policies	Global improvement in energy intensity adopted
Power plant	Considers 2021 RE share in power generation and grid emissions	Considers capacity expansion provided by national consultant	

5. Energy demand and emission projection

5.1. Current Policy (CP) scenario

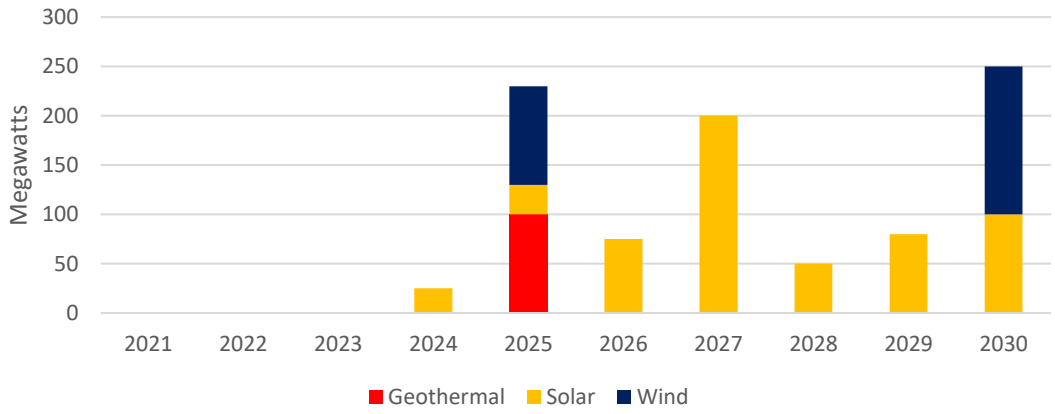
The CP scenario considers initiatives implemented or scheduled for implementation during the analysis period 2021-2030, considering the following two high-level strategies as they have been outlined in national policies. However, NEXSTEP modelling only considers policy measures that have come into force or already have a concrete implementation timeline within the analysis period[8].

a) **Energy efficiency:** reduce the energy intensity by at least 14 per cent across the residential, industry, transport, and commercial services.
b) **Power Generation:** According to Scaling Up Renewable Energy Program (SREP): Investment Plan for Armenia (Government of the Republic of Armenia, 2014) renewable generation capacity targets for both geothermal and wind energy aim to reach 50 MW by 2020 and 100 MW by 2025, respectively. Armenia is also targeting 40 MW of solar (PV) by 2020 and 80 MW by 2025. Additionally, the capacity expansion plan is considered as well. As projected in the figure below, the power capacity expansion plan is assumed to reach a total capacity of 4,962

[7] This assumes that the urbanisation rate grows with an annual rate of 0.05 per cent, with reference to the national historical urbanisation growth from 2010 to 2020.
[8] Only policies with concrete and implemented measures are considered in the scenario modelling for the current policy scenario. To further explain, measures mentioned in strategy policy or planning documents that are yet to be enforced or implemented prior to October 2023 are not considered in the modelling of the current policy scenario.

MW by 2030. This assumes that the expansion plan is carried out according to the planned timeline. The given capacity addition will increase the share of renewable (including large hydropower) in the total installed capacity to 48.94 per cent, where the share of solar generation will increase significantly from 4.2 per cent in 2021 to 14.7 per cent in 2030.

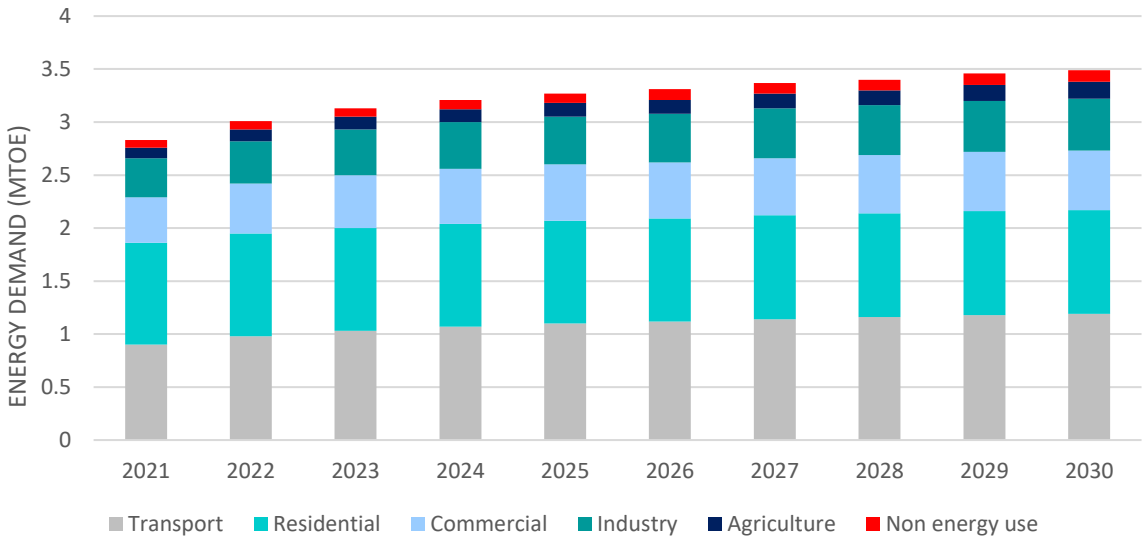
Figure 7: Power capacity expansion plan 2022-2030 by sector, CP scenario.



Source: Data collected from the national sources

The **total final energy consumption** is expected to increase from 2.84 Mtoe in 2021 to 3.5 Mtoe in 2030, an average annual growth rate of 2.4 per cent. TFEC is 0.34 Mtoe lower than the BAU scenario because of the planned implementation of energy efficiency measures in the industry, residential, and commercial sectors as targeted under the energy efficiency concept. In 2030, the transportation sector consumption will be the largest at 34.1 per cent, followed by the residential sector at 28.1 per cent, the commercial sector at 16.1 per cent, and the industrial sector at 14.1 per cent. Agriculture will account for 4.5 per cent while the remaining will go to non-energy use. Figure 6 shows the forecast of TFEC by sector under the CP scenario.

Figure 8 Final energy demand 2022-2030 by sector, CP scenario



GHG emissions from the energy sector are estimated to increase to 7.8 $MtCO_2$-e in 2030. Emissions from the transport sector will be the largest at 3.2 $MtCO_2$-e rising from direct fuel combustions in internal combustion engines. It is followed by the residential sector at 1.5 $MtCO_2$-e coming from natural gas combustions for cooking and space heating. The power and heat generation sector will account for 1.3 $MtCO_2$-e. The emissions attributable to the industrial sector were estimated at 0.7 $MtCO_2$-e. Commercial and agriculture sector emissions will be around 1.1 $MtCO_2$-e altogether.

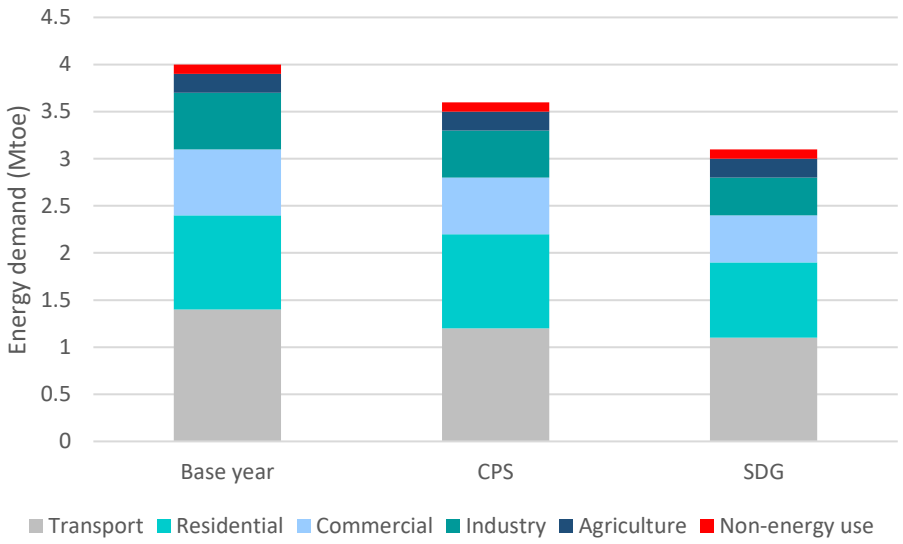
5.2. Sustainable Development Goal (SDG) scenario

Access to affordable, reliable, sustainable, and modern energy is essential to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. Armenia has achieved a 100 per cent electricity access rate in the current policy scenario. It is also predicted that the clean cooking share will be 100 per cent by 2026. Nonetheless, a concerted effort is needed in other areas to allow the achievement of all SDG7 targets, specifically the energy efficiency target, with measures recommended in the SDG scenario.

The **total final energy consumption** is expected to increase from 2.84 Mtoe in 2021 to 3.19 Mtoe in 2030, a reduction of 0.3 Mtoe compared to the CP scenario (Figure 9). This reduction is due to the adoption of higher energy efficiency measures, which will be presented in a later section. In 2030, the transportation sector consumption will be the largest at 35.3 per cent, followed by the residential sector at 26.6 per cent, the commercial sector at 15.8 per cent, and the industrial sector at 14 per cent. Agriculture will account for 8.4 per cent, while the remaining will go to non-energy use

GHG emissions from the energy sector are estimated to increase to 6.9 $MtCO_{2\text{-}e}$ in 2030. Emissions from the transport sector will be the largest at 3 $MtCO_{2\text{-}e}$ followed by the power and heat generation sector at 1.3 $MtCO_{2\text{-}e}$. The residential sector will account for 1.2 $MtCO_{2\text{-}e}$. The emissions attributable to the industrial sector were estimated at 0.6 $MtCO_{2\text{-}e}$. Commercial and agriculture sector emissions will be around 1 $MtCO_{2\text{-}e}$ altogether.

Figure 9 TFEC by sector comparison in the base year, CPS and SDG scenarios.

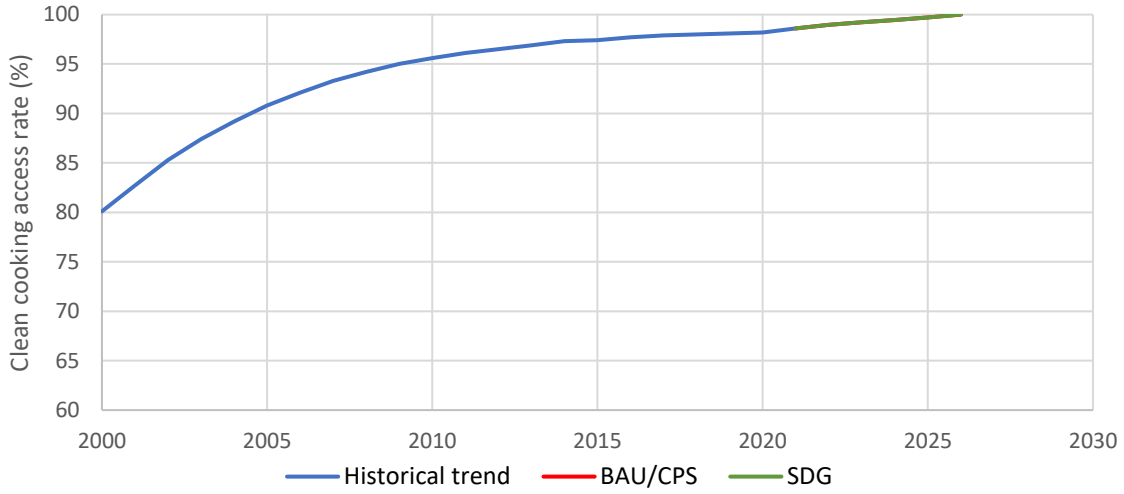


6. Assessment of the SDG 7 and NDC Targets

6.1. Energy access

The electrification rate in Armenia has already been 100 per cent in 2021. However, additional effort is required to achieve **universal access to clean cooking**. As of 2021, 98.6 per cent of households relied on polluting cooking technologies, specifically solid fuel stoves (assuming biomass and charcoal as a primary fuel). Access to clean cooking fuels and technologies will be achieved in the current policy scenarios – it will reach 100 per cent in 2026 (figure 10).

Figure 10 Armenia's access to clean cooking in the BAU, CPS and SDG scenarios



Natural gas plays a significant role in Armenian households since it can also provide heating energy. The current electricity tariff makes the natural gas stove more competitive compared to the electric stove. Table 3 summarises the estimated annualized cost of different cooking technologies in the context of Armenia. Therefore, natural gas is expected to help close the remaining population gap in the current policy scenario. However, in the long run, this situation might cause a challenge for the

energy security of the country since natural gas is imported. Therefore, NEXSTEP suggests that electric cook stoves might provide the most appropriate solution for Armenia in the long run due to their reliability and environmental effectiveness since the technology has been adopted widely in the country. In the SDG scenario, at least 20 per cent of the population is suggested to adopt electric cook stoves by 2030. This 20 per cent value is chosen as per suggested recommendation in the Net Zero 2050 Roadmap document developed by IEA (IEA, 2021)

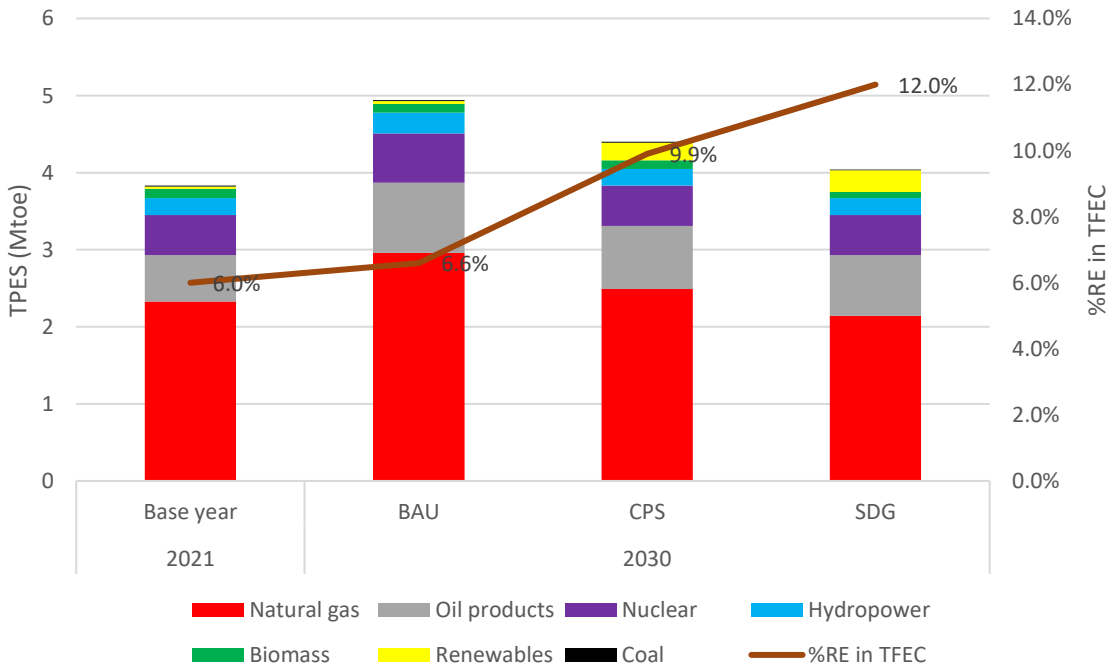
Table 2. The annualized cost of cooking technologies

Technology	Annualized cost
Electric cooking stove	US$ 164
Natural gas stove	US$ 98

6.2. Renewable energy

SDG 7.2 does not have a quantitative target but encourages a "substantial" increase in **the renewable energy share in TFEC.** The share of renewable energy (excluding traditional biomass usage) in TFEC in 2030 will be 9.9 per cent in the CP scenario and 12 per cent in the SDG scenario. The increase is attributable to the higher share of renewable energy (including large hydropower) in power generation. Armenia will be able to increase the renewable share in power generation from 37.4 per cent to 48.9 per cent as per the capacity expansion plan. An additional increase in the renewable energy share of TFEC in the SDG scenario is caused by the improvement in energy efficiency.

Figure 11 power generation comparison in the base year, CPS and SDG scenarios 2030



6.3. Energy efficiency

A doubling of the 1990-2010 improvement rate is required to achieve the SDG 7.3 target. However, due to the difficulties to achieve an ambitious target of reaching an energy intensity of 0.2 MJ/USD$_{2017}$. As discussed in section 3.3, it is suggested that Armenia achieve a global improvement rate of 3.4 percent between 2021 and 2030. Consequently, the energy intensity in 2030 would need to be capped at 2.9 MJ/USD$_{2017}$.

Under the CP scenario, the energy intensity will be around 3.1 MJ/USD$_{2017}$, which is a 2.8 per cent average annual drop from the 2021 value of 4 MJ/USD$_{2017}$. This is a significant improvement due to the planned implementation of energy efficiency measures, which NEXSTEP projects will result in a 0.34 Mtoe energy reduction under the current policy scenario. Table 2 lists different energy-saving opportunity measures under the CP scenario.

Table 3. The energy saving under CP scenario compared to BAU scenario.

Sector	Measure	Energy demand reduction in 2030 (ktoe)
Residential	The development of energy-efficient construction, for which the requirements for energy efficiency of building materials, products and structures will be revised, and measures will be developed to stimulate the construction of high-class energy efficiency facilities, will simultaneously raise the awareness of the citizens.	16.0
Transportation	Improve fuel economy of passenger cars and trucks while implementing eco-driving and operational transport monitoring system	165.6
Industry	Financing measures for modernizing technological processes and equipment and introducing energy-saving measures in all industries, which will reduce physical wear and tear and increase the efficiency of existing equipment	69.8
Commercial	An increase in the share of purchased energy-efficient equipment will be ensured by monitoring public procurement of goods, works and services for compliance with energy efficiency requirements, as well as establishing administrative liability for their violation	91.7
Total		343.1

This saving is substantial but fails to achieve the SDG 7 target by a small margin. NEXSTEP analysis finds that Armenia, however, can improve its energy intensity in 2030 further to 2.8 MJ/USD$_{2017}$, meeting the global energy efficiency target for SDG 7. An additional 0.3 Mtoe of energy demand reduction can be achieved through several measures.

Firstly, although in the CP scenario, Armenia might achieve 100 per cent clean cooking access by 2026, more effort can be made to promote energy security and reduce emissions. Increasing the share of

efficient electric cook stoves (e.g. induction type) can be implemented in the residential sector. NEXSTEP suggest the adoption of electric cook stoves to 25 per cent of urban households and 10 per cent of rural households in 2030. This will help follow the pathways towards net zero by adopting 20 per cent of the clean cooking share in the total population. Additionally, the adoption of MEPS will be beneficial in reducing the electricity consumption for lighting, refrigeration, and television (the three appliances with the largest energy consumption).

Due to its climatic conditions, Armenia consumes a significant amount of energy for heating[9]. Most of the demand, however, is supplied by natural gas boilers or heaters, increasing the country's vulnerability to the volatility of gas prices. The country can transition to a new heating demand by considering cleaner technologies like heat pumps. NEXSTEP suggests replacing 15 per cent of natural gas boilers with heat pumps in urban areas and promoting electric heaters to a quarter of the rural population to reduce fuelwood usage. Table 3 shows additional energy-saving opportunities under the SDG scenario, compared with the CP scenario.

Table 4. Additional energy saving in the residential sector – SDG scenario compared to CP scenario

Sector	Measure	Energy demand reduction in 2030 (ktoe)
Residential Cooking	Adoption of electric cook stoves to 25 per cent of urban households and 10 per cent of rural households in 2030	22.0
Residential Heating	Replacement of 15 per cent natural gas boilers with heat pumps in urban areas and the promotion of electric heaters to a quarter of the rural population to reduce the usage of fuelwood.	71.3
Residential MEPS	Increase the adoption of energy-efficient lighting, refrigeration, and television	40.9
Total		**134.2**

According to the Second National Energy Efficiency Action Plan (NEEAP), the expected energy intensity savings, achievable through energy efficiency (EE) measures, can be up to 23 per cent. NEXSTEP investigated whether achieving the 23 per cent energy reduction can be achieved further in both commercial and industry sectors. In the commercial sector, further improvement of energy intensity in commercial buildings can be achieved by extensive deep retrofitting of the building. The same measures can also be implemented in the industrial sectors. Furthermore, at least 15 per cent of electricity savings can be achieved by just doing the motor replacement, oversizing correction, VSD installation, and digitisation (de Almeida, Ferreira, & Fong, 2023).

[9] In terms of heating as well, further improvement of energy intensity in urban areas can be achieved by deep retrofitting, while improvement of thermal efficiency in rural areas can also be achieved by improving insulation.

Table 5. Additional energy saving in the commercial and industry sectors – SDG scenario compared to CP scenario

Sector	Measure	Energy demand reduction in 2030 (ktoe)
Commercial	External insulation of commercial buildings to achieve at least 23 per cent energy saving in heating	58.9
Industry	Improvement of efficiency of electricity through motor replacement and deep retrofitting to reduce thermal loss	44.9
Total		**103.8**

The Armenian government can significantly reduce the demand for transport energy by promoting the utilization of electric vehicles in the country. NEXSTEP analysis suggests that at least 20 per cent of electric cars might reduce the energy demand by around 68.9 ktoe. The target for passenger cars must be higher since a significant amount of energy is needed in this category. The government may initially replace the government's fleet of cars with electric vehicles before promoting the electric vehicle to a wider public.

Table 6. Additional energy saving and GHG emission reduction in the transport sector – SDG scenario compared to CP scenario

Sector	Measure	Energy demand reduction in 2030 (ktoe)
Transport – Passenger transport	Electric car penetration by 20 per cent[10]	68.9
Total		**68.9**

In the future, the government might also consider electrification of trucks and buses. The electrification of heavy trucks is challenging because of the competition with long-range diesel trucks. However, it is expected that the electrification of freight trucks might also become an economically feasible option. In terms of infrastructure, the government may start to develop charging facilities in urban areas first since mobility is concentrated in urban areas.

6.4. NDC target

Emission analysis in this study suggests that the BAU emission in 2030 will be 9.2 $MtCO_2$-e. Armenia has committed to reducing GHG emissions by 40 per cent compared to 1990 level. In 1990, the energy sector's emission was around 22.7 $MtCO_2$-e. This translates to a cap of 13.6 $MtCO_2$-e. Under the current policy setting, the total emissions are expected to be 7.8 $MtCO_2$-e (Figure 12) or a 65.6 per cent emission reduction compared to the 1990 level, achieving the NDC target due to the increase of

[10] This 20 per cent electric car share is chosen as per the suggested recommendation in the Net Zero 2050 Roadmap document developed by IEA (IEA, 2021).

renewable share in electricity supply as per the capacity expansion plan. In the SDG scenario, total emissions are expected to further decrease to 6.9 $MtCO_2$-e by 2030 or an emission reduction of 69.6 per cent compared to the 1990 level, which also meets the NDC target in the energy sector. Figure 13 summarizes the SDG 7 indicators from three different main scenarios.

Figure 12 Emissions comparison for CP and SDG scenarios

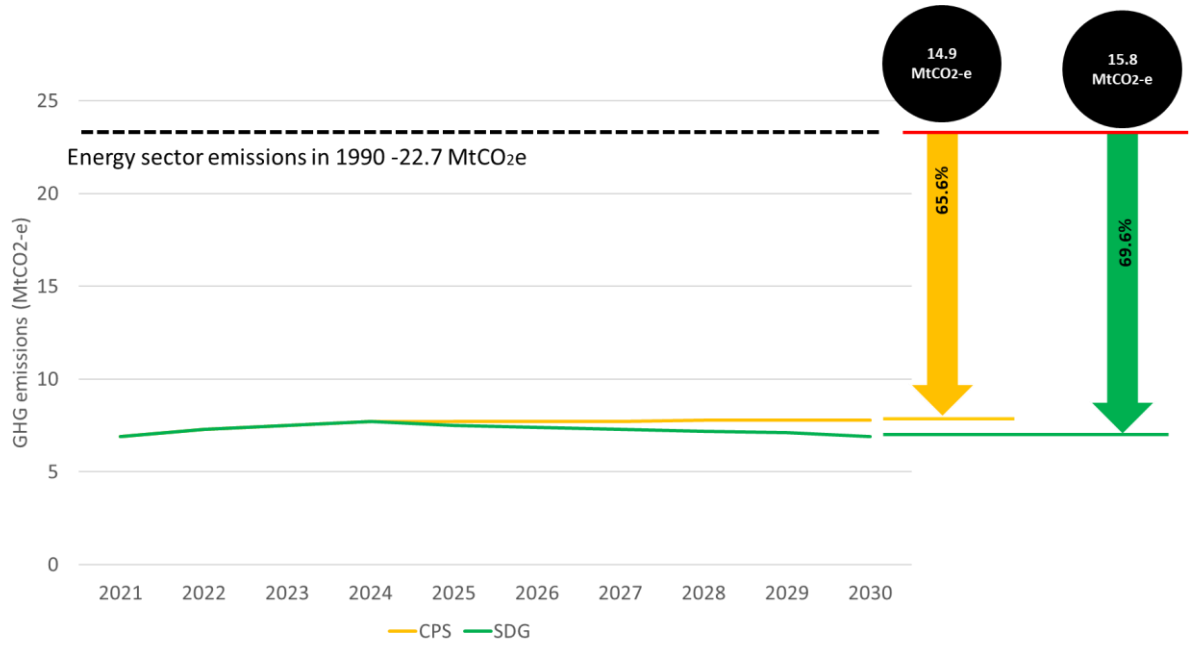
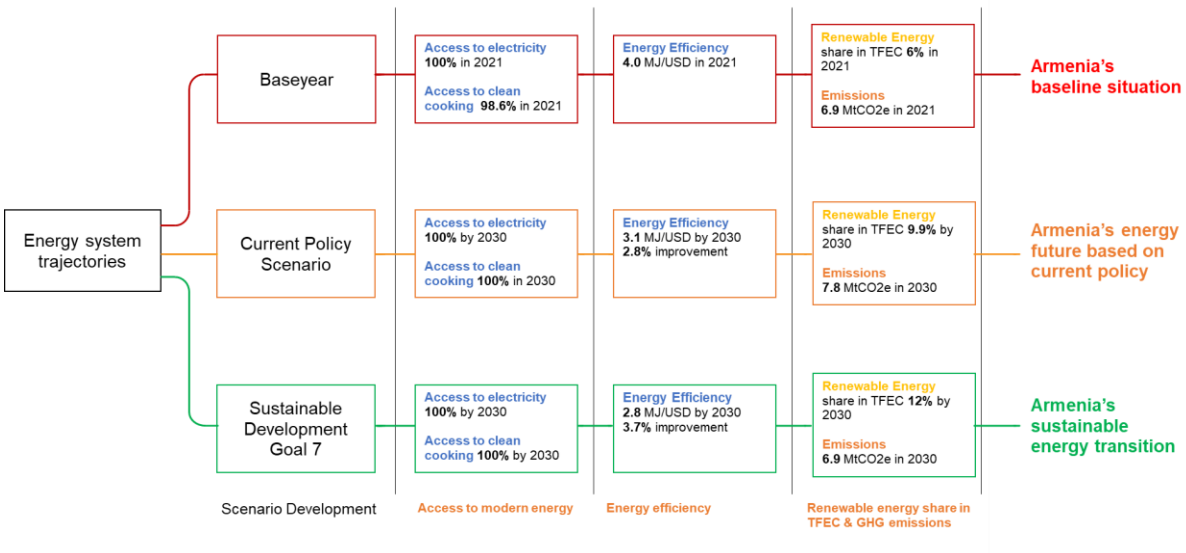


Figure 13 Summary of SDG 7 indicators for CP and SDG scenarios



7. Beyond 2030 Scenarios

As discussed in section 1, the following scenario has been developed, looking beyond 2030 to provide the Government of Armenia with information on how the country can raise its ambitions in the energy sector and align with future global goals and targets.

7.1. Towards Net Zero by 2050

This scenario explores challenges and opportunities for the Government of Armenia to align its energy sector in line with the global ambition of achieving net zero emissions by 2050. Various stringent measures across different sectors will need to be implemented as we move beyond 2030. On the demand side, the utilization of 100 per cent electric cook stoves will be needed to achieve by 2050 decarbonize the residential sector. The transport sector will need to adopt 100 percent e-mobility. In the commercial and industrial sectors, fuel switching has a significant role, particularly the switching from fossil fuels to electricity.

This scenario would reduce energy demand by around 2.1 Mtoe compared to the CP scenario in 2050. However, this scenario requires 49.4 TWh of electricity, an additional 31.5 TWh, compared to the CP scenario. Further implementation of energy efficiency would help reduce this electricity demand. In terms of supply, the power sector will need to be decarbonized; it is predicted that 0.3 GW of wind power plants, 34.5 GW of solar power plants, 1.4 GW of hydropower, and 0.1 GW of geothermal are required on top of 0.5 GW of nuclear is required to fulfil the rising electricity demand. In addition to this, 18 GW heat pump will be required to fulfill heat demand by 2050.

Figure 14 Comparison of energy demand by scenario in 2050

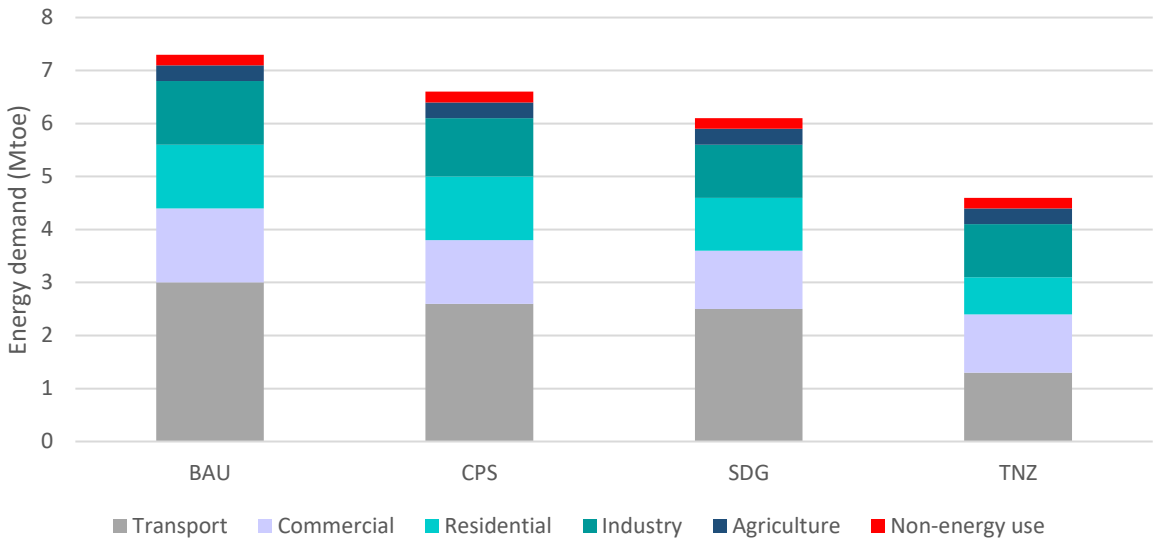
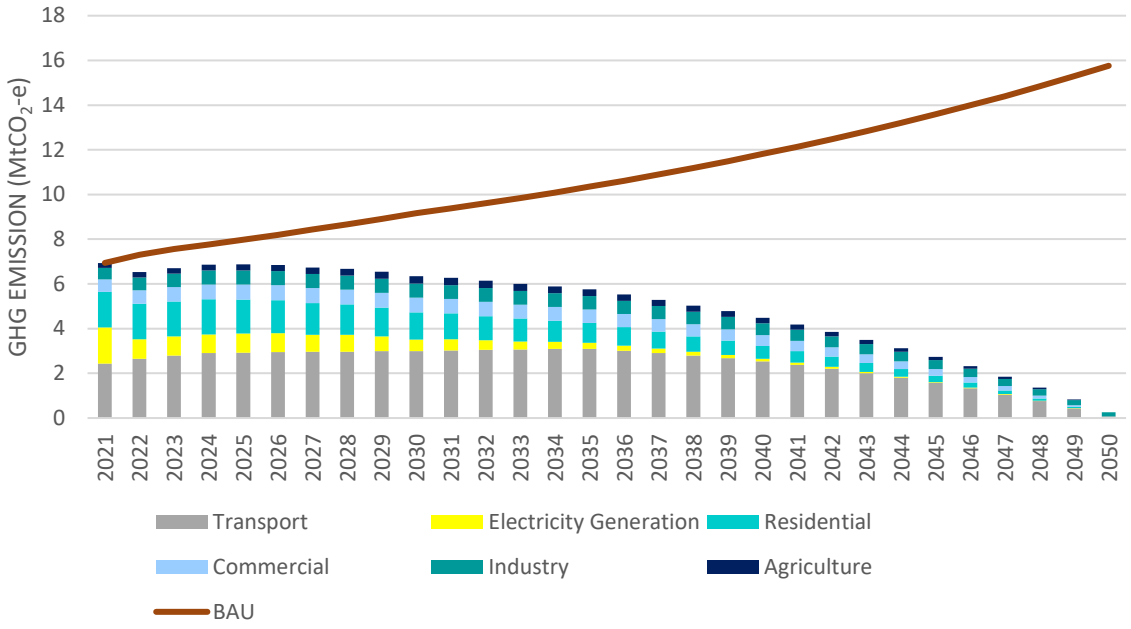


Figure 15 illustrates GHG emission under this scenario by 2050. It appears that there will be a significant emission reduction. However, due to certain limitations to implementing measurements in the transport and industry sectors, a small amount of emission would still be produced in this sector. Therefore, carbon sinks, such as reforestation or forest management, or other carbon capture technologies should be considered to absorb the remaining carbon emissions.

Figure 15 GHG emission in the demand sector 2022-2050 by sector, towards net zero scenario



The additional advantage of this scenario is that the energy security of Armenia will significantly increase due to its move to indigenous resources for energy generation – eliminating the need for energy imports.

8. Policy recommendations

- **Increasing the efficiency of energy use in all economic sectors should be pursued.** The presence of a national energy efficiency plan will help Armenia reduce its energy intensity by 2030. Armenia can further increase its energy reduction by 2030 through an additional implementation under the SDG scenarios. The residential sector is the most energy-consuming sector in Armenia. Therefore, the utilization of heat pumps for space heating in urban areas and electric heaters in rural areas will significantly help improve energy efficiency and reduce emissions. More aggressive MEPS adoption and improvement in thermal insulation in the residential sector can be implemented to achieve a more sustainable target. In addition to the residential sector, industry and commercial sectors might have significant energy-saving potential through deep retrofitting and motor replacement. The very high consumption of fossil fuels in Armenia will pose a major challenge should the country wish to pursue a net zero emissions pathway. Therefore, fuel-switching options might need to be further considered.
- **Transport electrification provides multi-fold benefits in the long run**. Vigorous adoption of electric vehicles reduces the demand for oil products, hence reducing Armenia's reliance on imported petroleum fuels. At the same time, it can contribute to climate mitigation and improve local air quality. Transport electrification would be critical to decarbonise the passenger transport sector by 2050. An adoption rate of 15 per cent of passenger cars has the potential to save energy by 68.9 ktoe and reduce emissions by 0.24 $MtCO_2$-e.

- **Decarbonisation of the power supply is the key to achieving net zero emissions by 2050.** Decarbonising the power sector is important to prevent emissions from shifting from one sector to the other when implementing policies, particularly on clean cooking and electric vehicles. This would also be needed if the country plans to move towards carbon neutrality or net zero by 2050. Decarbonisation attempts will require a substantial increase in renewable capacities, which could be challenging technically and economically, but they will offer multiple benefits, including reducing emissions and improving energy security through the utilization of indigenous resources. In terms of electricity supply, it is predicted that 0.3 GW of wind power plants, 34.5 GW of solar power plants, 1.4 GW of hydropower, and 0.1 GW of geothermal are required to fulfil the rising electricity demand.
- **Enabling policy measures are required to improve clean cooking by 2030.** Achieving access to clean cooking technologies will not be a challenge for Armenia since the gap is already small. The adoption of electric cookstoves by at least 20 per cent of the population will significantly help improve energy security and reduce emissions. The cost of deployment of electric cook stoves would require USD 21.7 million by 2030.

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