Energy Transition Pathways for the 2030 Agenda

SDG 7 Road Map for Armenia

Developed using National Expert SDG 7 Tool for Energy Planning (NEXSTEP)

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Acknowledgments

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Foreword

The United Nations Economic Commission for Europe (UNECE) and the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) extend their gratitude to the Ministry of Territorial Administration and Infrastructure for productive cooperation in shaping the SDG 7 Roadmap for Armenia. This document has been developed in the framework of the United Nations Development Account (UNDA) project "Strengthening energy policies of Countries with Special Needs to build back better from COVID-19" and it supports the Government's commitment to achieving the ambitious targets of the Sustainable Development Goal 7 (SDG 7) and the Paris Agreement. The SDG 7 Roadmap assesses existing policies and plans, identifies gaps, and provides recommendations for an enabling policy framework and technology interventions to ensure the attainment of these targets.

The key objective of this SDG 7 Roadmap is to align and synergize the Government of Armenia's energy policies and measures to achieve the SDG 7 and Nationally Determined Contribution (NDC) targets. The Roadmap contains a matrix of technology options and enabling policy measures for the Government to consider. It presents several scenarios that have been developed using national data, considering existing energy policies and strategies as well as reflecting on other development plans. These scenarios are expected to enable the Government to make an informed decision to develop and implement a set of policies to achieve SDG 7 by 2030, together with the NDC.

With the presence of multiple enabling frameworks, Armenia's progress towards achieving the SDG 7 and NDC targets is promising. Armenia has achieved universal access to electricity in recent years. The current pace will be enough to close the clean cooking access gap by 2030. In Armenia, electricity is mainly generated by nuclear, hydro and thermal power plants. Armenia depends heavily on natural gas in its energy system, with a low share of renewable energy. However, renewable energy capacity is expected to increase to almost 53 per cent by 2030, meeting the 50 per cent renewable capacity target, since a significant amount of solar and wind generation capacity will come on stream. The extension of the operational lifetime of the Armenian Nuclear Power Plant (ANPP) Unit 2 after 2026 is among the main priorities of the Government of Armenia along with the construction of a new nuclear power plant upon the expiration of the term. Armenia's energy efficiency plans might significantly improve the energy intensity. Following the SDG 7.3 energy efficiency definition, Armenia's energy intensity is expected to be 2.8 MJ/US$2017 in 2030 under the current policy scenario. The National Expert SDG Tool for Energy Planning (NEXSTEP) applied to the development of this Roadmap analysis identifies that Armenia can even further lower its energy intensity to 2.7 MJ/US$2017 in order to align with the global energy efficiency improvement rate of 4 per cent per annum.

In addition to a highly efficient energy system, a faster transition towards cleaner energy sources, especially renewables in both electricity and heat generation, will help Armenia to reach Net Zero GHG Emissions by 2050. This, however, requires an ambitious effort to switch from a fossil fuel-based energy system to one based on renewables. Electrification of existing technologies, such as vehicles and cookstoves, will be a necessity in the long run. A deeper analysis indicates that the lifecycle cost of renewables-based power generation is already cheaper than fossil-fuel energy.

The Roadmap sets out the following four key policy recommendations to help Armenia achieve the SDG 7 targets as well as reduce reliance on imported energy sources: 1) Strong policy measures are required to address the gap in clean cooking by 2030; 2) Accelerating the efficiency of energy use in all economic sectors should be pursued; 3) Fuel switching strategies, including electrification, accelerate SDG 7 progress and provide multiple benefits in the long run; and 4) Decarbonisation of the power and heating supply provides the highest potential in GHG emission reduction as well as improvement of energy security.

UNECE and ESCAP express their unwavering commitment to assisting Armenia in delivering a secure, resilient and sustainable energy future.

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Abbreviations and acronyms

ADB	Asian Development Bank
BAU	business-as-usual
BESS	battery and energy storage system
CBA	cost benefit analysis
CO_2	carbon dioxide
CPS	current policy scenario
EE	energy efficiency
EERF	Energy Efficiency Revolving Fund
ERC	Energy Regulatory Commission
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
ESCO	energy services companies
EV	electric vehicle
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt
ICS	improved cooking stove
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producers
IRENA	International Renewable Energy Agency
ktoe	thousand tonnes of oil equivalent
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LEAP	Low Emissions Analysis Platform
LED	light-emitting diodes
LPG	liquified petroleum gas
MCDA	Multi-Criteria Decision Analysis
MEPS	minimum energy performance standard
MJ	megajoule
MoE	Ministry of Energy
MTF	Multi-Tier Framework
Mtoe	million tonnes of oil equivalent
MW	megawatt
NDC	nationally determined contributions
NEXSTEP	National Expert SDG Tool for Energy Planning
OECD	Organisation for Economic Co-operation and Development
PP	power plant
RE	renewable energy
SDG	Sustainable Development Goal
SPP	small power producers
TFEC	total final energy consumption
TPES	total primary energy supply
TWh	terawatt-hour
UNDA	United Nations Development Account
UNEP	United Nations Environment Programme
US$	United States dollar
VSD	variable speed drive
WHO	World Health Organization

Executive Summary

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure sustained economic growth as well as respond to increasing energy demand, reduce emissions, and consider and capitalize on the interlinkages between SDG 7 and other SDGs. To address this challenge, ESCAP has developed the National Expert SDG Tool for Energy Planning (NEXSTEP).[1] This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as nationally determined contributions (NDCs). The initiative has been undertaken in response to the Ministerial Declaration of the Second Asian and Pacific Energy Forum (April 2018, Bangkok) and Commission Resolution 74/9, which endorsed its outcome. NEXSTEP also garnered the support of the Committee on Energy in its Second Session, with recommendations to expand the number of countries being supported by this tool.

Under the United Nations Development Account (UNDA) project "*Strengthening Energy Policies of Countries with Special Needs to Build Back Better from COVID-19*", ESCAP and UNECE have collaborated to develop SDG 7 Road Map for Armenia. The key objective of this SDG 7 Road Map[2] is to assist the Government of Armenia in assessing whether the existing policies and strategies are well aligned to achieving the SDG 7 and NDCs targets by 2030. This Road Map presents three core scenarios (BAU, CPS and SDG scenarios) that have been developed using national data, which consider existing energy policies and strategies and reflect on other development plans. This Road Map also investigates one ambitious scenario: the Toward Net Zero by 2050 scenario offers policymakers a strategic viewpoint on how Armenia could plan for a carbon-free energy pathway in alignment with the global race to net zero carbon.

A. Highlights of the Road Map

With the presence of multiple enabling frameworks, Armenia's progress towards achieving the SDG 7 and NDC targets is promising. In terms of access to modern energy, Armenia has achieved universal access to electricity in recent years. The current pace will be enough to close the clean cooking access gap by 2030. However, Armenia can strengthen their measures for universal access to clean cooking technology by 2030. One option for Armenia is to explore using highly energy-efficient induction-type electric cooking stoves, particularly in areas with sufficient electricity supply. In Armenia, electricity is mainly generated by nuclear, hydro and thermal plants whereof 39% is generated by the nuclear power plant while the remaining 60% is almost generated equally by hydro and thermal plants. The share of all the other plants in the power system is quite low - up to 1%. Armenia depends heavily on natural gas in its energy system, causing a low share of renewable energy in the system. Renewable energy capacity is expected to be 52.9 per cent by 2030 meeting the 50 per cent renewable capacity target

[1] The NEXSTEP tool has been specially designed to perform analyses of the energy sector in the context of SDG 7 and NDC, with the aim that the output will provide a set of policy recommendations to achieve the SDG 7 and NDC targets.

[2] This Road Map examines the current status of the national energy sector and existing policies, compares them with the SDG 7 targets, and presents different scenarios highlighting technological options and enabling policy measures for the Government to consider.

since a significant amount of solar and wind generation will be in operation in Armenia. The extension of the operational lifetime of ANPP Unit 2 after 2026 is of the main priorities of the RA Government and the construction of a new nuclear power plant upon the expiration of the term is the main objective.[3] Armenia's energy efficiency plans might significantly improve the energy intensity. Following the SDG 7.3 energy efficiency definition, Armenia's energy intensity is expected to be 2.8 MJ/US$$_{2017}$ in 2030 under the current policy scenario. NEXSTEP analysis identifies that Armenia can even further lower its energy intensity to 2.7 MJ/US$$_{2017}$ in order to align with the global energy efficiency improvement rate of 4 per cent per annum.

In addition to highly efficient energy system, a faster transition towards cleaner energy sources, especially renewables in both electricity and heat generation, will help Armenia to reach Net Zero GHG Emissions by 2050. This, however, requires an ambitious effort to switch fossil fuel-based energy systems to renewables. Electrification of existing technologies, such as vehicles and cookstoves, will be a necessity in the long run. A deeper analysis indicates that the lifecycle cost of renewables-based power generation is already cheaper than fossil-fuel energy.

B. Achieving Armenia's SDG 7 and NDC targets by 2030

1. Universal access to electricity

Armenia has achieved universal electricity access by 2021. There is a possibility that a small proportion of unelectrified households that exist may be unregistered. In such cases, it is suggested that mini/off-grid systems technologies (i.e., solar mini-grid and solar home systems) would be the more appropriate technologies, based on the technologies' cost-effectiveness and climate resiliency while allowing faster implementation than the grid extension.

2. Universal access to clean cooking technology

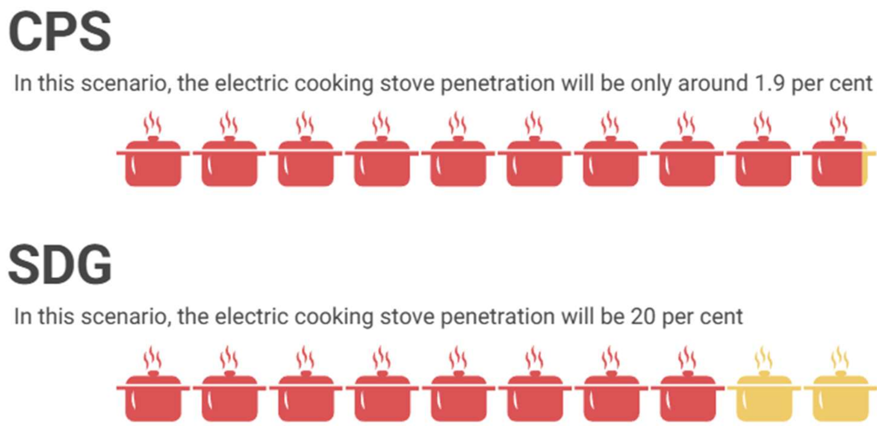
Under the current policy settings, clean cooking access is projected to reach 100 per cent by 2030 from 98.6 per cent in 2021 (figure ES 1). Natural gas is expected to help close the remaining gap in the current policy scenario since natural gas has a significant role in Armenian households, including heating energy. The current electricity tariff also makes the natural gas stove more competitive than the electric stove. The natural gas stove is expected to account for 98.1 per cent of clean cooking share, while electric cookstoves will be only 1.9 per cent.

However, since Armenia imports natural gas, this situation might cause a challenge for energy security in the long run. NEXSTEP suggests that electric cook stoves might provide the most appropriate solution for Armenia due to their reliability and environmental effectiveness. This technology has also

[3] Strategic Plan for the Development of the Energy Sector of the Republic of Armenia (until 2040) (2023).

been adopted widely in the country. In the SDG scenario, at least 20 per cent of the population or around 0.14 million households, is suggested to adopt electric cook stoves by 2030 (Figure ES1).

Figure ES 1. Armenia's access to clean cooking under the CPS and SDG scenarios



3. Renewable energy

The share of modern renewable energy (excluding traditional biomass usage in residential cooking) in the total final energy consumption (TFEC – including non-energy use) was 6 per cent in 2021. Based on current policies, the share of renewable energy is projected to increase to 10.3 per cent by 2030. The increase is due to the projected increase in renewable electricity as per current expansion plan. In the SDG scenario, the share of renewable energy is projected to increase to 10.9 per cent of TFEC in 2030. The additional 0.6 percentage point increase can be attributed to phasing out traditional biomass usage as well as further energy efficiency improvements to reach a lower energy intensity. Although the share of renewable energy increases, natural gas will still dominate the energy system in Armenia.

In terms of renewable energy in power generation, Armenia aims to reach at least 50 per cent renewable capacity by 2050. Armenia is on track to achieve 52.1 per cent of renewable capacity (including hydropower) as long as the expansion plan is implemented. The government must ensure that funding can be secure to ensure the operation commences within the remaining five years until 2030.

4. Energy efficiency

Under the SDG 7.3 targets, energy intensity 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. Energy intensity in Armenia has declined at an average annual rate of 7.3 per cent between 1990 and 2010. 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. However, between 2010 and 2021, the annual improvement rate was only around 0.1 per cent. To reach the expected 2030 intensity, the annual improvement rate between 2021 and 2030 must be around 29.7 per cent, which is quite challenging. Therefore, NEXSTEP analysis suggests that Armenia's energy intensity target to be aligned with the global target of 4 per cent annual improvement (IEA, IRENA, UNSD, World Bank, WHO, 2023). This corresponds to a 2030 energy intensity target of 2.7 MJ/US$$_{2017}$.

Under CPS, the energy intensity is projected to drop to only 2.8 MJ/US$$_{2017}$. This translates to a 3.6 per cent annual improvement rate. Armenia can further reach an energy intensity of 2.7 MJ/US$$_{2017,}$ aligning with the global energy efficiency improvement rate of 4 per cent per annum, by implementing some global best practices, such as MEPS, energy management standards, and green building code. In addition, electric vehicle and electric cooking stove might provide additional demand reduction in Armenia energy system.

5. Nationally determined contribution

Armenia's updated Nationally Determined Contribution (NDC) sets ambitious targets to reduce greenhouse gas (GHG) emissions by 40 per cent compared to the 1990 emissions by 2030 (Government of The Republic Of Armenia, 2022)**.** Armenia will be able to achieve this target by 2030. Emissions will reach 7.9 MtCO2-e in 2030, a 14.8 MtCO2-e (65.2 per cent) reduction compared to the 1990 level. The decrease in GHG emissions, relative to the BAU, is due to the increase in renewable share in electricity supply according to the existing capacity expansion plan. Raising the implementation of energy-saving measures in order to align with the global improvement target of 4 per cent will further reduce a significant amount of emissions. In the SDG scenario, total emissions will reach 7.4 MtCO2-e by 2030, corresponding to a 15.3 MtCO2-e (or a 67.3 per cent) reduction compared to the 1990 level.

C. Increasing ambition beyond SDG 7

A well-planed and concerted effort must be undertaken by the Government of Armenia to reach net zero emissions by 2050. Achievement of this target will require decarbonization of the energy sector. This is best done in the following two steps (a) decarbonizing the power and heat sector and (b) switching all energy consumption to renewables and electricity. Fortunately, the energy system of Armenia is well-positioned for an accelerated decarbonization effort since many of the required net zero technologies, such as renewable power generation, electric cook stoves and electric vehicles, are mature and readily available technologies. Due to certain limitations to implementing measurements in the transport sectors, however, a small number of emissions would still be produced. Therefore, carbon sinks, such as reforestation or forest management, or other carbon capture technologies should be considered to absorb the remaining carbon emissions.

D. Important policy directions

The Road Map sets out the following four key policy recommendations to help Armenia achieve the SDG 7 targets as well as reduce reliance on imported energy sources:

(1) **Strong policy measures are required to address the gap in clean cooking by 2030.** Increasing the adoption of electric cook stoves will significantly help improve clean cooking access. The cumulative deployment cost of both technologies would require US$ 23.8 million altogether by 2030. In the long run, the deployment of electric book stoves will also help Armenia achieve the net zero emissions targets.

(2) **Accelerating the efficiency of energy use in all economic sectors should be pursued.** Armenia needs to enhancing and strengthen its energy saving measures to align it with the 4

per cent global improvement pathway. These can be done by implementing best practice, such as energy management standard, building energy codes, mode shifting, and fuel economy improvement, in the years to 2030. Further can be done to eliminate inefficient and unclean heating technology while simultaneously improve thermal insulation. It is unavoidable that these measures require international assistance since the target will be more ambitious compared to the existing plan.

(3) **Fuel switching strategies, including electrification, accelerate SDG 7 progress and provide multi-fold benefits in the long run.** The electrification of end uses would be critical to decarbonise the entire economy by 2050. Since electrical equipment is more efficient compared to fossil-fuel based equipment, this will significantly reduce fossil fuel demand. Rapid adoption of electric vehicles, for instance, reduces the demand for oil products, hence reducing Armenia's reliance on imported petroleum fuels. The government might start putting an electric vehicle target for passenger cars and buses by 2030. Electrification of energy demand as well as higher adoption of efficient system will reduce the investment in renewable energy systems.

(4) **Decarbonisation of the power and heating supply provides the highest potential in GHG emission reduction as well as improvement of energy security.** In both ambitious scenarios, a projected decrease in grid emissions can realize a substantial GHG emission reduction. NEXSTEP analysis suggests that the lifecycle costs of renewables, such as hydropower, solar, and wind, are cheaper than fossil-fuel technologies. The underlying financial risks of investment in coal-based power plants should not be ignored. Fulfilling the required capacities net zero scenarios could be challenging technically and economically, yet these investments will help improve energy security through the utilization of indigenous resources. The government may consider renewable energy auctions and/or carbon tax. NEXSTEP analyses that a minimum carbon cost of around US$ 79.5/ tonne CO_2-e is needed to cover the required investment.

1. Introduction

1.1. Background

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure sustained economic growth, respond to increasing energy demand, reduce emissions as well as consider and capitalise on the interlinkages between SDG 7 and other SDGs. In this connection, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as nationally determined contributions (NDCs) emission reduction targets. The initiative has been undertaken in response to the Ministerial Declaration of the Second Asian and Pacific Energy Forum (April 2018, Bangkok) and Commission Resolution 74/9 which endorsed the meeting's outcome. NEXSTEP also garnered the support of the Committee on Energy in its Second Session, with recommendations to expand the number of countries being supported by this tool. The ministerial declaration advises ESCAP to support its member States, upon request, in developing national SDG 7 Road Maps.

The Government of Armenia has expressed its interest in developing the SDG 7 Road Map to better understand if the existing policies and strategies are well aligned to achieving the SDG 7 targets by 2030. The objective of this SDG 7 Road Map developed in the framework of the United Nations Development Account (UNDA) project "*Strengthening energy policies of Countries with Special Needs to build back better from COVID-19*" by ESCAP and UNECE is to assist the Government of Armenia in developing enabling policy measures to achieve the SDG 7 and NDC targets as well as set the course of the energy sector towards Net Zero Emissions by 2050.

1.2. SDG 7 targets and indicators

SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. It has three key targets, which are outlined below.

• Target 7.1. "By 2030, ensure universal access to affordable, reliable and modern energy services." Two indicators are used to measure this target: (a) the proportion of the population with access to electricity and (b) the proportion of the population with primary reliance on clean cooking fuels and technology.

• Target 7.2. "By 2030, increase substantially the share of renewable energy in the global energy mix". This is measured by the renewable energy share in TFEC. It is calculated by dividing energy consumption from all renewable sources by total energy consumption. Renewable energy consumption includes the consumption of energy derived from hydropower, solid biofuels (including traditional use), wind, solar, liquid biofuels, biogas, geothermal, marine and waste. Due to the inherent complexity of accurately estimating the traditional use of biomass, NEXSTEP focuses entirely on modern renewables for this target.

• Target 7.3. “By 2030, double the global rate of improvement in energy efficiency”, as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the International Energy Agency (IEA), TPES is made up of production plus net imports, minus international marine and aviation bunkers, plus stock changes. For comparison purposes, GDP is measured in constant terms at 2017 PPP.

In addition to the above-mentioned targets, the SDG 7 goal includes target 7. A – promote access, technology and investments in clean energy, and target 7. B – expand and upgrade energy services for developing countries. These targets are not within the scope of NEXSTEP.

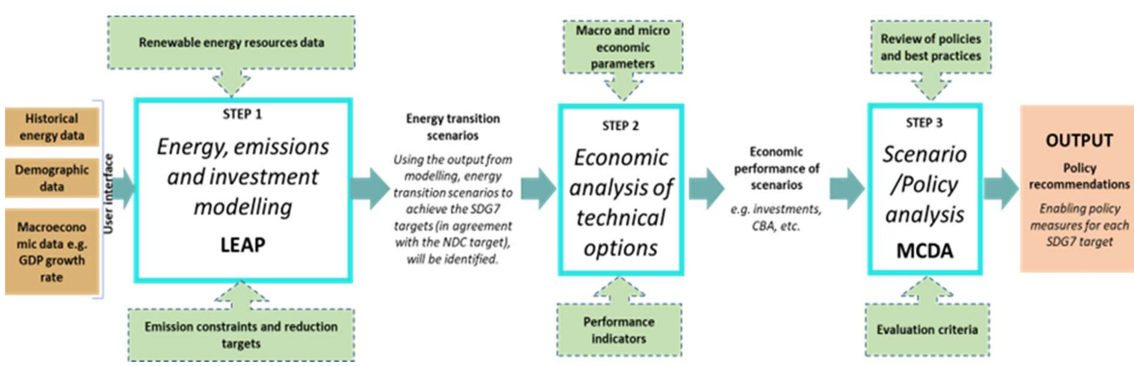
1.3. Nationally Determined Contribution (NDC)

NDCs represent pledges by each country to reduce national emissions and are the stepping-stones to the implementation of the Paris Agreement. Since the energy sector is the largest contributor to GHG emissions in most countries, decarbonising energy systems should be given a high priority. Key approaches to reducing emissions from the energy sector include increasing renewable energy in the generation mix and improving energy efficiency. In its NDC document, Armenia has pledged to reduce GHG emissions by 40 per cent compared to the emissions in 1990 (Government of The Republic of Armenia, 2022).

1.4. NEXSTEP methodology

The main purpose of NEXSTEP is to help design the type and mix of policies that would enable the achievement of the SDG 7 targets and the emission reduction target (under NDCs) through policy analysis. The tool helps modelling energy, emissions and economics to analyse a range of policies and options for their suitability. This tool is unique in a way that no other tools look at developing policy measures to achieve SDG 7. One key feature of this tool is the back-casting approach to energy and emissions modelling, which is important in planning for SDG 7, where the trajectory is developed backwards from the (known) 2030 targets to the present day. Figure 1 shows components of the methodology.

Figure 1. Components of the NEXSTEP methodology



1.4.1. Energy and emissions modelling

The NEXSTEP analysis begins by developing a model of the energy system for each scenario, defining the technical options in terms of the final energy (electricity and heat) requirement for 2030, possible generation/supply mix, emissions and the size of investment required. The energy and emissions modelling component uses the Low Emissions Analysis Platform (LEAP) tool.[4] This widely used proprietary software is used by many countries to develop scenarios for the energy sector, policy analysis and develop NDC targets.

1.4.2. Economic analysis

The second step builds on the selection of appropriate technologies through an economic optimisation process that identifies the least-cost energy supply options for the country. A comparative assessment of selected power generation technologies is done using the Levelized Cost of Electricity (LCOE) as an economic indicator. This provides policymakers with insights into the costs and benefits of economically attractive technology options, allowing better allocation of resources and better-informed policy decisions. While the economic analysis has been kept to a simple level, it contains enough information to support policy recommendations in this Road Map. Some key cost parameters used in this analysis are (a) capital cost, including land, building, machinery, equipment, and civil works, and (b) operation and maintenance costs, such as fuel, labour, and maintenance costs.

1.4.3. Scenario analysis

The scenario analysis evaluates and ranks scenarios using the Multi Criteria Decision Analysis (MCDA) tool, with a set of criteria and weights assigned to each criterion. Although the criteria considered in the MCDA tool can include the following, stakeholders may wish to add/remove criteria to suit the local context:

- Access to clean cooking fuel
- Energy efficiency
- Share of renewable energy
- Emissions targets in 2030
- Alignment with the Paris Agreement
- Fossil fuel subsidy phased out
- Price of carbon
- Fossil fuel phase-out
- Cost of access to electricity
- Cost of access to clean cooking fuel
- Investment cost of the power sector
- Net benefit from the power sector

[4] Developed by the Stockholm Environment Institute https://leap.sei.org/

This step is performed using the NEXSTEP online portal,[5] to suggest the best way forward for the countries by prioritising the scenarios. Stakeholders can update this scenario ranking using a different set of criteria and their weights. The top-ranked scenario from the MCDA process is used to inform the Government on the best possible energy transition pathway for the country.

1.5. Data sources

The primary source of data collection has been from Government databases and reports. Some data have been collected directly from Government agencies through a formal letter of request from the Ministry of Territorial Administration and Infrastructure of the Republic of Armenia. In a few instances where Government data were unavailable, research papers and analyses have been consulted. The final dataset has been presented to and approved by the Ministry.

[5] Available at https://nexstepenergy.org/

2. Country overview

2.1. Demographic and macroeconomic profile

Armenia is a landlocked country in West Asia, bordered by Iran to the south, Georgia to the north, Azerbaijan to the east, and Turkey to the west. The country occupies a total area of 29,743 km^2. Armenia has a wide seasonal temperature variation, with temperatures as high as 36^o Celsius in summer and as low as -10^o Celsius in winter.

In 2021, the country had a population of 2.96 million people, with an estimated 0.76 million households, which amounted to an average of 3.9 persons per household.[6] The annual population growth rate was around -0.52 per cent between 2020 and 2021, showing a reduction in the population in Armenia due to emigration. The urbanisation rate in 2021 was around 67.3 per cent.[7] The country's capital, Yerevan, is the most populous city, with around 1.1 million people.

Armenia's GDP in 2021 was estimated at US$ 13.88 billion (constant 2015 US$), a significant growth of 5.8 per cent from the value of 2020. Over the ten-year period between 2011 and 2021, the GDP growth rate averaged 3.6 per cent. The GDP per capita has increased from just US$ 3,043 in 2011 to US$ 4,527 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.

2.2. Energy sector overview

2.2.1. National energy profile in the baseline year 2021

The following details describe the estimated national energy consumption using data from a bottom-up approach, such as activity level and energy intensity for the different sectors. The bottom-up estimation generally agrees with the national energy statistics in terms of total energy supply and total final energy consumption by fuel type. The baseline year 2021 has been chosen based on the latest year for which all data points are available.

Energy demand: In 2021, the total final energy consumption (TFEC[8]) was around 2.84 Mtoe (Figure 2). Most of the demand came from the residential sector (33.8 per cent), followed by the transport sector (31.7 per cent). The third largest consumption was the commercial sector, estimated at 15.3 per cent or 0.43 Mtoe. The industry sector consumed 13.1 per cent and the agricultural sector 3.6 per cent. The remaining goes to non-energy use.

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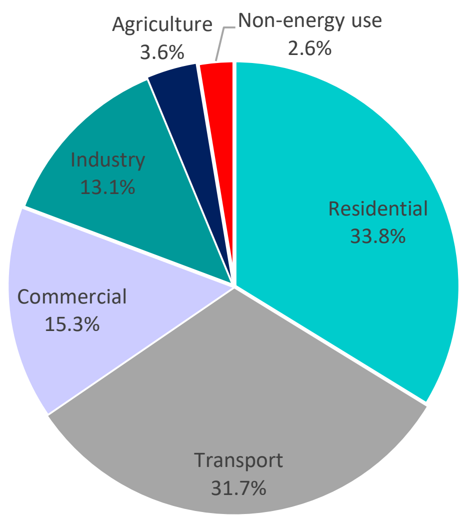
[6] based on the data provided by the Ministry of Territorial Administration and Infrastructure through national consultants

[7] based on the data collection provided by the national consultant. The value is slightly higher compared to the data presented in The World Bank (2024)

[8] This includes residential, commercial, industry, transport, agriculture, and non-energy use sectors.

In terms of fuel usage in TFEC, natural gas accounted for the highest share, at 54.6 per cent. Natural gas is the main energy source of Armenia, and its consumption occurs in all sectors. In the second position, oil products accounted for 21.2 per cent of energy consumption, followed by electricity at 19 per cent. The transport sector, which operated predominantly with internal combustion engine vehicles, was the main consuming sector for oil products. In terms of biomass, traditional biomass use was around 4.3 per cent and consumed mainly in the residential sector. The remaining demand went for district heating and coal consumption.

Figure 2.**Total final energy consumption by sector in 2021**



In the residential sector, around 62.8 per cent of energy was consumed for heating purposes (0.6 Mtoe). Heating demand in Armenia is quite high since the country experiences a long and cold winter season. Around 34.6 per cent of the population used fuelwood for heating (15.5 per cent in urban area and 74 per cent in rural area). Gas boilers were used by around 27.9 per cent of the population. Gas and electric heaters were used by 24.1 per cent and 10.1 per cent of the population, respectively. Only 1.6 per cent of the population uses coal boilers. Homemade biogas accounted for one per cent, while district heating accounted for 0.7 per cent. Cooking activities consumed around 21.1 per cent of residential energy demand. The distribution of cooking technology will be discussed later in section 2.2.2. 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.

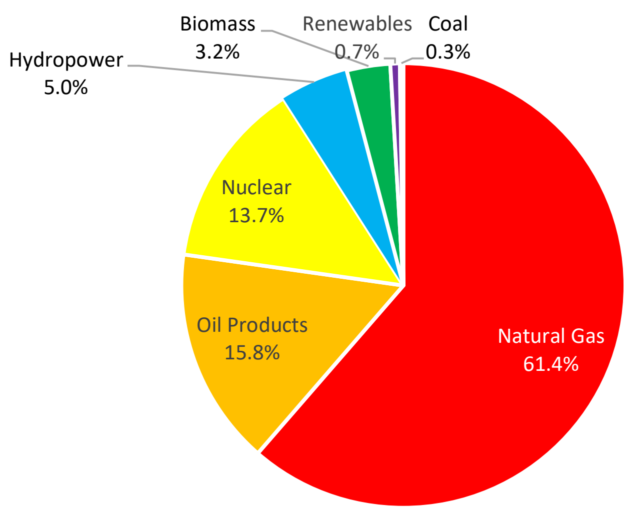
Within the transport sector, 99.2 per cent of energy was consumed by road transport. Around 0.7 per cent was consumed by rail, metro, and other electrical transport. The remaining 0.1 per cent went to the aviation sector. Within the road transport category, 41.7 per cent of energy was used by passenger cars, followed by trucks and vans, at 36.2 per cent and 10 per cent, respectively. Buses accounted for 9.8 per cent of the energy demand. The remaining went for taxis, minibuses, and motorcycles.

The service and commercial sector analysis is usually based on floor space and the energy intensity per square metre of various sub-sectoral activities. However, due to the limited 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, non-ferrous metal, and non-metallic minerals – 32.2 per cent and (2) food and beverages – 21.3 per cent. 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 industries.

Primary energy supply: The total primary energy supply (TPES) in 2021 was around 3.75 Mtoe (Figure 3). The energy supply mix was as follows: natural gas was 61.4 per cent, oil products 15.8 per cent, nuclear 13.7 per cent, hydropower 5 per cent, biomass 3.2 per cent, and renewables 0.7 per cent

Figure 3.Total primary energy supply by sector in 2021



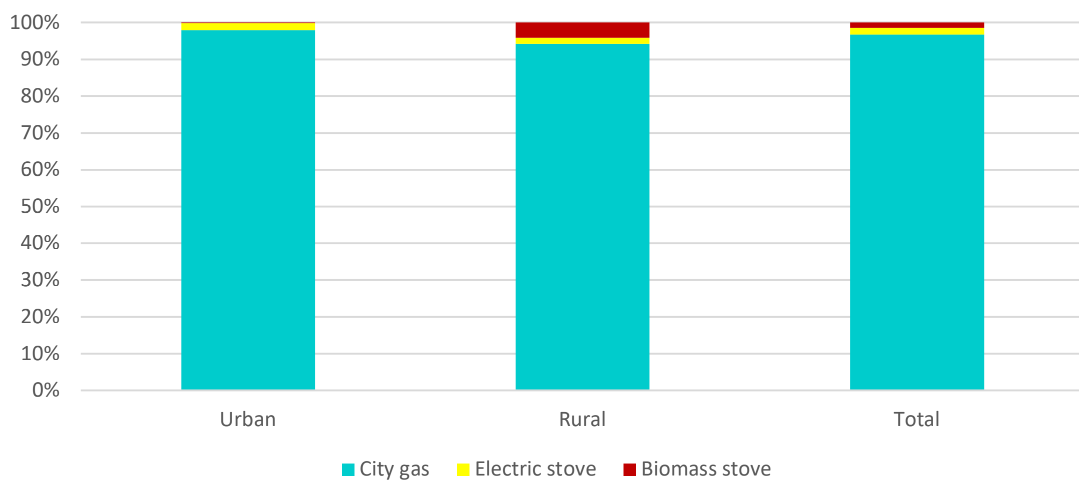
Electricity and heat generation: The total installed power generation capacity was 4,052.3 MW in 2021. Regarding capacity mix, natural gas accounted for 51.5 per cent of the capacity, while nuclear accounted for 11.1 per cent. Renewables accounted for 37.5 per cent of capacity, of which large hydropower was 33.2 per cent, solar was 4.2 per cent, and wind was 0.1 per cent.

The total electricity generation was 7.9 TWh in 2021. Thermal power plants accounted for 43 per cent of power generation, followed by the nuclear power plant at 25.4 per cent. The remainder came from renewable energy (hydropower 27.9 per cent and solar and wind 3.7 per cent). Total heat generation in 2021 was 15.7 ktoe from natural gas-fired CHP.

2.2.2. 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. As of 2021, 98.6 per cent[9] of the population relied on clean fuel and technologies, 99.9 per cent in urban areas, and 95.9 per cent in rural areas. The remaining 1.4 per cent of the population, corresponding 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, estimated at 1.8 per cent. Figure 4 shows the distribution of different cooking fuels and technologies in 2021.

Figure 4. 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 8.9 per cent of TPES. If the traditional biomass usage in the residential sector was excluded, the renewable share was 6 per cent of TFEC. While endowed with abundant renewable potential, Armenia relies on fossil fuels (i.e., natural gas and oil products) to meet its stationary and mobile energy demands.

Energy intensity: Energy intensity under SDG 7.3 is defined as the total primary energy supply (TPES) in megajoules per USD of gross domestic product in terms of power purchase parity in 2017. Armenia's energy intensity in 2021 is estimated to have been 3.9 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

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

3.9 MJ/USD_{2017}. The corresponding figure at the global level was 7.1 MJ/USD_{2017} and 5.6 MJ/USD_{2017} in 1990 and 2010, respectively.

GHG emissions: The energy sector emissions from fossil fuel combustion 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 6.94 MtCO2-e in 2021. Emissions from the transport sector were the largest at 2.43 $MtCO_2$-e, rising from direct fuel combustions in internal combustion engines. It is followed by the power generation sector at 1.62 $MtCO_2$-e. The emissions from the residential sector were 1.59 $MtCO_2$-e, coming from natural gas and biomass combustions for cooking and space heating. The emissions attributable to the commercial sector were estimated at 0.56 $MtCO_2$-e. Industrial and agriculture sector emissions were around 0.74 $MtCO_2$-e altogether.

2.2.3. National energy policies, plans, strategies and institutions

Armenia's energy sector is governed by several stakeholders. These include the Ministry of Territorial Administration and Infrastructure (MTAI), the Public Service Regulatory Commission (PSRC), and the Committee on Nuclear Safety Regulation (ANRA). MTAI is responsible for planning, managing, and coordinating the energy sector. PSRC is an independent government body that regulates tariffs, licensing, and investment in electricity and gas networks. ANRA is overseeing nuclear safety and regulations. The main provider of energy-related data and statistics is The Statistics Committee (ArmStat) (IEA, 2022).

Armenia's energy sector development is guided by several national policies and articles of legislation. These have been used as guiding references for the NEXSTEP modelling to better understand the country context and to develop recommendations in adherence to the 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.[10] The key policies and strategic documents consulted are detailed below.

- **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 modernisation of the public administration and governance. The strategy prioritizes the maximisation of RE use, promoting EE in all sectors, and diversifying energy supply and

[10] Only policies with concrete measures are considered in the scenario modelling for the current policy scenario. plan/strategy policy documents without concrete measures enforced are not considered but are compared with scenario result findings.

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.

- **Strategic Plan for the Development of the Energy Sector of the Republic of Armenia (until 2040)** (Government of the Republic of Armenia, 2023) 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 realising small hydro potential, mostly after 2000, the focus has shifted to solar energy and wind. Armenia is developing solar energy capacity from 59.57 MW to 1000 MW before 2030 to increase green energy share and energy security (at least 50 per cent renewable including large hydropower 2030 in the power generation mix and about 60 per cent by 2040). Around 500 MW of solar will be built between 2030 and 2040 and 500 MW of wind between 2025 and 2040. Therefore, total solar and wind will reach 2,000 MW by 2040.
- **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 liberalise 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 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 also targets 40 MW of solar (PV) by 2020 and 80 MW by 2025.
- **The European Union-Armenia Comprehensive and Enhanced Partnership Agreement (CEPA)** (European Union and the Government of the Republic of Armenia, 2021) includes promoting the use of renewable energy sources, energy efficiency and energy savings.
- **The National Programme on Energy Saving and Renewable Energy for the period 2022-2030/RA Government Decision No. 398-L** (Government of the Republic of Armenia, 2022) sets out the action plan ensuring implementation of the program's first phase (2022-2024) on

energy saving and renewable energy for 2022-2030. The plan sets the following indicators for primary energy supply of around 4.5 Mtoe in 2024, 4.9 Mtoe in 2027 and 5.3 Mtoe in 2030 while final energy consumption of around 3.2 Mtoe in 2024, 3.5 Mtoe in 2027 and 3.8 Mtoe in 2030. The project aims to achieve at least 15 per cent of solar energy production by 2030, with around 300 MW (1200 MWh) battery capacity. The energy saving will be around 20 per cent compared to the baseline scenario, and the GHG emissions will decrease by about 50 per cent compared to the value in 1990. The share of electric passenger cars will gradually increase, reaching at least 10 per cent in 2030 while the share of electric public transport will reach 50 per cent in 2030. There will be energy efficiency improvement by 70 per cent of public transport due to the new route introduction. This will increase the share of public transport to 60 per cent.

- **Long-Term Low Greenhouse Gas Emission Development Strategy of The Republic of Armenia (Until 2050)/RA Government Decision No. 2318-L** (Government of the Republic of Armenia, 2023) sets implementation based on the best practices and active participation to reduce greenhouse gas emissions by replacing current nuclear reaching a capacity of 1,060 MW. The capacity of solar PV will be 1,500 MW and wind will be 500 MW. Small hydropower will be around 450 MW in addition to the operation of the current construction, with a total of 211 MW. The number of electric vehicles will be between 200,000 and 400,000 in 2050.
- **The 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 use of renewable energy, efficiency measures in the building sector, efficiency of public transport, stimulation and support in the uptake of electric vehicles.

2.2.4. National energy resources and potentials

Natural gas is the main fuel used for electricity and heat generation in Armenia. Unfortunately, Armenia has no natural gas resources, where most imported supply is coming from Russia and Iran (IEA, 2022). Armenia also imports all its oil products since the country has no oil reserves or refineries.

Despite having no fossil fuel reserves, Armenia has abundant hydro, solar, and wind potential. Armenia has substantial experience with hydropower technologies. There is around 2.9 GW of hydropower potential, of which around one-third has been utilised. Among prospective areas for developing hydropower projects situated around Araks River, Debed River, and Dzoraget River (IEA, 2022). There are plans to further increase solar PV and wind deployment within the next few years. Armenia has a daily average of solar insolation around 3.86 – 5.43 kWh/m^2, with a typical power output of 3.25 – 4.48 kWh/kWp (IEA, 2022). There is also considerable wind energy resource potential in Armenia, located around the Sevan Pass in the Areguni Range, the Karakhach, Pushkin and Jajur Pass in the Bazum Mountain Range, and the Sisian Pass in the Zangezur Range. The wind resource can supply up to 5 GW of installed capacity (IEA, 2022)

Geothermal energy in Armenia has not been fully developed due to low temperatures. A study in the Karkar region in the southern province of Syunik found that the geothermal reserves in Armenia may not be suitable for power generation due to low temperatures between 130 degrees and 135 degrees Celsius (IEA, 2022). Yet, this temperature can be used for space heating. The study of bioenergy and waste for energy production has not been fully explored. Some populations have used traditional biomass as fuelwood for heating, with around 0.29 m^3 per person (IEA, 2022). Waste incineration plants might be an alternative in Armenia for district heating while simultaneously removing waste management problems. However, more research is required. Table 1 presents a SWOT analysis of renewable energy resources in Armenia.

Table 1. SWOT analysis of renewable energy resources in Armenia

	Strength	Weakness	Opportunities	Threats
Hydro energy	• Endowed with water resources • Already established technology	• Seasonal variability	• Player in the market is already available • Favourable investment incentive	• Biodiversity loss • Damage to nature • River loading problems
Solar energy	• Abundant resource availability • Already commercially mature technology	• Stronger competition among bidder and lender	• Huge potential to meet the supply and demand gap • Reduction in GHG emissions	• High capital cost
Wind energy	• Moderate potential	• Limited availability of suitable sites with adequate wind speeds • Isolated nature	• Reduction in GHG emissions	• High capital cost • High transport and construction cost
Geothermal and heat pump	• Low to moderate potential	• Temperature too low for power generation	• Potential to meet the heating demand	• Very high capital cost • Lack of investor interest
Biomass and waste energy	• Availability of biomass and waste	• Limited research has been conducted	• Opportunity to retrofit old thermal power plant	• Very high capital cost

3. Modelling assumptions

This section presents an outline of the scenarios considered by NEXSTEP, together with the key demographic and macroeconomic assumptions used in modelling Armenia’s energy system.

3.1. Scenario definitions

NEXSTEP is designed for scenario analysis, using the LEAP modelling system to enable energy specialists to model energy system evolution based on current energy policies. The baseline year 2021 was chosen, as it is the most recent year with sufficient data information for modelling. In the NEXSTEP model for Armenia, five scenarios have been developed. These include three core scenarios: (a) business-as-usual (BAU) scenario, (b) current policy scenario (CPS), and (c) Sustainable Development Goal (SDG) scenario. In addition, (d) Towards Net Zero Emissions by 2050 scenario has been developed to present technological options and policy measures required for Armenia to transition beyond 2030.

3.1.1. BAU scenario

This scenario hypothetically projects the energy demand and emissions trajectory based on historical improvement without any new actions or policies. While this scenario is not a practically true scenario, since there will be policies and plans implemented along the way, it helps compare the emission trajectories. In this scenario, the final energy demand is met by a fuel mix reflecting the current shares in TFEC, with the trend extrapolated to 2030.

3.1.2. Current policies scenario

Inherited from the BAU scenario, this scenario considers initiatives implemented or scheduled to be implemented during the analysis period of 2021-2030 in establishing its baseline performance, with reference to the SDG 7 and NDC targets, as well as national targets for energy efficiency improvement and renewable energy share. Otherwise, the energy intensities from different demand sectors are assumed to be constant throughout the analysis period. Only policies with concrete measures are considered in this scenario. Plans/strategies/policies that are unlikely to be implemented are not considered but are compared with scenario results and findings later in this Road Map.

3.1.3. SDG scenario

The SDG scenario builds on the current policy scenario to provide recommendations for achieving the SDG 7 targets. This scenario aims to achieve the SDG 7 targets, including universal (100 per cent) access to electricity and clean cooking fuel, substantially increasing the renewable energy share and doubling the rate of energy efficiency improvement. For clean cooking, different technologies (electric cooking stoves, LPG cooking stoves, and improved cooking stoves) have been assessed, with subsequent recommendations on the uptake of the most appropriate technology. Energy intensity has been modelled to help achieve the SDG 7 target. It also allows achieving the country’s NDC target by 2030.

3.1.4. Towards Net Zero Scenario by 2050

This 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

3.2. Assumptions

The energy demand is estimated by using the activity level and energy intensity in the LEAP model. The demand outlook throughout the NEXSTEP analysis period is influenced by factors such as annual population growth and GDP growth. The assumptions used in the NEXSTEP modelling are further detailed in Annex II, while Table 2 provides a summary of key modelling assumptions for the three main scenarios (i.e., BAU, CPS and SDG).

Table 2. Important factors, targets and assumptions used in NEXSTEP modelling

Parameters	Business as usual scenario	Current policy scenario	Sustainable Development Goal (SDG) 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[11], 5 per cent per annum between 2024 and 2027, and 5.6 per cent from 2027 onwards[12]		
Population growth	-0.48 per cent per annum[13]		
Urbanisation rate	67 per cent in 2021, growing to 68 per cent in 2030[14]		
Commercial floor space	Assumed annual energy consumption increasing at the same growth as GDP		
Industrial activity	Industrial activities are assumed to grow at the same rate as GDP		
Transport activity	Passenger transport activities and freight transport activities are assumed to growing at the same rate as GDP per capita growth		
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. A 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

[11] Historical data and estimation from the Asian Development Bank
[12] Estimation from the 398-L Document
[13] Calculated based on the historical population data
[14] 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.

Parameters	Business as usual scenario	Current policy scenario	Sustainable Development Goal (SDG) scenario
Power plant	Considers 2021 RE share in power generation and grid emissions	Considers capacity expansion based on the national strategy	Considers capacity expansion to reach at least 50 percent of renewable energy

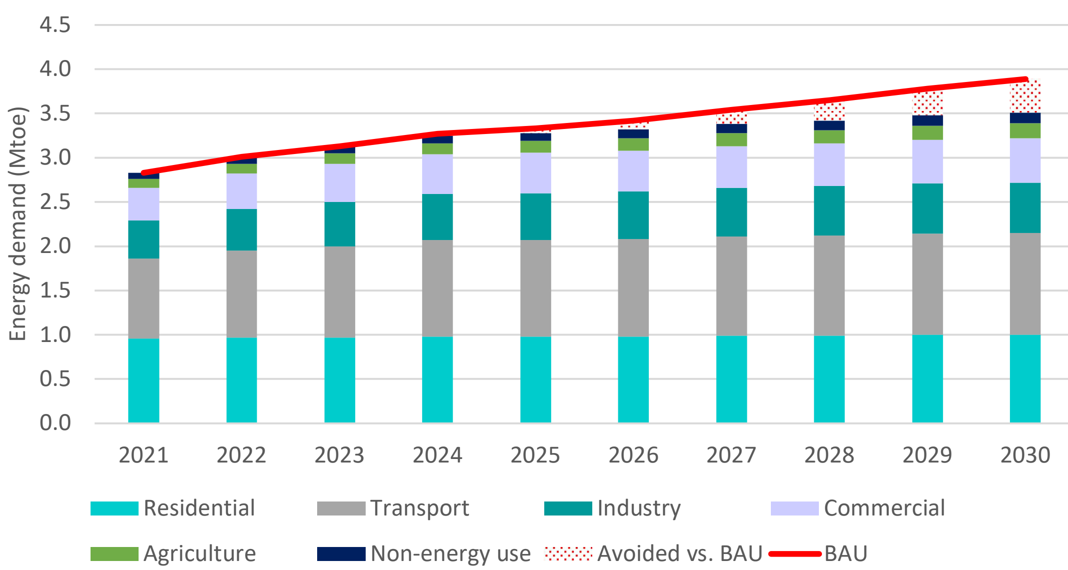
4. Energy transition outlook in the current policy scenario

This section presents key modelling results under the NEXSTEP current policy scenarios, focusing on impacts in key areas of the economy and the energy sector.

4.1. Energy demand

Under the current policy setting, the demand for total final energy is expected to increase from 2.84 Mtoe in 2021 to 3.5 Mtoe in 2030, an average annual growth rate of 2.3 per cent. In 2030, the transport sector will be the largest energy-consuming sector with 33 per cent, while the residential sector share will be 27.9 per cent. The commercial sector consumption will be at 16.4 per cent followed by the industry sector at 14.4 per cent. The agricultural sector and non-energy use will account for 4.9 per cent and 3.5 per cent of energy demand, respectively. Figure 5 shows the forecast of TFEC by sector under the CP scenario. The sectoral energy efficiency measures are described further below.

Figure 5. Energy demand outlook in the current policy scenario 2021 - 2030



4.1.1. Transport sector

The transport sector will consume 1.15 Mtoe in 2030, an annual growth of 2.8 per cent, up from 0.9 Mtoe in 2021. The road transport sector will account for 98.9 per cent of energy demand in the transport sector. Rail transport and aviation will consume around 0.9 per cent and 0.2 per cent of energy demand, respectively. The Government has considered introducing electric vehicles targeting private and public transport under the National Programme on Energy Saving and Renewable Energy for 2022-2030/RA Government Decision No.398-L (Government of the Republic of Armenia, 2022). The penetration rate of electric passenger cars will gradually increase, reaching at least 10 per cent in 2030 while half of public transport will be electric in 2030. The government will introduce a new route for public transport to improve its efficiency by 70 per cent. This measure is expected to increase the share of public transport to 60 per cent.

4.1.2. Residential sector

Energy demand in the residential sector will increase from 0.96 Mtoe in 2021 to 0.97 Mtoe in 2030, with an annual growth of 0.2 per cent. The low annual growth rate is expected due to the low population growth and the improvement of energy efficiency in the residential sector. Around 54.4 per cent of energy demand will be used for heating, while 19.3 per cent will be consumed for cooking. The remaining will be consumed to power electric appliances.

Armenia experiences a long and cold winter season. Hence the heating demand is quite high. The government plans to reduce heat losses. Under the National Programme on Energy Saving and Renewable Energy for 2022-2030/RA Government Decision No.398-L (Government of the Republic of Armenia, 2022), the government plans to establish standards for thermal insulation of new buildings since the heat loss in precast buildings is very high because of thin walls and wooden-framed windows. While theoretically, external insulation can save annual energy demand by up to 36 per cent, the actual savings can be lower depending on the building's condition. A typical improvement for thermal insulation and heating efficiency is ranging from 21 per cent to 27 per cent (Yang, Lao, & Bayasgalan, 2022). The energy saving in the residential sector is expected to be around 0.05 Mtoe in 2030.

4.1.3. Industry sector

The industrial sector will consume 0.5 Mtoe in 2030, an annual growth of 3.5 per cent, up from 0.37 Mtoe in 2021. Within the industrial sector, it is projected that 31.4 per cent of energy in 2030 will be consumed by cement and non-metallic quarry. The food and beverage industry will account for 20.7 per cent of industrial energy demand, followed by iron and steel at 8.4 per cent of energy demand. The remaining 39.5 per cent will be consumed across six industries, including machinery and transport equipment, pulp and paper, and textile and leather. Energy efficiency measures will be driven by policy conducted by the state to improve investment attractiveness.

4.1.4. Commercial and agricultural sector

Total energy consumption in the commercial sector will increase from 0.43 Mtoe in 2021, at an average annual growth of 3.2 per cent, to 0.57 Mtoe in 2030. There is expected to be a 0.14 Mtoe energy demand reduction in this sector if the Government implements measures to reduce heat loss by improving external insulation. The agricultural sector will consume 0.17 Mtoe of energy in 2030. Table 3 summarises energy efficiency measures modelled in the current policy scenario and corresponding energy reduction opportunities in different sectors.

Table 3. Energy efficiency measures and energy demand reduction opportunities in the CP scenario compared to BAU scenario by 2030

Sector	Measure	Energy demand reduction in 2030 (ktoe)
Residential	The development of energy-efficient construction, for which the requirements for energy efficiency of building	47.1

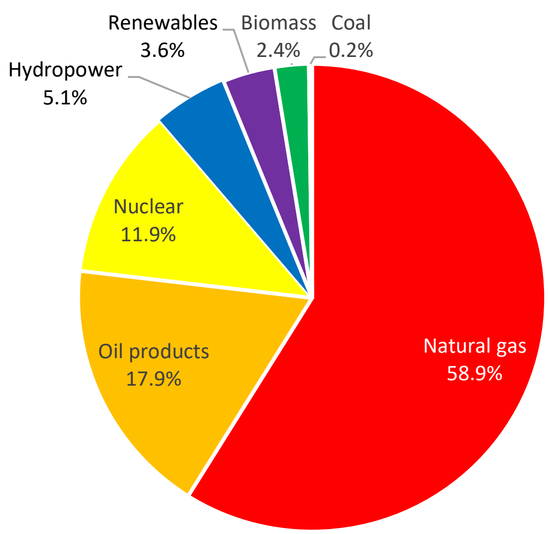
	materials, products and structures will be revised, and measures will be developed to stimulate the construction of high-class energy efficiency facilities, will simultaneously raise the citizens' awareness.	
Transportation	Increase electric car penetration of passenger cars and public transport while implementing new routes for public transport.	336.1
Industry	Financing measures for modernising 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	109.1
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	143.2
Total		635.5

4.2. Energy supply outlook

Primary energy supply

In the current policy scenario, TPES is forecasted to increase from 3.7 Mtoe in 2021 to 4.4 Mtoe in 2030. The fuel shares in 2030 (Figure *6*) will still be dominated by fossil fuels: natural gas 2.58 Mtoe (58.9 per cent), oil products 0.79 Mtoe (17.9 per cent), and coal 0.01 Mtoe (0.2 per cent). Nuclear power will be around 0.52 Mtoe (11.9 per cent). The remaining share will be for hydropower 0.22 Mtoe (5.1 per cent), solar and wind 0.16 Mtoe (3.6 per cent), and biomass 0.1 Mtoe (2.4 per cent).

Figure 6. Total primary energy supply by fuel type in 2030 in the CP scenario



Electricity and heat generation

To ensure the sustainability of the energy sector development and create the basis for enhanced deployment of renewables in the future, Armenia targets the share of RE in electricity generation capacity to reach 50 per cent in 2030. There is no specific renewable target for heat generation.

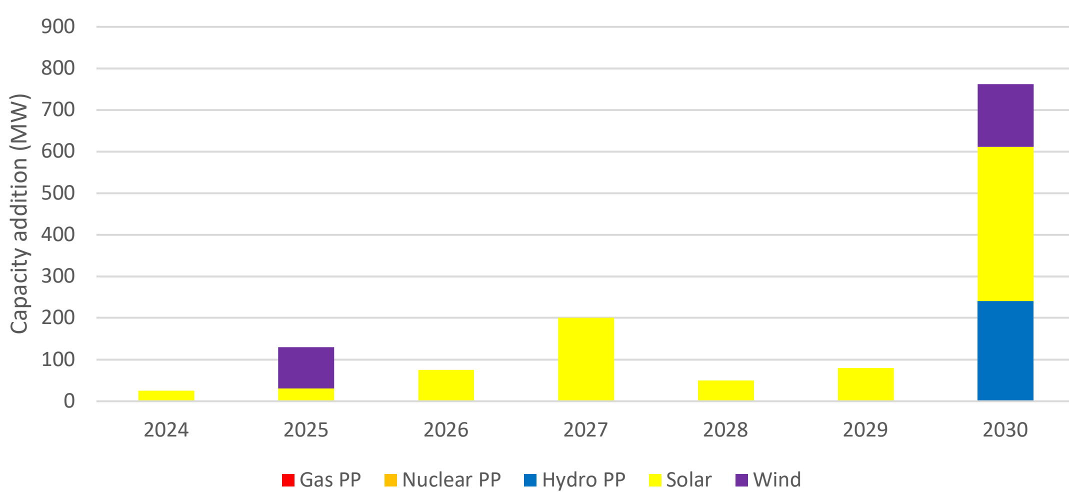
According to the capacity expansion plan provided by Armenia, the installed power generation capacity for Armenia is forecasted to be 5,374.3 MW. Fossil fuel will continue to dominate installed capacity at 38.8 per cent. Nuclear capacity will be around 8.3 per cent. Renewables share will be 52.9 per cent meeting the renewable target. The renewable capacity share increases from 37.4 per cent in 2021. It happens since a significant amount of solar and wind generation will be in operation in Armenia (Table 4 and Figure 7).

In terms of generation, electricity generation is expected to rise from 7.9 TWh in 2021 to 9.8 TWh in 2030. The renewable energy share of electricity supply will increase from 31.7 per cent in 2021 to 45.1 per cent in 2030. The solar generation will be around 17.7 per cent meeting the target of at least 15 per cent. District heating generation will remain the same, coming from CHP, since there is no plan to add additional capacity. There is no renewable energy system planned for the heating sector in Armenia.

Table 4. Power capacity expansion plan by fuel type

Capacity expansion
The capacity of solar PV will be 1,000 MW by 2030.
The wind capacity will be 500 MW by 2040 (assumed that 250 MW will be achieved in 2030).
Meghri HPP 100 MW
Shnogh HPP 75 MW
Lori Berd HPP 66 MW

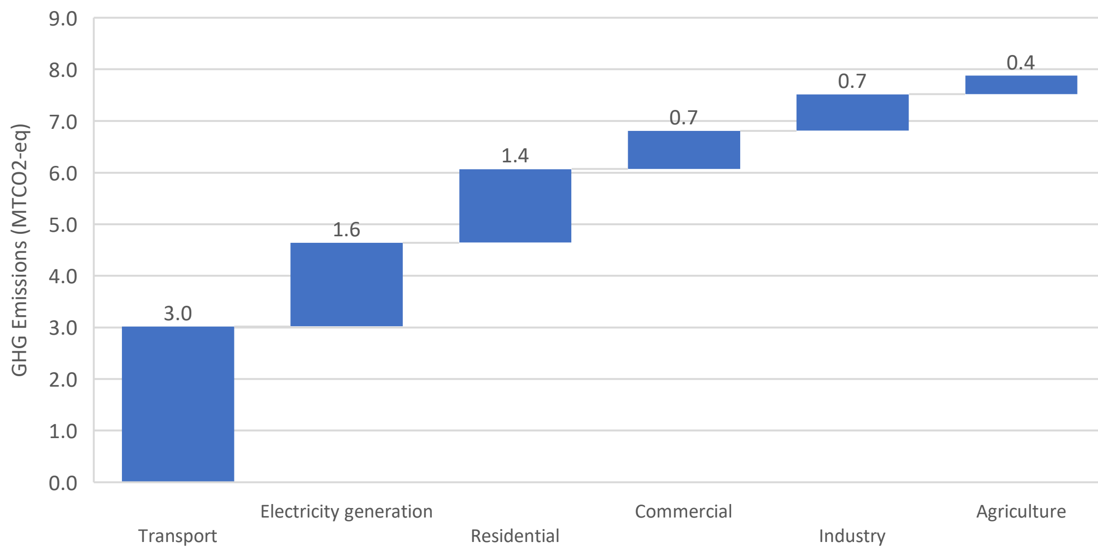
Figure 7. Power capacity expansion assumption 2024 - 2030



4.3. GHG emissions

In the BAU scenario, emissions are expected to be 10 $MtCO_2$-e by 2030. In this scenario, GHG emissions are projected to reach 7.9 $MtCO_2$-e by 2030, a decrease of 2.1 $MtCO_2$-e . This reduction is attributable mainly to the Government's plan for increasing renewable energy in the power generation sector. Most emissions will come from the transportation sector (38.4 per cent), followed by the power sector (20.5 per cent) and residential sector (18.1 per cent). The industrial, commercial, and agricultural sectors will share the remaining emissions. Figure 8 shows the emissions distribution by sector in 2030.

Figure 8. Distribution of emissions by sector in 2030 in the CP scenario



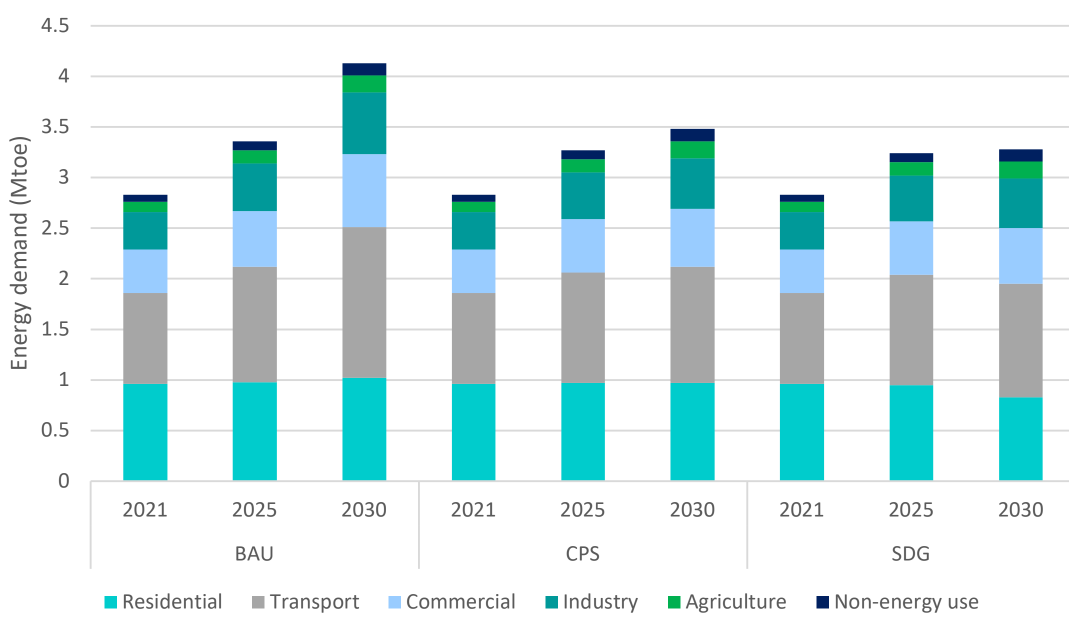
5. SDG scenario: An assessment of SDG 7 targets and indicators

This section begins with a concise overview of the energy demand projections under the SDG scenario. Later, the results are evaluated against the SDG 7 and NDC targets, along with other relevant indicators. This evaluation is based on the outputs from the NEXSTEP analysis, aiming to spotlight any policy gaps in Armenia's current energy policies. To conclude, the future energy supply outlook is presented.

5.1. Energy demand outlook

In this scenario, TFEC increases to 3.27 Mtoe in 2030, which is a 0.86 Mtoe reduction compared to the BAU (an additional 0.22 Mtoe demand reduction compared to CPS). This reduction is due to additional energy efficiency modelled to ensure the achievement of the SDG 7.3 target. In 2030, the transport sector will have the largest share of TFEC at 1.12 Mtoe (34.1 per cent), followed by the residential sector at 0.83 Mtoe (25.2 per cent). Commercial and industrial sectors will account for 0.55 Mtoe (16.8 per cent) and 0.49 Mtoe (14.9 per cent), respectively. The agriculture sector will account for 0.17 Mtoe (5.2 per cent). Non-energy use will be around 3.7 per cent. Figure 9 shows the total final energy consumption by scenario in 2030.

Figure 9. Comparison of energy demand between BAU, CPS and SDG scenarios



5.2. SDG 7 targets

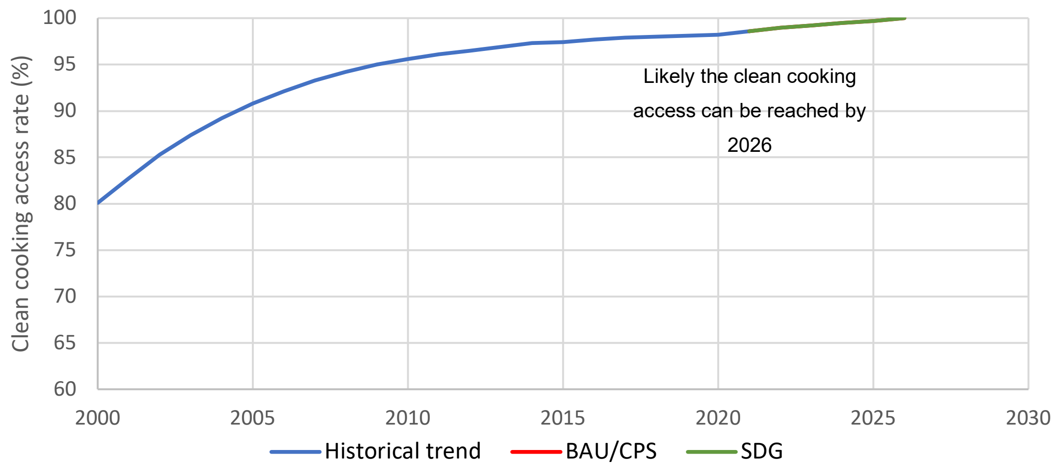
5.2.1. Access to electricity

Armenia has achieved universal access to electricity in 2021, up from a 99.7 per cent access rate in 2017. Despite the remarkable achievement, the government of Armenia should continue its effort to improve the power supply reliability.

5.2.2. Access to clean fuels and technologies for cooking

Armenia has made progress towards clean cooking, increasing from 97.7 per cent in 2017 to 98.6 per cent in 2021. As of 2021, Only 1.4 per cent of households relied on polluting cooking technologies, specifically biomass as a primary fuel. Considering the current trend, access to clean cooking fuels and technologies will be achieved in all 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 also provides heating energy. The current electricity tariff makes the natural gas stove more competitive than the electric stove. Table 5 summarises the estimated annualised cost of different cooking technologies in 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 or around 0.14 million households is suggested to adopt electric cook stoves by 2030 (

Figure *11*). This 20 per cent value is chosen as per the suggested recommendation in the Net Zero 2050 Roadmap document developed by IEA (IEA, 2021) . Box 1 explains the basis for the evaluation of clean cooking technologies. Annex IV summarises the cost and technical assumptions used in the economic analysis.

Figure 11. Share of clean cooking technologies by 2030 under CPS and SDG scenarios

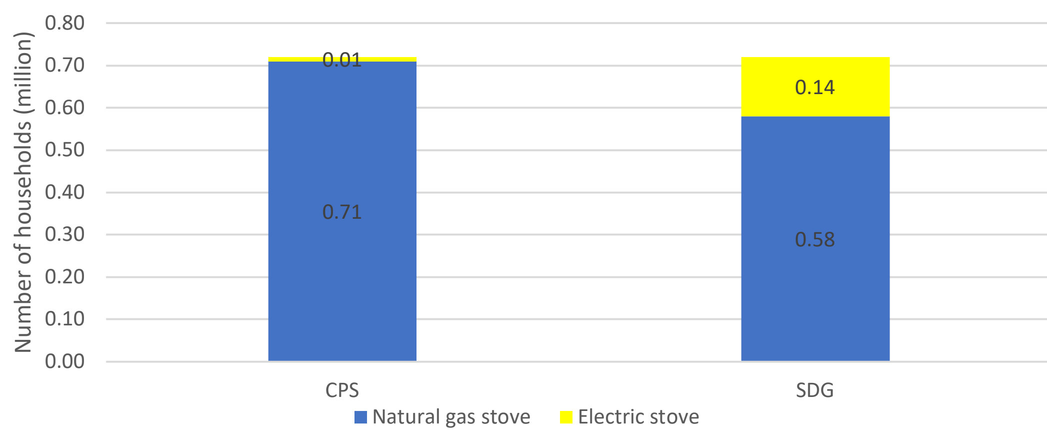


Table 5. The annualized cost of cooking technologies

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

Box 1. Evaluation of clean cooking technologies

Electric cook stoves

Electric cooking technology is classed as Level 5 in the World Bank Multi-Tier Framework (MTF) for Indoor Air Quality Measurement. Electric cook stoves are more efficient than other cook stoves, including gas stoves. Electric cook stoves can generally be divided into two types – solid plate and induction plate. While solid plate cook stoves use a heating element to transmit radiant energy to the food and reach about 70 per cent efficiency, induction plate cook stoves, on the other hand, use electromagnetic energy to directly heat pots and pans, and can be up to 90 per cent efficient.

Improved cook stoves

ICS programmes initially require strong advocacy to promote adoption, after which they require ongoing follow-up, monitoring, training, maintenance and repairs in order to facilitate continuing usage. In addition, based on the World Health Organization (WHO) guidelines[15] for emissions for clean cooking, only certain types of ICS technology comply, particularly when considering the fact that cook stove emissions in the field are often higher than they are in laboratory settings used for testing. Tier 3+ ICS, which meets the WHO clean cooking guidelines, has the potential to reduce GHG emissions and provide socio-economic and health benefits, when it is promoted in carefully planned programmes.

Natural gas stove

Clean cooking with natural gas might be an attractive solution in the short term. However, since Armenia has no natural gas reserves, fuel imports cannot be avoided. Natural gas is also not a viable solution for rural households as it would require building a gas distribution infrastructure, which is extremely difficult for remote locations. Additionally, the natural gas requirement competes with the needs for power sectors.

LPG cook stove

LPG is constrained due to fuel import dependency and supply chain challenges. LPG cook stoves generate lower indoor air pollution compared to ICS. They are classified as Level 4 in the World Bank Multi-Tier Framework (MTF)[16] for cooking exposure and reduce indoor air pollution by 90 per cent compared to traditional cook stoves.

5.2.3. Renewable energy

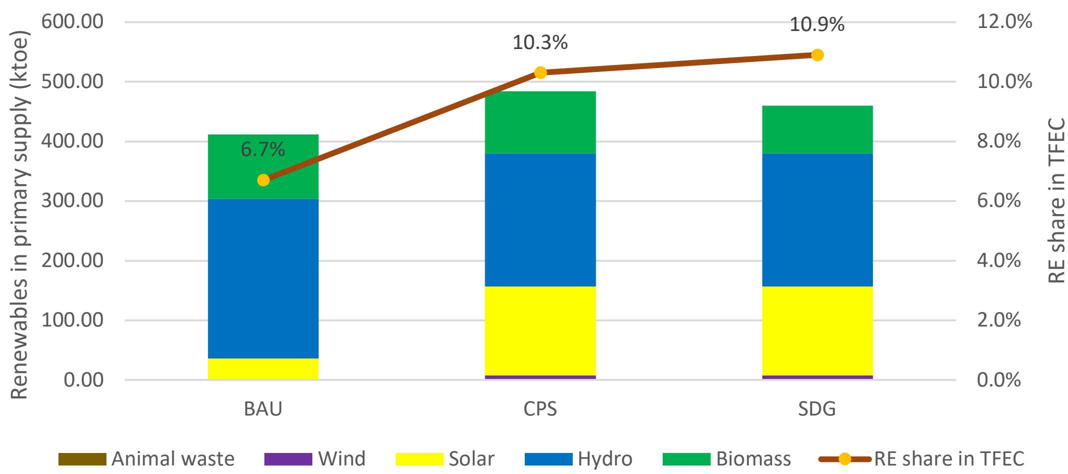
SDG 7.2 does not have a quantitative target but encourages a “substantial” increase in the renewable energy share in TFEC. The share of renewable energy in TFEC (excluding biomass) in 2030 will be 6.7 per cent in the business-as-usual scenario, which is expected to grow to 10.3 per cent, in the current policy scenario (

[15] Defining clean fuels and technologies https://www.who.int/tools/clean-household-energy-solutions-toolkit/module-7-defining-clean

[16] https://www.esmap.org/mtf_multi-tier_framework_for_energy_access

Figure 12). This increase is largely driven by the increase in the renewable energy share in power generation in the current capacity expansion plan. The renewable energy share in TFEC is further increased to 10.9 per cent in the SDG scenario, resulting from increased energy efficiency measures as well as switching from gas-based cooking stoves to electric cooking stoves. Despite the increase in renewable energy share in TFEC, the energy system in Armenia will still be dominated by fossil-fuel.

Figure 12. Renewable energy in TPES and TFEC in 2030

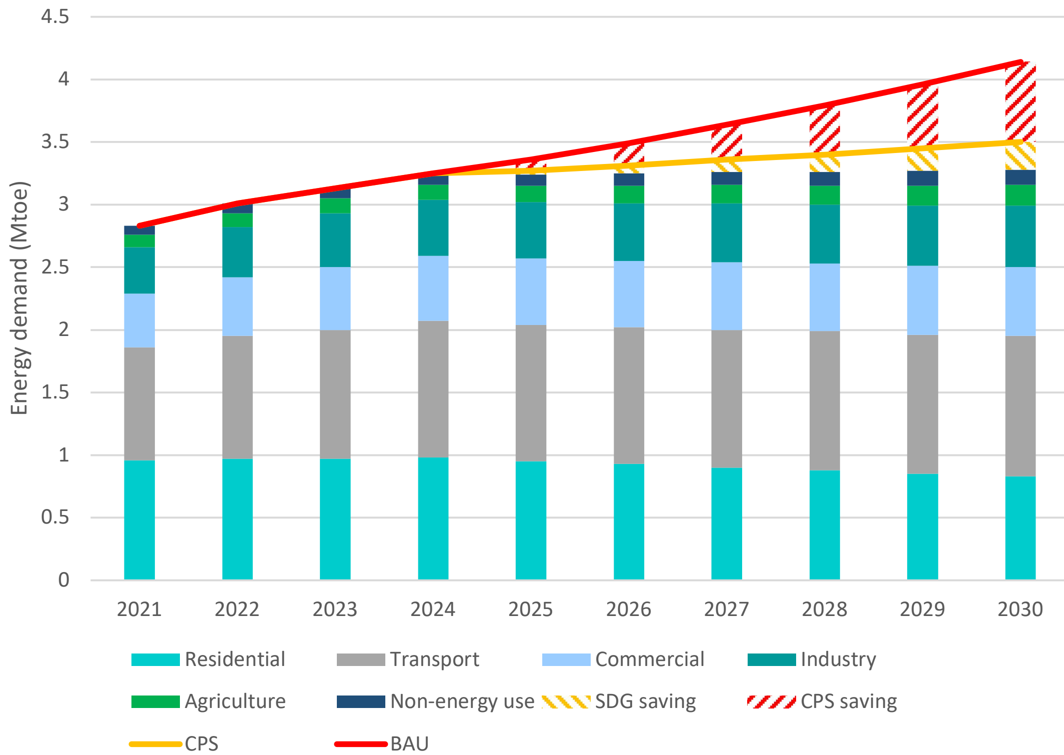


5.2.4. Energy efficiency

Under the SDG 7.3 targets, energy intensity 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. 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}. 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 3.9 MJ/USD_{2017}. To reach the expected 2030 intensity, the annual improvement rate between 2021 and 2030 must be around 29.5 per cent, which is quite challenging. Therefore, NEXSTEP analysis suggests Armenia's energy intensity target to be aligned with the global target of 4 per cent annual improvement (UNSD, 2024). This corresponds to a 2030 energy intensity target of 2.7 MJ/USD_{2017}.

Under the CP scenario, Armenia's energy intensity in 2030 was estimated to be 2.8 $MJ/US\$_{2017}$ a reduction from 3.9 $MJ/US\$_{2017}$ in 2021. The annual improvement rate is expected to be 3.6 per cent between 2021 and 2030 due to the planned implementation of energy efficiency measures. NEXSTEP analysis finds that Armenia can further reduce the energy intensity to 2.7 $MJ/US\$_{2017}$, to align with the global energy efficiency target of 4 per cent annual improvement for SDG 7. This requires the addition of 0.22 Mtoe of energy demand reduction compared to the CPS scenario. Figure ***13*** shows additional energy-saving opportunities under the SDG scenario compared to the CPS and BAU scenarios.

Figure 13. Energy saving potential in different sectors and sub-sectors under the SDG scenario compared to the CPS and BAU scenarios



5.2.5. Transport sector

In the SDG scenario, the transport sector will consume 1.12 Mtoe in 2030 an additional reduction of 36 ktoe compared to CPS (Table 6). The road transport sector will account for 98.9 per cent of energy demand in the transport sector. Rail transport and aviation will consume around 0.9 per cent and 0.2 per cent of energy demand, respectively.

The Government has considered introducing electric vehicles targeting both passenger and public transport under the National Programme on Energy Saving and Renewable Energy for 2022-2030/RA Government Decision No.398-L (Government of the Republic of Armenia, 2022). In this scenario, NEXSTEP suggests that the government accelerate the implementation of electric vehicles in road transport and raise the penetration target. Regarding passenger transport, the Government can further adopt a 20 per cent EV rate for passenger cars to be achieved by 2030 instead of only 10 per cent. The target for passenger cars must be higher since this category uses significant energy demand. The government may initially replace the government's fleet of cars with electric vehicles while simultaneously promoting the electric vehicle to a wider public.

Regarding freight transport, the electrification of heavy trucks is challenging because of its competition with long-range diesel trucks. However, it is expected that the electrification of freight trucks might also become an economically feasible option. NEXSTEP suggests that the government consider the adoption of hybrid and electric trucks to improve energy efficiency in this category. Regarding infrastructure, the government may start developing charging facilities in the Yerevan area first since the mobility is concentrated in the capital region. See box 2 for information on electric vehicles.

Table 6. Additional energy saving in the transport sector under the SDG scenario by 2030, compared to CPS

Sector	Measure	Energy demand reduction (ktoe) 2030
Passenger cars	Electric car penetration increased to 20 per cent in 2030 (from only 10 per cent in CPS scenario)	36
Total		**36**

Box 2. Electric vehicle gains global interest

Electric vehicles have garnered great interest globally, growing exponentially during the past decade. Electric car sales passed two million globally in 2019, with a projected compound annual growth rate of 29 per cent to 2030 (Deloitte, 2020). Various government policies have been introduced that directly or indirectly promote the adoption of electric vehicles as a means to achieve environmental and climate objectives. For example, 17 countries have stated their ambition to phase out internal combustion engines before 2050, while the European Union's stringent CO_2 emissions standard has accelerated the adoption of electric vehicles (IEA, 2022).

Despite supply chain bottlenecks and the ongoing COVID-19 pandemic, electric car sales hit a new high in 2021. Sales nearly doubled to 6.6 million, representing a world sales share of approximately 9 per cent, compared to 2020, increasing the total number of EVs on the road to 16.5 million. In 2021, the sales share of EVs rose by 4 percentage points. China had the most sales in 2021, tripling those of 2020 with 3.3 million, followed by Europe with 2.3 million sales, an increase from 1.4 million in 2020. In 2021, 630,000 EVs were sold in the United States, doubling their market share to 4.5 per cent. Electric car sales increased more than twice as much in emerging nations, although they are still relatively small (IEA, 2022).

Vehicles with an electric motor assisting the conventional internal combustion engines that cannot be charged are not considered electric vehicles. The following categories may be considered EVs: (1) battery electric vehicles (BEV), (2) plug-in hybrid electric vehicles (PHEV), and (3) fuel cell electric vehicles (FCEV).

5.2.6. Residential sector

Energy demand in the residential sector will reduce from 0.96 Mtoe in 2021 to 0.83 Mtoe in 2030, a 147 ktoe reduction compared to CPS and 197 ktoe reduction compared to BAU. In addition to achieving 100 per cent clean cooking access, phasing out a proportion of cooking technologies with more efficient electric cook stoves (e.g., induction type) might help reduce cooking demand since this technology is more efficient than other stoves. 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. According to IEA, 75 per cent of dwellings lack proper insulation (IEA, 2017). Consequently, the demand for heating is quite high in the long and cold winter season. Most of the demand, however, is supplied by natural gas boilers or heaters, increasing the country's vulnerability to the volatility of gas prices. To overcome this situation, the government plans to develop standards to improve thermal insulation, particularly for new buildings since Comprehensively retrofitting entire existing buildings, including their envelopes (i.e. external walls, insulation, windows, doors, etc.) can be a significant challenge for the country.

The country can also transition to a new heating demand by considering cleaner technologies. The utilization of individual furnaces must be limited to reduce at least half of coal and fuelwood consumption in the residential sector. These must be replaced by more sustainable heating technology, such as electric heating and/or district heating. 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.

In rural households where electric heating may not be available, high-efficiency, low-emission (HELE) heating stoves can be promoted. HELE heaters are the appropriate short-term heating technology to be promoted for rural households. These heaters reduce fuel consumption by 40 per cent due to their higher efficiency, while keeping a larger area of homes warm. Indoor air pollution is reduced significantly which ultimately reduces negative impacts on health. For example, a World Bank study has seen the mean $PM_{2.5}$ exposure decreased 65 per cent from 92.3 μg/m^3 to 32.4 μg/m^3 (World Bank, 2019). This meets the WHO interim target, IT-1 of 35 μg/m^3, for annual mean concentration of $PM_{2.5}$ (World Health Organization, 2014). The results also show that the CO_2 exposure dropped below the WHO air quality guidelines.

More can be done to raise community awareness of the benefits of HELE heating technology. Similar to promoting clean cooking technologies, a participatory approach with key stakeholders, together with frequent monitoring, evaluation and feedback should be pursued to ensure a successful implementation of programmes. In addition, the sustainable heating issues should garner more attention and have a place in national policies and plans. In the long term, progressing towards electric heating should be considered, as the affordability of households increases.

Table 7. Additional energy saving in the residential sector under the SDG scenario by 2030, compared to CPS

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 promoting electric heaters to a quarter of the rural population to reduce fuelwood usage.	63.3
Residential MEPS	Increase the adoption of energy-efficient lighting, refrigeration, and television	62.2
Total		**147.5**

5.2.7. Industry sector

In the SDG scenario, the industrial sector will consume 0.49 Mtoe in 2030, a reduction of 16 ktoe compared to CPS. A significant amount of energy savings of 20 per cent can be expected in the CPS scenario by adopting energy efficiency measures and industrial best practices across different industry subsectors. 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 this 23 per cent energy reduction can be achieved further. Several pathways can be implemented in Armenia (See Box 3). NEXSTEP suggests that the government enforce energy management standards, energy audits, equipment standards, and labelling in the industrial sector as a starting point. For example, electric motors have been used widely in the industry sector. It is estimated that at least 15 per cent of electricity savings can be achieved by just replacing the motor, oversizing correction, VSD installation, and digitisation (de Almeida, Ferreira, & Fong, 2023). It is estimated that additional saving can be obtained (Table 8).

Box 3. Energy Efficiency Measures in the Industry Sector

The areas of potential savings that are generally present in the different sub-sector includes (but not limited to) the following:

- Improvement in motor loading.
- Replacement of old and rewound motors.
- Installation of capacitor banks and increasing efficiency of existing capacitor banks.
- Improvement in combustion efficiency of boilers.
- Regular cleaning and maintenance of boiler equipment (i.e. condenser pipes).
- Installation of more efficient electric motors.
- Improvement of the steam distribution system including leakage control and insulation improvement.
- Electricity load management.
- Minimizing energy losses by partitioning cooling areas, installing and effectively using air curtains.

- Minimizing heat losses from the boiler (or kilns for the cement sector).
- Condensate and waste heat recovery.

In addition, various policy measures can be considered for accelerating the green transformation through various policy measures. These may include market instruments (i.e., subsidies or taxes), emissions caps and trade systems (e.g., the European Union Emission Trading Scheme) or regulatory instruments. The *Practitioner's Guide to Strategic Green Industrial Policy* by Partnership for Action on Green Economy (PAGE)[17] provides industrial policymakers with tools and information for developing a strategic green industry policy (SGIP).

Table 8. Additional energy saving in the industry sector under the SDG scenario by 2030, compared to CPS

Sector	Measure	Energy demand reduction in 2030 (ktoe)
Industry – Energy Audit and Energy Efficiency Improvement	Improvement of energy saving in the industry to 23 per cent in 2030 (from only 20 per cent in the CPS scenario), particularly in food and beverages as well as cement and non-metallic Products industries.	16
Total		**16**

5.2.8. Commercial sector

In the SDG scenario, the commercial sector will consume 0.55 Mtoe in 2030 a reduction of 22 ktoe compared to CPS. The government plans to improve energy efficiency in public schools. NEXSTEP suggest that the expansion of energy efficiency measures to all buildings, not only public schools, will be required in the commercial sector (see Box 4 for more information), which can be encouraged through setting up a green building code, which mandates a set of minimum building standards. This shall ensure sustainable building designs for the upcoming buildings. Moreover, this can be equally applied to existing buildings scheduled for retrofitting. This amounts to an estimated additional reduction of 22 ktoe[18]. Notwithstanding, one possible way to promote sustainable measures in existing buildings is the high upfront cost of conducting an energy audit and the subsequent implementation of measures. The Government should consider providing financial incentives and, at the same time, raising energy conservation awareness among the public.

Box 4. Policy Options for a More Sustainable Building Sector

[17] See https://www.unido.org/sites/default/files/2016-11/practitioners_guide_to_green_industrial_policy_1__0.pdf
[18] This assumes a 23 per cent energy savings potential. However, energy savings potential is building-specific, depending on the baseline design, climate and energy efficiency measures.

The building sector contributes significantly to the global energy consumption and GHG emissions. This calls for adoption of green building measures and designs in new and existing building stocks to allow energy savings and rapid GHG emissions reduction to meet the Paris Agreement. A ‘green’ building can be defined as *a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment* (WorldGBC, 2021). Green building adoption can be made obligatory through the implementation of building codes or promoted with certification/rating systems.

Building code is a comprehensive set of mandatory minimum building standards. One example is the 2018 International Green Construction Code (IgCC), developed to aid government jurisdictions in administering minimum requirements covering the design, construction and operation of buildings (ICC, 2021). Another implemented green building code by state jurisdiction is the California Green Building Standards Code (CALGreen) (State of California, 2021). *Certification systems or rating tools*, which provides third-party assessment and confirmation that a building meets certain green requirements or standards, are also widely used. Examples are such as the LEED (Leadership in Energy and Environmental Design) rating system and Australia’s Green Star Buildings rating tool. For instance, the Green Star certification has been given to almost 3,000 buildings with an average reduction of 56 per cent (Green Building Council of Australia, 2020).

Table 9. Additional energy saving in the commercial sector under the SDG scenario by 2030, compared to CPS

Sector	Measure	Energy demand reduction (ktoe) 2030
Private office and government building	Green building code to ensure improvement in the external insulation of whole commercial buildings to achieve at least 23 per cent energy saving.	22
Shopping mall		
Hotel		
Healthcare facilities		
Educational institutions		
Others		
Total		**22**

5.3. Energy Supply Outlook

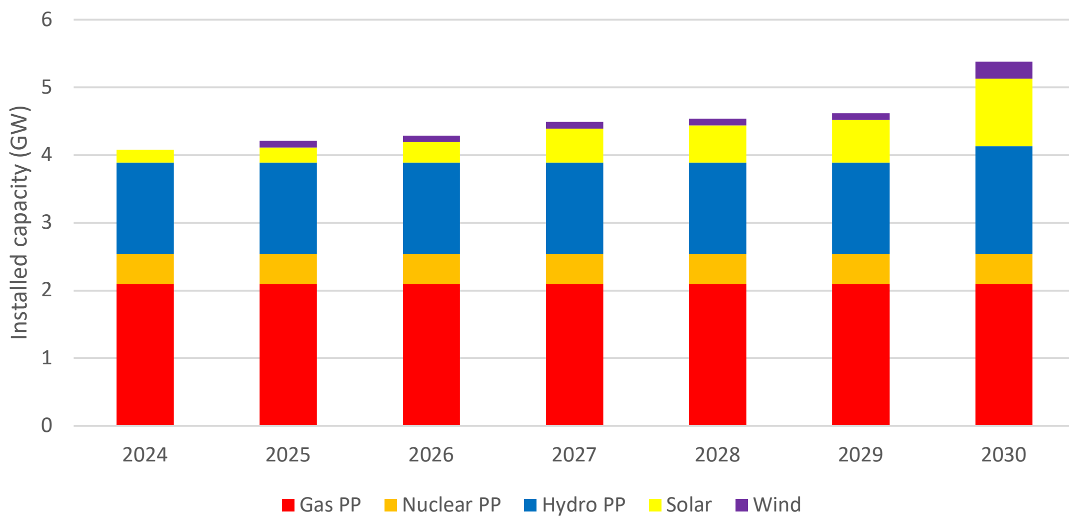
Primary energy supply

In the SDG scenario, the TPES is forecasted to increase from 3.71 Mtoe in 2021 to 4.17 Mtoe in 2030. The fuel shares in 2030 are projected as 2.4 Mtoe (57.4 per cent) natural gas and 0.77 Mtoe (18.5 per cent) oil products. Nuclear will be around 0.52 Mtoe (12.5 per cent). The remaining share will be for hydropower 0.22 Mtoe (5.4 per cent), biomass 0.08 Mtoe (1.9 per cent), and other renewables 0.16 Mtoe (3.8 per cent). Compared to the CP scenario, the 0.2 Mtoe supply reduction comes from the additional energy efficiency improvements discussed in the previous section.

Electricity and heat generation

In 2030, the installed power generation capacity would be similar to the CP scenario at 5,374 MW, where renewables capacity will be 52.9 per cent meeting the target of at least 50 per cent by 2030. The electricity generation is also expected to be the same as CPS. Despite increasing electricity demand due to the higher penetration of electric cookstoves, heaters, and vehicles, this is compensated by energy-saving improvements, such as through MEPS.

Figure 14. Power plant installed capacity 2024 - 2030



5.4. Nationally Determined Contribution Targets

Emissions from the combustion of fossil fuels are calculated based on IPCC Tier 1 emission factors. For the combustion of biomass and biomass products, the carbon emissions are not attributed to the energy sector but are accounted for in the agriculture, forest and land-use change (AFOLU)[19] as per the accounting system suggested by IPCC. Nevertheless, the emissions of other GHGs, such as methane and nitrous oxide, are included in the total emissions in the energy sector.

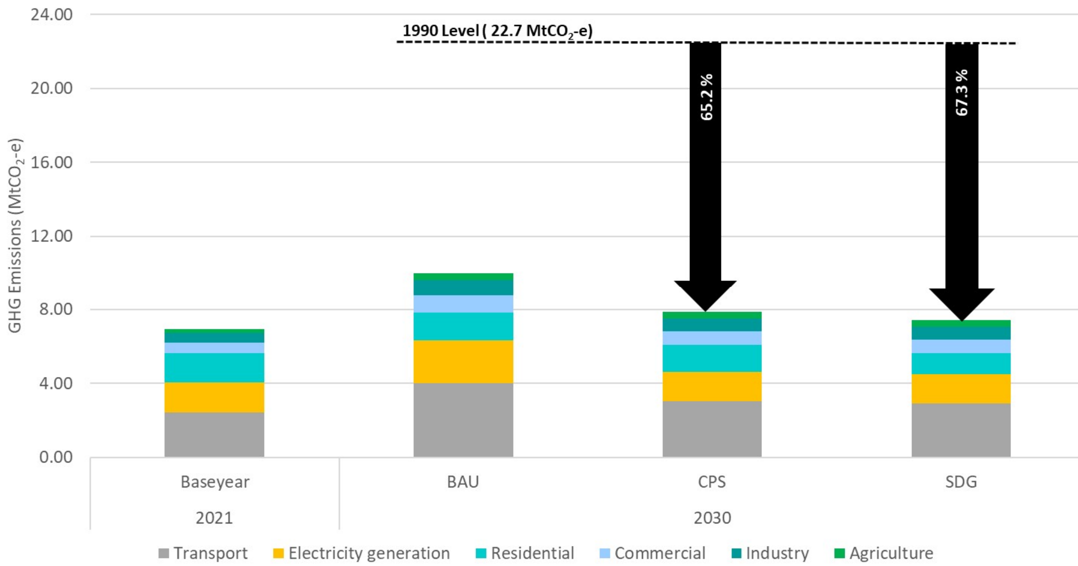
Emission analysis in this study suggests that the BAU emission in 2030 will be 10 $MtCO_2$-e. Armenia has committed to reducing GHG emissions by 40 per cent compared to the 1990 level. In 1990, the energy sector's emission was around 22.7 $MtCO_2$-e. This translates to a cap of 13.6 $MtCO_2$-e. Under the current policy setting, the total emissions are expected to be 7.9 $MtCO_2$-e or a 65.2 per cent emission reduction compared to the 1990 level, achieving the NDC target due to the increase of renewable share in electricity supply per the capacity expansion plan (Figure *15*).

Armenia can further enhance its efforts to achieve higher emission reduction by accelerating the implementation of energy-saving measures to align with the global improvement target of 4 per cent

[19] The AFOLU sector is not within the scope of NEXSTEP

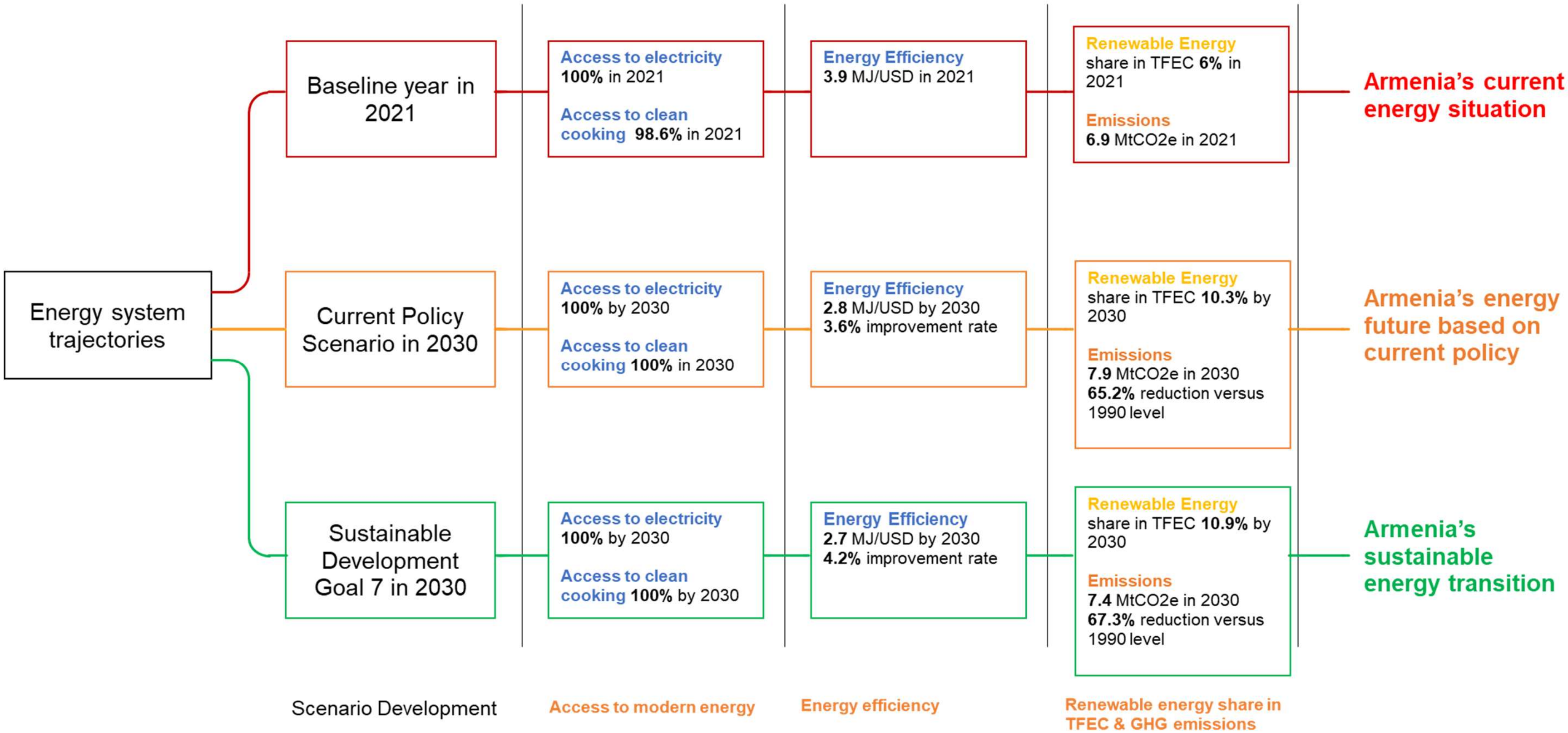
discussed in the previous section. In the SDG scenario, total emissions are expected to further decrease to 7.4 $MtCO_2$-e by 2030 or an emission reduction of 67.3 per cent compared to the 1990 level, which also meets the NDC target in the energy sector

Figure 15. Emission trajectories for different main scenarios



Despite reaching the universal access to electricity and NDC target, Armenia must accelerate and strengthen its effort to achieve clean cooking access, increase renewable share in TFEC, and improve energy efficiency. These can be enforced in the updated national energy policy if any. Figure 16 summarises the SDG 7 indicators for different main scenarios.

Figure 16. Summary of SDG 7 indicators for different main scenarios



6. Going beyond SDG 7 with ambitious scenarios

The SDG scenario, as discussed in the previous chapter, sets out various strategies for facilitating an economy-wide, energy-efficiency improvement in alignment with the 2030 Agenda for Sustainable Development and the Paris Agreement. It also identifies appropriate technology options for advancing sustainable energy transition in Armenia. The measures discussed in the previous chapter, have allowed an energy demand reduction of 0.9 Mtoe and emission reduction of 2.6 MtCO2-e in the SDG scenario, relative to BAU by 2030.

Despite the measure allowing GHG emission reduction sufficient to meet the NDC target, a stronger measure is required to achieve a net zero target. The towards net zero (TNZ) scenario aims to assess the potential to transition beyond 2030 by identifying technological interventions, defining the timeframe for implementing different measures and suggesting policy recommendations to help put Armenia's energy sector on the right path to achieving net zero GHG emissions by 2050.

6.1. Towards Net Zero by 2050 scenario

Around three-quarters of current greenhouse gas emissions globally come from the energy sector. Although this sector might have a critical role in averting the worst impact of climate change, a significant challenge cannot be avoided. Limiting the temperature rise to 1.5^{o} C requires climate mitigation efforts on an unprecedented scale and speed to reduce GHG emissions by about 45 per cent from 2010 levels by 2030, reaching net zero around 2050 (IPCC, 2018). Failing to act on the most pressing issue of this generation may lead to a catastrophic impact on human livelihoods.

In addition, COP 26 in Glasgow has created momentum and called for transitioning towards net zero. This scenario examines the potential for Armenia to achieve net zero by 2050. The rationale for choosing a longer timeframe for this scenario is to allow non-electric energy consumers, e.g., direct fuel combustion in the transport sectors, to transition to a fully electric system gradually.

Achieving the Net Zero Emissions target will require decarbonisation of the energy sector, which is best done in the following two steps (a) decarbonising the power and heat sectors and (b) switching all energy sources to electricity. Gladly, the energy system of Armenia is well-positioned for an accelerated decarbonisation effort as some required net zero technologies, such as electric cook stoves and electric vehicles, in decarbonising its energy system are readily available.

The Long-Term Low Greenhouse Gas Emission Development Strategy of The Republic of Armenia (Until 2050)/RA Government Decision No.2318-L (Government of the Republic of Armenia, 2023) sets some action plans to reduce greenhouse gas emissions in 2050. The proposed measures include ind. Small hydropower will be around 450 MW. The number of electric vehicles is expected to be between 200,000 and 400,000 in 2050. Residential and public buildings are expected to meet at least level C of energy efficiency requirements. Using the provided information, NEXTSTEP modelling indicates that the energy sector's emission in 2050 will be around 12.3 $MtCO_2$-e in alignment with the results from the RA Government Decision No.2318-L document of emission between 9.7 $MtCO_2$-e and 19.7 $MtCO_2$-e.

In this report, NEXSTEP further investigates the possibility of reaching zero emissions. Building on the SDG scenario and extending the timeframe to 2050, this scenario suggests the following additional measures. 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 the adoption of 100 per cent e-mobility. In the commercial and industrial sectors, fuel switching has a significant role, particularly the switching from fossil fuels to electricity. NEXSTEP identified that replacing oil products and natural gas with electricity in the industry sector will be a more appropriate strategy. NEXSTEP has not performed quantitative analysis on hydrogen for implementation in Armenia since hydrogen is not commercially available and the technology has various unknown variables. Further investigation is needed to identify the techno-economic potential of hydrogen in the long run (see Box 5).

Box 5. Hydrogen gains global interest, but application is still limited

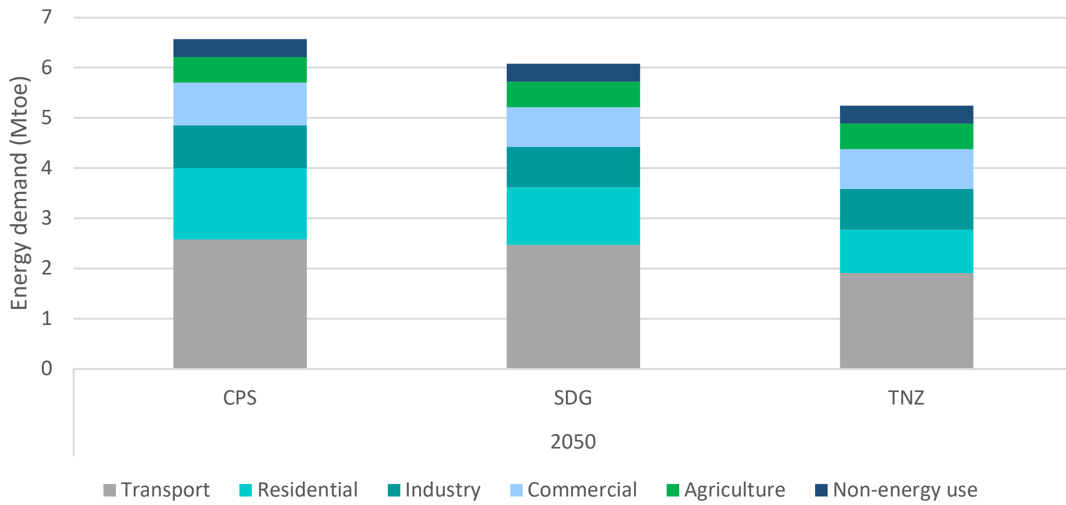
Green hydrogen, created using renewable electricity, have garnered great interest globally. Various government policies have been introduced that directly or indirectly promote the adoption of renewable hydrogens as a means to achieve environmental and climate objectives. It is driven by an increasing interest to use renewable heat in large industry sectors. For example, 5 countries (Australia, Brazil, South Africa, Spain and Sweden) have road maps that include green hydrogen in the industry sector (REN21, 2023)

The implementation of green hydrogen, however, is still limited due to high production costs and the need for associated infrastructure. IEA (2019) reported that producing hydrogen from low-carbon energy is still costly at the moment despite the declining costs of renewables. IEA analysed that the cost of hydrogen production from solar PV and wind in the ASEAN region will be around 3 US$/kg. The development of hydrogen through electrolysis may also require a significant amount of water and electricity. IEA estimated that if all current dedicated global hydrogen production were produced through water electrolysis, this would result in an annual electricity demand of 3,600 TWh – and water requirements would be 617 million meter cubic. The widespread hydrogen adoption is also being hold due to the slow development of hydrogen infrastructure. Planning and coordination between governments and industries are required to address refuelling station problems in the future.

With these measures, the total energy demand is expected to increase from 3.27 Mtoe in 2030 to 5.25 Mtoe in 2050, a reduction of about 1.32 Mtoe relative to the CPS scenario and 0.84 Mtoe relative to the SDG scenario (

Figure ***17***). The transport sector consumption will remain the largest at 36.4 per cent, followed by the residential sector at 16.3 per cent. The industrial sector will account for 15.6 per cent, the commercial sector at 15 per cent, and the agricultural sector at 9.7 per cent.

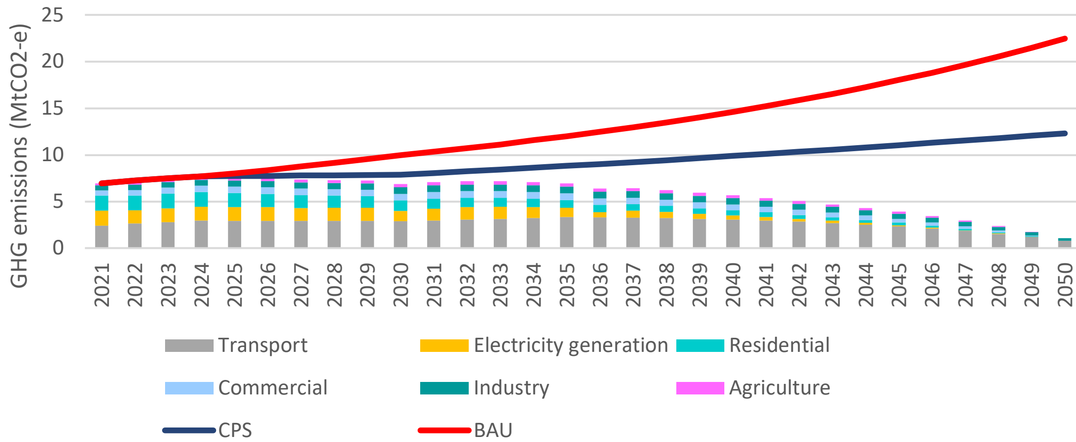
Figure 17. Comparison of total final energy demand in 2050 by sector



Despite requiring less energy compared to the CP scenario by 2050, the electrification of the energy system in this scenario will require an additional 28 TWh of electricity compared to the CP scenario. NEXSTEP estimated that an additional 15 GW of solar PV will be required compared to the capacity proposed in the LT-LEDS document since this scenario aims to bring the emission in the energy sector to zero. There will be a significant emission reduction in this toward net zero by 2050 scenario. This is because of (1) full implementation of fuel switching and (2) fully decarbonising the electricity and heat supply. In this scenario, the emission peaks in 2025 and starts to decline gradually until 2050 due the implementation of several measures discussed above (

Figure **18**). Due to certain limitations to implementing measures in the transport and agricultural sectors, however, a small number of emissions would still be produced in those sectors. In 2050, the transportation sector will still emit 1.1 $MtCO_2$-e from the rail transport and aviation system. Therefore, carbon sinks, such as reforestation or forest management, or other carbon capture technologies should be considered to absorb the remaining carbon emissions.

Figure 18. GHG emission in the Towards Net Zero by 2050 Scenario



7. Economic analysis and financing options

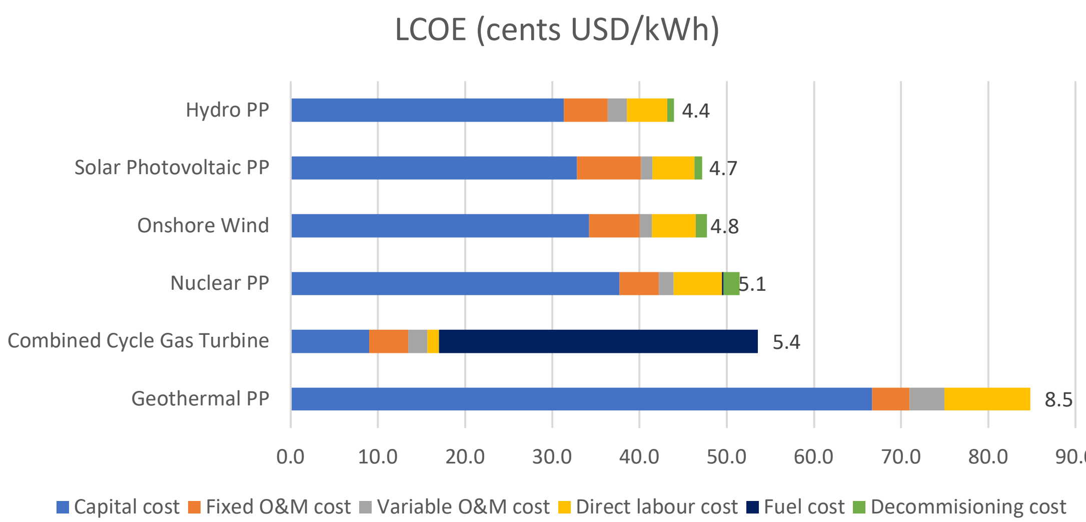
Sustainable, green transition in the energy sector offers financial benefits in the long term. This could entail financial incentives to promote efficient vehicles or efficient household appliances. It should be noted that the transport, residential, commercial and industrial sectors have a high GHG mitigation potential, with which most scenarios are cost-effective in the long-term. For instance, mode shifting in the transportation sector would provide the highest savings with high abatement potential. Nonetheless, cost savings can be expected due to the reduced usage of expensive imported oil products.

Armenia can consider the role of ESCOs in promoting energy efficiency in the building sector. The key to supporting the growth of ESCOs is the availability of accessible financing. Armenia might learn from the country, such as Thailand, which has previously demonstrated leadership in this approach by establishing a "revolving fund" for energy conservation and efficiency. ESCOs can borrow funds from financial institutions at an interest rate lower than commercial rates, over an extended repayment period.

Raising ambition towards net zero emission in 2050 might seem challenging since the country must (1) increase renewable share significantly and (2) implement fuel switching to electricity by 2050. However, it will be feasible in the future. In the past, investment in fossil fuel generation was a cheap and reliable, albeit polluting, method of generating electricity. This is no longer the case as renewables have matured and costs have dropped significantly. It is cheaper today to generate electricity from renewables such as solar, hydropower, wind and biomass than fossil-fuel technologies. The Levelized Cost of Electricity (LCOE) is a widely used metric in the energy industry for comparing the economic value of different electricity generation technologies. It calculates the unit cost of electricity (US$/MWh or cents/kWh) over the lifetime of the project, including capital, operating and financing costs. LCOE is measured using the lifecycle cost of a system and therefore balances out the disparity where some technologies have a high capital cost but low operating cost, whereas the other technologies have low capital cost and high operating cost.

NEXSTEP has calculated LCOE for Armenia (Figure 19) using cost figures presented in Annex 3. This makes LCOEs entirely reflective of the national context of Armenia. The LCOE component analysis highlights renewable electricity generation technologies e.g., hydro (4.4 cents/kWh), solar photovoltaic (4.7 cents/kWh), onshore wind (4.8 cents/kWh), and are cheaper than fossil-g generation technologies today in Armenia. The given LCOE for renewable energy is without energy storage consideration. Box 5 shows the impact of battery energy storage system (BESS) on the LCOE.

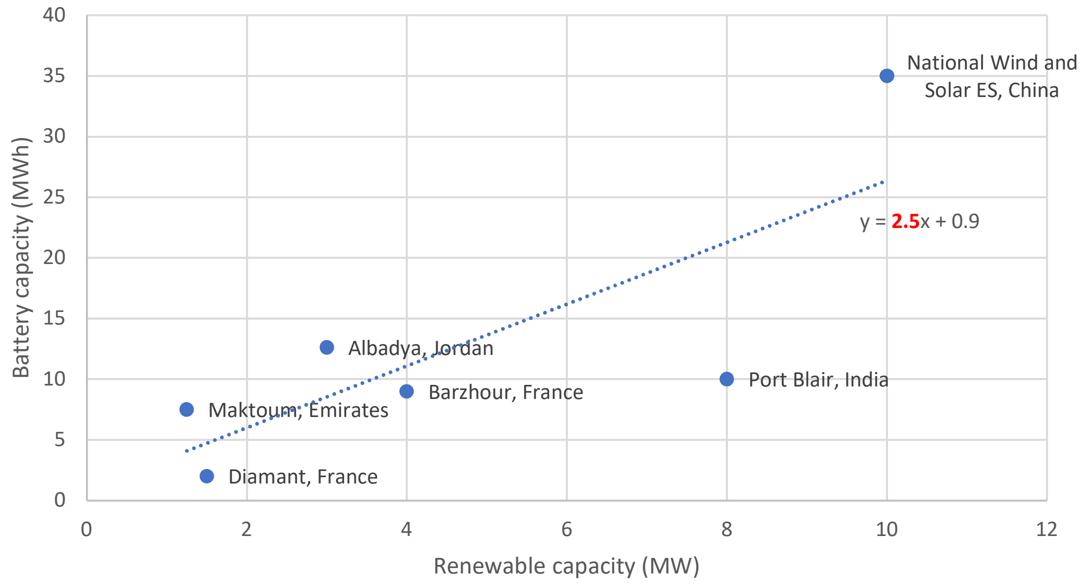
Figure 19. Comparison of Levelized Cost of Electricity



Box 6. LCOE of electricity generation with battery energy storage system

Battery energy storage system will have a critical role in a fully decarbonized energy system. However, calculating battery capacity requirement for national level is impractical since the ratio between battery capacity and solar capacity vary depending on the size and location of the project. For instance, the Port Blair project in India has a ratio between battery capacity and renewable capacity of 1.25 (8 MW/10 MWh Li-ion). However, the Maktoum project in the United Arab Emirates has a battery capacity and renewable capacity by a factor around 6 (1.25 MW/ 7.5 MWh). In France, the Diamant and the Barzhour projects have different factors despite being installed in the same country. Therefore, storage capacity is better estimated at the project level. Because of its inherent difficulties, NEXSTEP analysis has avoided to estimate specific storage capacity at the national level. Instead, it has estimated a ratio between battery and renewable capacity, which is expected to be around 2.5 as shown in Figure 20.

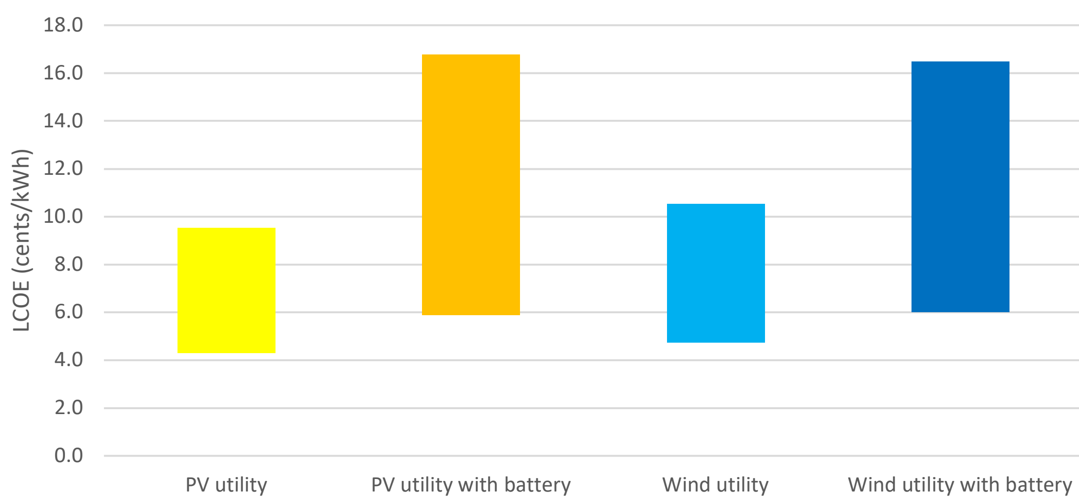
Figure 20. Relationship between battery capacity and renewable capacity



Data is taken from (Beltran, Cardo-Miota, Segarra-Tamarit, & Pérez, 2021)

Using this factor, NEXSTEP has estimated the LCOE of utility-scale renewable project with and without storage (**Figure 21**). Without storage, the LCOE of utility-scale solar photovoltaic will range from 4.3 to 5.2 cents/kWh while the LCOE of utility-scale onshore wind will range from 4.8 to 5.8 cents/kWh. With storage, the LCOE of utility-scale solar photovoltaic will range from 5.9 to 10.9 cents/kWh while the LCOE of utility-scale onshore wind range from 6 to 10.5 cents/kWh depending on the capacity of storage. The higher the battery size, the higher the LCOE. Therefore, finding the optimum battery sizing will be critical for the development of renewable with BESS projects.

Figure 21. LCOE comparison with and without batteries for Armenia



NEXSTEP estimated that the capacity requirement to achieve net zero would be higher than the proposed measure in the LT-LEDS document. Solar capacity will be around 16.5 GW, hydropower will be around 1.6 GW, nuclear will be around 1.1 GW, and wind will be 0.5 GW in 2050. The investment costs required in power generation will be US$ 17.5 billion until 2050, with a net benefit of around US$ 35.2 billion.

There are a few pathways that the country may explore, in collaboration with citizens and/or private investors, in order to achieve a net-zero carbon power supply objective. One workable solution and the recent policy instrument that can be considered is the renewable energy auction. This approach is likely to substantially decrease the cost of electricity supply through a competitive pricing bidding and therefore, return a greater net benefit. The recent auctions e.g., the 60 MW solar PV auction in Cambodia has achieved $0.0387 per kWh.

A renewable energy auction, also known as a “demand auction” or “procurement auction”, is essentially a call for tenders to procure a certain capacity or generation of renewables-based electricity. The auction participants submit a bid with a price per unit of electricity at which they are able to realize the project. The winner is selected on the basis of the price and other criteria, and a power purchase agreement is signed. The auctions have the ability to achieve deployment of renewable electricity in a well-planned, cost-efficient and transparent manner. Most importantly, it makes the achievement of targets more precise than would be possible by other means, such as a Feed-in-Tariff (FiT).

Auctions are flexible and they allow Governments to combine and tailor different design elements to meet deployment and development objectives. Unlike FiTs, where the Government decides on a price, auctions are an effective means of discovering the price appropriate to the industry, which is the key to attracting private sector investment. In addition, an auction provides greater certainty about future projects and is a fair and transparent procurement process. However, the administrative and logistic costs associated with auctions are very high unless multiple auctions are undertaken at regular intervals. Further details of designing renewable auction can be found in Box 7.

Box 7. Key design principles of a renewable auction

It is imperative that an auction be appropriately designed to (a) avoid the risk of underbuilding and project delays, and (b) allow sufficient competition among different levels of bidders in order to drive down the cost. IRENA suggests the following key design elements:

- Auction demand. Governments need to clearly indicate the scale or size of each auction, the preferred technology (technology neutral of a specific technology), auction frequency, and the upper and lower limits of projects size and price.
- Pre-qualification. A strict or high pre-qualification for bidders will leave out the smaller entities, while a relaxed pre-qualification may undermine the quality of the project and increase the administrative costs. Governments need to make a trade-off, depending on the project size and other development objectives.
- Selection criteria. Commonly two selection criteria are used: (a) the lowest bid where only the lowest bidder will win; and (b) lowest bids plus other objectives where in addition to the price, other objectives such as local content and jobs are taken into consideration.
- Payment modalities. The pay-as-bid model is good to minimize the cost; however, the marginal cost payment model, where the same price (selected based on the highest cost winner) is paid to all winners is also practised.
- Penalties for non-compliance. There could be cases where the developer either delays the project or fails to complete. To avoid such cases, penalties should be in place. There are two modes of penalty. In the monetary penalty, money will be deducted from bidder's "bond", or the price of energy will be reduced for a delayed completion. A form of non-monetary penalty can be the exclusion of the bidder from future auctions.

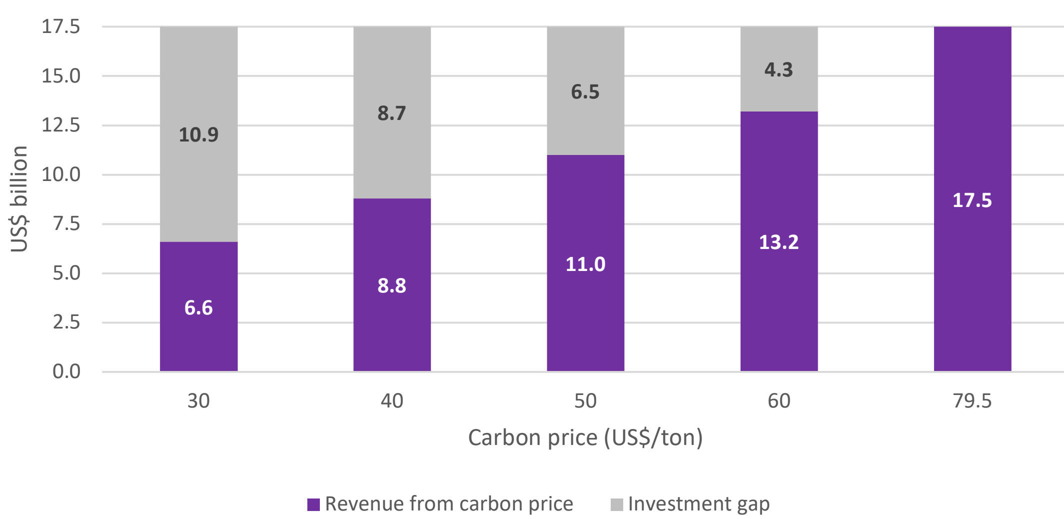
Another consideration for the long term is internalizing externalities. The challenges associated with accurately estimating the externalities of fossil fuel energy technologies have continued to result in unfair comparisons with renewables. If the external costs of fossil fuel systems are considered, energy generation from renewables would have been equal, if not lower, to that of conventional energy systems. The external costs arise from pollution and environmental degradation caused by the extraction of fossil fuel resources, indoor and outdoor air pollution, and the negative economic impacts of extreme weather events caused by global warming, such as its impact on agricultural yields.

Carbon pricing is recognized around the world as an effective policy tool to facilitate sustainable energy transition. The external cost of carbon emissions paid by society should be shifted towards the producers and consumers responsible for producing pollution-causing goods by directly setting a price on carbon emissions. There are two main mechanisms for carbon pricing – emission trading schemes (cap and trade) and carbon taxation. Emission trading systems place a cap on CO_2-e emissions and allow participants to trade an allowance of CO_2-e emissions under the cap. The mechanism results in a wealth transfer from high emission to low-emission technology proponents, increasing the attractiveness of low-emission technology investments. Carbon taxes simply put a price on the GHG emissions or on the carbon content of fuels. Governments may choose to treat this as a revenue stream or hypothecate these funds to use it as a wealth transfer mechanism.

In today's market, there is no consistency in carbon price, and it is therefore very difficult to choose a carbon price that will suit the national context. The State and Trend of Carbon Pricing 2022 report published by the World Bank (World Bank, 2022) suggests that a minimum carbon price of US$ 50-US$ 100 per ton of is needed by 2030 to cost-effectively reduce emissions in line with the temperature goal of the Paris Agreement. In Singapore, the carbon tax rate will be increased to US$ 18/tCO_2e in 2024 and 2025, and US$ 33/tCO_2e in 2026 and 2027, with a view to reaching US$ 37-59/tCO_2e by 2030.

The investment cost to achieve net zero will require an additional US$ 17.5 billion compared to business as usual. However, this will provide a cumulative reduction of 218 MtCO_2-e up to 2050. In the absence of any carbon price in Armenia, an indicative price of US$ 79.5/ tCO_2-e could be considered to close the investment gap (Figure 22). This is an indicative price to demonstrate how a price on carbon would support the proposed transformation of the energy sector. Further in-depth investigation should be performed, involving subject matter experts and stakeholders, to identify the price suitable for Armenia.

Figure 22. Indicative carbon price to close the investment gap in 2050



8. Conclusions and recommendations

8.1. Conclusions

The 2030 Agenda for Sustainable Development and Paris Agreement provide a common goal for all countries to achieve sustainability and climate objectives. Achieving the SDG 7 and NDC targets is not an easy feat, but it will help to create a more sustainable and resilient society. This Road Map has presented a number of different scenarios together with their technical feasibility, investments, benefits, challenges and opportunities to inform policymakers on different pathways to energy transition. NEXSTEP has also looked beyond just achieving SDG 7 targets and explored the full potential of the country in relation to decarbonizing its power sector and assessing the potential to advance towards net zero by 2050.

Armenia has achieved universal access to electricity. While the gap is small to achieve universal access to clean cooking by 2030, a coordinated approach is therefore much desired from the private and public sectors in providing advanced clean technologies to the population. For example, electric cook stoves, which build on commonly used practices, should be promoted to reduce fuel consumption and household indoor pollution. Opportunities also exist in the residential, industrial, transport, and commercial sectors to save more energy through implementing energy efficiency measures, particularly via mode shifting, fuel switching, energy management standards, and energy codes. Increased efforts can help achieve the global energy efficiency improvement target of 4 per cent annually.

Armenia is on track to achieve the renewable energy capacity target by 2030. The renewable energy share in TFEC will improve since Armenia has an ambitious plan to increase renewable generation. In the long run, the promotion of electric cook stoves and electric vehicles will require a substantial amount of electricity in the future. Diversification of generation sources using solar PV, wind, and hydropower would help the country fulfil the increasing electricity and heat demand and improve energy security. The MCDA tool analysis suggests that the net zero emissions scenario is the highest-ranked scenario for navigating the energy sector towards 2050. In addition to achieving the SDG 7 targets, this scenario will also enable Armenia to exploit its full potential for emission reduction in the long term as well as fulfil the commitment made in COP 26.

8.1.1. Scenario evaluation

The current policy, SDG and the ambitious scenarios have been evaluated and ranked, using the Multi-Criteria Decision Analysis (MCDA) tool, with a set of 12 criteria and weights assigned to each criterion (Table 10). While the criteria and weights have been selected based on expert judgement, ideally the process should use a stakeholder consultation. If deemed necessary, this step can be repeated using the NEXSTEP tool in consultation with stakeholders where the participants may want to change weights of each criterion. The following factors have been considered to assume comparative weights across the set of criteria, where the total weight needs to be 100 per cent:

(a) Universal access to electricity to be achieved;
(b) Universal access to clean cooking fuel to be achieved;

(c) Renewable energy share in the total final energy consumption to increase;

(d) Energy efficiency improvement should be doubled, and where there is an economic benefit, it should be further enhanced;

(e) The unconditional NDC target should be achieved. Where possible, the conditional target should be achieved if it is economically viable;

(f) Total investment should be kept low, but the net benefit should be high. This was done by assigning both indicators the same weight to ensure that a scenario is chosen on the value-for-money basis; and

(g) Carbon pricing should be introduced to encourage investments in clean energy.

Table 10. Criteria with assigned weights for MCDA

Criterion	Weight
Access to clean cooking fuel	10%
Energy efficiency	10%
Share of renewable energy	11%
Emissions targets in 2030	10%
Alignment with Paris Agreement	10%
Fossil fuel subsidy phased out	5%
Price on carbon	5%
Fossil fuel phase-out	5%
Cost of access to electricity	7%
Cost of access to clean cooking fuel	7%
Investment cost	10%
Net benefit from the power sector	10%
Total	**100%**

Table 11 shows the summary of results obtained through this evaluation process. The scenario evaluation suggests that the “Towards Net Zero by 2050” scenario is the highest-ranked energy transition pathway for Armenia since there will be a significant energy efficiency improvement, renewable share increase, and emission reduction, and most importantly, it would set the course of the energy sector to achieve the goal of net zero emissions in the long-run. Therefore, Armenia should begin developing/aligning strategies and plans in line this scenario, which will also ensure the achievement of all SDG 7 targets as well as NDC conditional target since the scenario is developed based on SDG scenario.

Table 11. Scenario ranking based on MCDA

Scenarios	Weighted scores	Rank
Towards Net Zero 2050	59.5	1
SDG scenario	46.8	2

Scenarios	Weighted scores	Rank
Current policy scenario	41.9	3
Business-as-usual scenario	0	4

8.1.2. Revisiting existing policies

Armenia's current energy policies have been evaluated based on the outputs from the LEAP model, in order to highlight any revisions required to achieve the SDG 7 and NDC targets by 2030. These are summarized in Table 12.

Table 12. Assessment of SDG7 and NDC targets

Category	Existing policy	Policy evaluation	NEXSTEP analysis
Access to electricity	Not applicable since Armenia has achieved universal access to electricity.	Armenia has achieved 100 per cent universal access to electricity.	There may be some unregistered households that still have no access to electricity. In such minor cases, solar mini-grids and solar home systems could be considered.
Access to clean cooking	Not available.	The NEXSTEP analysis projects that Armenia may reach a100 per cent clean cooking access rate as per the historical improvement trend.	NEXSTEP analysis suggests bridging the remaining gap with electric cook stoves as the most appropriate clean cooking solution. It is also critical to start promoting electric stove to increase the penetration to at least 20 per cent of population by 2030.
Renewable Energy in TFEC	Not specific policy targeting renewable energy share in TFEC	The share of renewables in TFEC is projected to be 10.3 per cent in the CP scenario due to the increase of planned renewable power capacities under existing capacity expansion plan	The renewable energy share in TFEC will further increase to 10.9 per cent in the SDG scenario. This increase is attributable to phasing out of inefficient traditional biomass stoves with electric stoves. This increase is also contributed by the additional measures in the energy efficiency.
Renewable energy in Power sector	Strategic Plan for the Development of the Energy Sector of the Republic of Armenia (until 2040) (Government of the Republic of Armenia, 2023) aims to increase green energy share and energy security (at least 50 per cent renewable including large hydropower 2030 in the power generation	Armenia is on track to achieve 50 per cent renewable share in power generation. The share of renewables in TFEC is projected to be 52.9 per cent in the CP scenario due to the increase of planned renewable power capacities. The solar	Armenia can introduce renewable auctions as well as carbon tax to accelerate the development of renewable energy.

	mix and about 60 per cent by 2040). The National Programme on Energy Saving and Renewable Energy for the period 2022-2030/RA Government Decision No.398-L (Government of the Republic of Armenia, 2022) aims to achieve at least 15 per cent of solar energy production by 2030.	energy production will be at least 17.7 per cent in 2030.	
Energy efficiency	The National Programme on Energy Saving and Renewable Energy for the period 2022-2030/RA Government Decision No.398-L (Government of the Republic of Armenia, 2022) sets the energy saving will be around 20 per cent compared to the baseline scenario. The share of electric passenger cars will gradually increase, reaching at least 10 per cent in 2030 while the share of electric public transport will reach 50 per cent in 2030. There will be energy efficiency improvement by 70 per cent of public transport due to the new route introduction. This will increase the share of public transport to 60 per cent.	The CP scenario will not achieve the suggested global energy efficiency improvement target of 4 per cent or 2.7 MJ/US$$_{2017}$ in 2030. It is projected that the energy intensity will be 2.8 MJ/US$$_{2017}$ in 2030.	The energy intensity is further reduced to 2.7 MJ/US$$_{2017}$ in 2030 under the SDG scenario, which meets the global energy efficiency target. Achievement of this target requires phasing out inefficient cooking technologies, reducing the share of unclean heating technology, accelerating the implementation of energy management standards and building codes in designated factories/buildings, increasing the penetration of electric cars to 20 per cent, and promoting equipment performance benchmarks and labelling.
Emission reduction	The National Programme on Energy Saving and Renewable Energy for the period 2022-2030/RA Government Decision No.398-L (Government of the Republic of Armenia, 2022) sets the GHG emissions will decrease by about 50 per cent compared to the value in 1990. The 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.	Armenia is on track to achieve the target of 50 per cent emission reduction by 2030. The emission reduction will be 65.2 per cent in the current policy scenario.	Armenia will further achieve 67.3 per cent emission reduction by 2030 because of the additional measures in the demand sector to improve its energy efficiency.

8.2. Recommendations

8.2.1. Promote electric cook stoves to provide a sustainable solution to achieving universal access with multifold benefits

Universal access to clean cooking solutions should be a key priority in Armenia and it needs to be included in the energy policy. The NEXSTEP analysis suggests the remaining clean cooking gap in Armenia should be closed with the promotion of electric cook stoves. Electric cook stoves are more efficient than other cook stoves, including gas stoves. Yet, electric cook stoves have higher annualised cost compared to natural gas stoves, due to cheaper gas tariff. The annualized cost of electric cook stove will be US$164 while the natural gas cookstove will be US$98.

However, since natural gas is imported, Armenia is vulnerable to gas price volatility. In the long run, electric cook stoves are a prime solution to achieving net zero emission with no added burden on fuel imports. NEXSTEP suggest the adoption of electric cook stoves to 25 per cent of urban households and 10 per cent of rural households in 2030. It is estimated that total investment of US$ 23.8 million will be required to distribute electric cook stoves to 0.14 million households.

8.2.2. Adopt multi-sectoral approach to raise energy efficiency strategies by 2030 to align with global improvement target

Energy efficiency policies across sectors can help achieve substantial energy savings by reducing the need for investment in energy infrastructure, fuel costs and vulnerability to fossil fuel prices. Policymakers should improve the energy efficiency strategy by including well-defined best practice policies, implementation timelines and enforcement.

Achievement of the SDG 7 target of 2.7 MJ/US$ by 2030 (4 per cent annual improvement rate), will require a reduction of TFEC by 0.9 Mtoe compared to the BAU scenario. To achieve this target, the Government should consider accelerating the implementation of energy management standards, energy code, equipment performance benchmarks and labelling, and transport mode shifting by 2030. Phasing out inefficient individual heating technologies is also critical in the long-run.

8.2.3. Fuel switching strategies, including electrification, accelerate SDG 7 progress and provide multi-fold benefits in the long run.

This roadmap suggests that policymakers should raise the ambition further to align with net zero emissions scenarios. NEXSTEP identified that electricity will be an important strategy for Armenia to replace the oil products demand compared to hydrogen due to the current uncertainties in the hydrogen market. Further in-depth investigation should be performed, involving subject matter experts and stakeholders, to identify the techno-economic potential of hydrogen in Armenia.

Electrification of the transport system will also be critical for Armenia. A vigorous adoption of electric vehicles, for example, would reduce the demand for oil products. Another advantage of EVs is their ability to absorb excess renewable energy. With specialised networks and large numbers of EVs plugged into the grid at any one time, there is the possibility to use the combined stationary battery capacity as an element of load levelling. To promote the investments, Armenia can set financial and tax incentives, and safety standards.

8.2.4. Decarbonize the power and heating sector by investing in renewable energy to help achieve net zero emissions target

Armenia achieves 50 per cent renewable share in the installed capacity by 2030. As, renewables have matured and costs have dropped significantly. It is cheaper today to generate electricity from renewables such as solar, hydropower, and wind compared to fossil-fuel technologies. Strategies, such as renewable auction and carbon pricing, can be considered to provide revenue streams for investing renewable energy generation in a fully decarbonized energy system. The same measure must be implemented simultaneously in the heating generation as well.

8.2.5. Develop green financing policy

Accelerating green financing is critical to achieving the proposed sustainable energy transition. Policymakers need to work with central banks, regulatory authorities and investors to examine the possibility of developing a green finance policy or fund to help close the investment gap. Another option is green bonds to mobilize resources from domestic and international capital markets to finance climate solutions. Renewable energy technologies have relatively high financing costs in developing countries, which reflects their unattractive risk/return profile. This is because of their long-term horizon, high initial capital costs (including high infrastructure cost), unfavourable policy for grid access, illiquid equipment and project risks. Policymakers can reduce high financing costs by using two methods – de-risking and direct incentives. De-risking has two basic forms – policy de-risking instruments that reduce risk, and financial de-risking instruments that transfer risk. Direct incentives are direct finance transfers or subsidies to low carbon investments. The United Nations Development Programme’s (2021) De-risking Renewable Energy Investment (United Nations Development Programme, 2021) is an important guide for policymakers in developing strategies to reduce risks in renewable energy investment.

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Annexes

I. National Expert SDG 7 tool for energy planning methodology

The analysis presented in this national Road Map is based on the results from the National Expert SDG 7 Tool for Energy Planning (NEXSTEP) project. NEXSTEP is an integrated tool for assisting policymakers in making informed policy decisions that will help in achieving SDG 7 and NDC targets by 2030. The SDG 7 and NDC targets are integrated in the LEAP energy model and back casted from 2030, since the targets for 2030 are already defined.

Annex table 1.Targets and indicators for SDG 7

Target	Indicators	2021	2030
7.1. By 2030, ensure universal access to affordable, reliable, and modern energy services.	7.1.1. Proportion of population with access to electricity.	100%	100%
	7.1.2. Proportion of population with primary reliance on clean fuels and technology for cooking.	98.6%	100%
7.2. By 2030, increase substantially the share of renewable energy in the global energy mix.	7.2.1. Renewable energy share in total final energy consumption.	6% (excluding traditional biomass)	10.9%
7.3. By 2030, double the global rate of improvement in energy efficiency.	7.3.1. Energy intensity measured as a ratio of primary energy supply to gross domestic product.	3.9 MJ/US$ (2017) PPP	2.7 MJ/US$ (2017) PPP

SDG 7.2. Renewable Energy

Methodology: Share of renewable energy in total final energy consumption, where TFEC is total final energy consumption, ELEC is gross electricity production and HEAT is gross heat production.

$$\%TFEC_{RES} = \frac{TFEC_{RES} + \left(TFEC_{ELEC} \times \frac{ELEC_{RES}}{ELEC_{TOTAL}}\right) + \left(TFEC_{HEAT} \times \frac{HEAT_{RES}}{HEAT_{TOTAL}}\right)}{TFEC_{TOTAL}}$$

SDG 7.3. Energy Efficiency. "By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production, plus net imports minus international marine and aviation bunkers plus stock changes. For comparison purposes, GDP is measured in constant terms at 2017 PPP.

$$Primary\ energy\ intensity = \frac{Total\ Primary\ Energy\ Supply\ (MJ)}{GDP\ (USD\ 2017\ PPP)}$$

$$CAGR = \left(\frac{EI_{t2}}{EI_{t1}}\right)^{\frac{1}{(t2-t1)}} - 1$$

where EI_{t1} is energy intensity in year t1 and EI_{t2} is energy intensity in year t2.

Base period improvement rate for Armenia (1990-2010): 7.3 per cent

Doubling the improvement rate requirement for Armenia (2010-2030): 14.5 per cent

Historical improvement rate for Armenia (2010-2021): -0.2 per cent

Required improvement rate for Armenia in the remaining period to achieve the doubling improvement rate (1990-2010): 29.5 per cent

SDG 7.3. improvement rate for Armenia (suggested global improvement rate): 4 per cent.

II. Key assumptions for NEXSTEP energy modelling

(a) General parameters

Annex table 2. GDP, PPP and growth rate

Parameter	Value
GDP (2021, constant 2015 US dollar)	US$ 13.88 billion
PPP (2021, constant 2017 US dollar)	US$ 39.65 billion
Growth rate	2021 to 2022 (12.6%); 2022 to 2023 (8.7%), 2023 to 2024 (5.7%), 2024 to 2027 (5%), 2027 forward (5.6%)

Annex table 3. Population, population growth rate and household size

Parameter	Value
Population (2021)	2,961,367
Population growth rate	-0.48% per annum
Number of households (2021)	760,050
Household size (constant throughout the analysis period)	3.9

(b) Demand-side assumptions

(i) Transportation

- Land transport consumption is estimated using the vehicle statistics, load factor, annual travel mileage and estimated fuel economy as shown in annex table 4. The factors are based on vehicle statistics compiled by the local consultant.
- Land transport activities in 2021 are estimated to have been 38 billion passenger-kilometres and 40.4. billion tonne-kilometres. The growth in both passenger transport and freight transport activities is assumed growing at the same rate as the GDP per capita.

Annex table 4. Passenger-km and tonne-km distribution

Passenger Transport	%share of vehicles by fuel type	Annual travelled mileage (km)	Fuel consumption	%share of passenger-km
Passenger Car	Gasoline – 24.4%	13,323	12 km/l	39.2%
	Diesel – 1.1%		12 km/l	
	Electric – 0.4%		5 km/kWh	
	CNG – 74.1%		12 km/l	
Motorbike	Gasoline – 99.9%	9,000	15.1 km/l	0.1%
	Electric – 0.1%		6.7 km/kWh	
Taxi	CNG – 100%	54,750	8.3 km/l	1.2%
Bus	Gasoline – 56.2%	72,000	4.3 km/l	59.1%
	Diesel – 35.6%		4.3 km/l	
	Electric – 0.02%		0.5 km/kWh	
	CNG – 8.3%		4.3 km/l	
Minibus	Gasoline – 81%	60,000	8.5 km/l	0.4%
	Diesel – 18.7%		8.3 km/l	
	CNG – 0.3%		8 km/l	

Freight Transport	No. of vehicles	Annual travelled mileage (km)	Fuel consumption	% share of tonne-km
Freight Truck	Gasoline – 24.9%	43,800	8 km/l	84.5%
	Diesel – 33.6%		8 km/l	
	Electric – 0.1%		1 km/kWh	
	CNG – 41.5%		8 km/l	
Van	Gasoline – 36.2%	29,200	5 km/l	15.5%
	Diesel – 63.2%		5 km/l	
	Electric – 0.2%		2 km/kWh	
	CNG – 0.5%		5 km/l	

(ii) Residential

- The residential sector is further divided into urban and rural households. Both urban and rural households have achieved a 100 per cent electricity access rate and the overall clean cooking rate was 98.6 per cent in 2021. The breakdown is shown in annex table 5.

Annex table 5. Cooking distribution in urban and rural households[20]

Stove type	Energy intensity (GJ/household)	Urban	Energy intensity (GJ/household)	Rural
LPG stove	-	-	-	-
Natural gas stove	10.9	98%	10.9	94.2%
Electric stove	3.9	1.9%	3.9	1.7%
Biomass stove*	35.2	0.1%	35.2	4.1%
Charcoal stove*	-	-	-	-

*This is assumed as unclean fuel/technology.

- The residential appliance ownership data and energy use intensity in the baseline year were provided by the local consultant. The appliance ownership is projected to grow a rate similar to the growth in GDP. The average electrical demand per owning household for the different appliances are assumed to be constant throughout the analysis period, unless further energy efficiency measures are implemented.

Annex table 6. Residential appliance baseline assumptions

Appliance	Electricity intensity (kWh/HH/year)	Ownership – urban	Electricity intensity (kWh/HH/year)	Ownership – rural
Lighting	525.6	100%	350.4	100%
Air Conditioner	1752.0	32.9%	1095.0	16.2%
Refrigerator	821.3	100%	821.3	98.3%
Television	547.4	115%	273.8	107%
Washing machine	52.0	96%	52.0	94%
Water pump	365.0	-	255.5	5%

[20] The clean cooking access rate is indicated as 98.6 per cent (World Health Organization, 2022). The energy intensity is based on assumptions provided by the local consultant.

Iron	26.0	98.6%	26.0	98.1%
Other	36.5	100%	36.5	-

- The residential heating technology data and energy use intensity in the baseline year were provided by the local consultant. The average heat demand per owning household for the different technology are assumed to be constant throughout the analysis period, unless further energy efficiency measures are implemented.

Annex table 7. Heating distribution in urban and rural households

Heating technology	Energy intensity (GJ/household)	Urban	Energy intensity (GJ/household)	Rural
District heating	63.5	1%	-	-
Coal furnace	17.4	0.5%	38.3	4%
Gas heater	36	30%	54	12%
Tankless gas boiler	52.9	38%	70.5	7%
Wood furnace	17.4	15.5%	17.4	74%
Electric heater	14.0	14%	14.0	2%
Animal waste	17.4	1%	17.4	1%

(iii) Industry

- The industry sector is differentiated into eleven (9) subcategories. The fuel consumption by industry subcategories is as detailed in annex table 8.
- The industrial GDP is assumed to grow at a rate similar to the national GDP growth rate. The energy intensity is assumed constant throughout the analysis period in the absence of energy efficiency interventions

Annex table 8. Fuel consumption by industry subcategories in 2021

Industry	Fuel consumption (ktoe)					
	Coal	Oil products	Biomass	Natural gas	Electricity	Total
Cement and non-metals		0.46		102.99	16.02	**119.47**
Pulp and paper				4.39	2.05	**6.44**
Textile, leather, and leather products		0.001		1.00	1.90	**2.90**
Iron and steel		0.01		15.84	9.61	**25.47**
Fertilizer, chemical and rubber products		0.08		1.57	1.54	**3.18**
Food and beverages	0.01	0.02	0.01	55.94	22.77	**78.75**
Machinery and transport equipment			0.01	0.88	1.92	**2.82**
Wood and other products				0.03	0.03	**0.06**
Other processing industry		16.95	0.003	17.47	97.14	**131.57**
Total	**0.01**	**17.51**	**0.02**	**200.11**	**152.99**	**370.65**

(iv) Commercial sector

- The total annual energy consumption in the commercial sector was 433 ktoe in 2021. It is projected to grow at an annual rate similar to the national GDP growth rate.
- The commercial sector is further differentiated into seven categories and the energy consumption by categories are as shown in annex table 9.

Annex table 9. Commercial sector fuel consumption in 2021

Floor space (million m²)	Fuel consumption (ktoe)						
	Coal	Oil products	Biomass	Natural gas	Electricity	Heating	Total
167.5	-	17.67	2.32	216.35	188.86	7.75	432.95

(v) Other sectors

- The remaining demand is used for agriculture and non energy use. The consumption growth is projected to grow at the same as the national GDP growth rate.

Annex table 10. Consumption by other sectors in 2021

Category	Fuel consumption (ktoe)					
	Coal	Natural gas	Oil products	Electricity	Heating	Total
Agriculture	-	72.9	15.8	14.8	-	103.4
Non-energy use			73.7			73.7

III. Power technologies cost and key assumptions

The cost parameters considered for the power technologies are as follows:

Annex table 11. Power technologies' key assumptions

Technology	Efficiency	Investment cost (US$/MW)	Fixed O&M (US$/MW-year)	Variable O&M (US$/MWh)
Gas turbine	67%	988,000	33,400	2.2
Nuclear	33%	4,141,500	33,400	1.7
Hydro	-	2,426,800	26,570	2.2
Solar	-	840,000	12,726	1.3
Wind	-	1,327,000	15,209	1.4
Geothermal	-	7,667,300	33,400	4.0

IV. Economic analysis data for clean cooking technologies

The NEXSTEP economic model utilizes the technological and cost parameters to estimate the. annualised cost of clean cooking technologies (annex table 12). The calculation assumes an annual cooking thermal energy requirement of 4,925 MJ per household. In addition, a discount rate of 5.37 per cent is assumed.

Annex table 12. Technology and cost data for clean cooking technologies

Technologies	Efficiency[21] (%)	Lifetime[22] (years)	Stove cost (US$)	Variable O&M [23](US$/year)	Fuel cost (US$)
Natural gas stove	45	20	44	10	0.276 per kg
Electric stove	80	15	37	10	0.083 per kWh
ICS stove	30	4	35	10	0.1 per kg

V. Summary results for the scenarios

	BAU scenario	CPS scenario	SDG scenario
Universal access to electricity in 2030	100%	100%	100%
Universal access to clean cooking in 2030	100%	100%	100%, via electric stoves
Energy efficiency in 2030	3.4 MJ/US$	2.8 MJ/US$	2.7 MJ/US$
Renewable energy share in TFEC in 2030	6.7%	10.3%	10.9%
GHG emissions in 2030	10 $MtCO_2$-e	7.9 $MtCO_2$-e	7.4 $MtCO_2$-e
Renewable energy share in power generation in 2030	31.7%	45.1%	45.1%
The capacity of renewable power generation in 2030	37.4%	52.9%	52.9%
Net benefits from the power sector	US$ 4.2 billion	US$ 4.3 billion	US$ 4.3 billion
Total investment for the power sector up to 2030	US$ 3.1 billion	US$ 1.6 billion	US$ 1.6 billion

[21] Sourced from: ICS – own estimation, LPG stove efficiency ranges – (World Bank, 2014), electric cookstove (induction stove) – (IEA, 2012).
[22] Sourced from: ICS – own estimation, LPG stove – (Clean Cooking Alliance, 2021), electric stove – (IEA, 2012).
[23] Variable O&M is based on own assumptions