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ARMENIA LEAST COST ENERGY DEVELOPMENT PLAN: 2024–2050

MARKET LIBERALIZATION AND ELECTRICITY TRADE (MLET) PROGRAM

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Armenia Least Cost Energy Development Plan: 2024–2050

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Market Liberalization and Electricity Trade (MLET) Program

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ACRONYMS

AMD	Armenian Dram
ANPP	Armenian Nuclear Power Plant
CCGT	Combined-Cycle Gas Turbine
CHP	Combined Heat and Power Plant
CO2eq	Carbon Dioxide Equivalent
EE	Energy Efficiency
EU	European Union
EV	Electric Vehicle
FEC	Final Energy Consumption
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GT	Gas Turbine
GWH	Gigawatt-Hour
HPP	Hydropower Plant
IEA	International Energy Agency
kt	Kiloton
ktoe	Kiloton of Oil Equivalent
kW	Kilowatt
kWh	Kilowatt-Hour
LCEDP	Least Cost Energy Development Plan
LWR	Light-Water Reactor
MLET	Market Liberalization and Electricity Trade Program
MW	Megawatt
NPP	Nuclear Power Plant
PV	Photovoltaic
RES	Renewable Energy Source
SMR	Small Modular Reactor
TPES	Total Primary Energy Supply
TPP	Thermal Power Plant
TWh	Terawatt-Hour
USAID	United States Agency for International Development
USD	U.S. Dollar
VAT	Value-Added Tax
VVER	Water-Water Energetic Reactor
WEO	World Energy Outlook

EXECUTIVE SUMMARY

This report on Armenia's Least Cost Energy Development Plan (LCEDP) for 2024–2050 has been developed under the U.S. Agency for International Development (USAID) Market Liberalization and Electricity Trade (MLET) Program. MLET is supporting Armenia's electricity market reforms, the development of an energy sector strategy, and cross-border trade with Georgia.

The purpose of the LCEDP for 2024–2050 is to provide decision makers with initial information on options to meet future energy demand.

Section 1 describes Armenia's energy sector in the base year (2019) and details the transposition of the input data for model calibration. Section 2 summarizes the key assumptions and results of the Baseline Scenario and analyzes the drivers influencing projected end-use energy demand up to 2050. Section 3 describes the selected policy scenarios and summarizes their key assumptions and results. It outlines a set of possible alternative scenarios that are of interest to key stakeholders to reflect different potential pathways for the evolution of Armenia's energy system. This includes policy choices as well as sensitivity analyses to determine the possible impacts of variations in demand drivers. This set of scenarios is intended to provide vital inputs to policy and strategy development for Armenia's energy sector over the period to 2050.

METHODOLOGY

This report was prepared using the TIMES model generator developed under the International Energy Agency (IEA) Energy Technology Systems Analysis Program, combining two complementary approaches to modeling the energy sector: a technical engineering approach and an economic approach.[1] The TIMES model provides a platform for integrated energy system modeling to guide policy formulation over a wide range of energy, economic and environmental planning, and policy issues, and thereby help to establish investment priorities within a comprehensive framework. Annex 2 presents an overview of the TIMES model generator. The TIMES model aims to supply energy services at minimum global cost by simultaneously making decisions on equipment investment and operation, primary energy supply, and energy trade for each region. This presents a high-level economic analysis but does not aim to provide dispatch solutions for the operational planning of the electricity system.

Key features of the TIMES platform:

- It encompasses the entire energy system, from resource extraction to end-use demand.
- It employs least-cost optimization to identify the most cost-effective pattern of resource use and technology deployment over time.
- It provides a framework to evaluate medium-to-long-term policies and programs that can impact the evolution of the energy system and quantifies the costs and technology choices that result from imposing those policies and programs.

This tool lets users develop and compare scenarios for future energy development, which can help foster stakeholder buy-in and build consensus around energy sector policy. Besides the strengths of its core modeling features, the framework includes powerful model management tools to better inform decision makers.

To adapt the generic TIMES model into the TIMES-Armenia model, MLET first established a base year for which there is a complete set of data on the production and consumption of all energy

[1] https://iea-etsap.org/index.php/etsap-tools/model-generators/times

carriers used in Armenia—the energy balance. It was also necessary to establish the energy production and consumption technologies in all sectors of the economy for that year and to analyze and subdivide the initial volumes of energy among all available end-use technologies.

When data collection for model calibration began in April 2021, the latest year for which all statistical data were available was 2019. Furthermore, COVID-19 and Armenia's political situation in 2020 resulted in unusual economic development and energy system operation, making 2019 a better base year for the model. Having calibrated the model to confirm that its 2019 results matched available data, the next step was to establish the Baseline Scenario for 2024–2050.

BASELINE SCENARIO

The following key assumptions address Armenia's economy, power sector development options, new power generation and demand-side technology build-up rates, and potential energy sources in the country for the Baseline Scenario.

- The International Monetary Fund forecasts that Armenia's gross domestic product (GDP) will grow by 4.2 percent in 2024 and 4.0 percent in 2026. For years beyond 2026, the growth rate is considered to be constant and equal to the 2026 growth rate.

- The population shows negative growth of -0.2 percent during the planning horizon.

- The industrial sector is one of the main contributors to the demand for useful energy, with an average annual growth rate of around 4 percent. The residential and commercial sectors contribute less, with average annual growth rates of around 2.2 percent and 2.7 percent, respectively.

- Fuel price projections are based on the IEA forecast of prices for the European Union (EU) in World Economic Outlook (WEO) 2021.

- Electricity losses in the transmission and distribution networks are assumed to fall from 8.6 percent in the base year to 8.1 percent at the end of the planning period.

- Considering 2020 geopolitical circumstances in Artsakh, electricity imports and exports have been modeled according to actual 2021 data. In the Baseline Scenario, Armenia's energy exchange is modeled without electricity exchange with Georgia. This enables the study to assess the energy source and generation technology required to meet projected energy demand in Armenia.

- Capacity limitations have been applied to power generation capacities based on existing available energy and technical resources in Armenia.

- In the Armenia Energy Strategy, the Government of Armenia stated its commitment to maintaining nuclear power in Armenia's power generation mix. After modeling several options for the Baseline Scenario, MLET found that that the only time the model chooses the construction of a new nuclear power plant is when a limitation on thermal power plant (TPP) construction is set. For this Baseline Scenario, it is assumed that no new TPP will be constructed during the planning period.

The Baseline Scenario calculations show that natural gas remains the dominant energy source throughout the planning horizon. Its share of total primary energy supply (TPES) in 2024 is around 52 percent, increasing to 74 percent in 2027 due to the end of the Armenian Nuclear Power Plant's

(ANPP) life. The share of renewable energy sources (RES) increases over the horizon from around 7 percent to nearly 14 percent. The share of oil products remains approximately the same through the whole planning period.

Final energy consumption (FEC) will increase by more than 50 percent during the planning period, but without any significant changes in shares by sector. The industrial and commercial sectors show increased FEC, rising four and two percentage points respectively from 2024 to 2050. Natural gas, electricity, and oil products will provide around 98 percent of total FEC, with natural gas representing the highest share during the whole planning period. The Baseline Scenario assumes that by the end of the planning period, 24 percent of FEC will be attributed to improved technologies with higher energy efficiency (EE) and the remainder will be covered by the existing technologies, which will be replaced by the same type of technology after the end of their useful lives.

It will take $68 billion (in 2019 dollars) to finance the demand-supply activities. This comprises all costs associated with energy supply and end-use demands for energy across the agriculture, commercial, industrial, residential, and transport sectors. In the investment category, the model's methodology includes not only the spending required to build new power plants or new industrial facilities, but also the costs associated with replacing existing facilities. For FEC by sector, the variable and fixed operation and maintenance (O&M) costs include all costs (excluding fuel) required to ensure the safe and uninterrupted operation of all technologies and installations in the supply, transmission, and distribution systems as well as on the demand side.

Armenia's least-cost generation mix foresees the development of RES and storage technologies. Those include solar photovoltaics (PV) with a total installed capacity of 2,630 megawatts (MW); wind, 375 MW; small hydropower plants (HPP), 439 MW; and large HPPs (Loriberd and Shnokh), 141 MW, as well as storage plants with 130 MW in 2050. In addition, the model found the least-cost solution to meet demand by implementing a new nuclear power plant (NPP) with 600 MW installed capacity in 2033. This development will require around $13 billion in investment.

This study assesses two important indicators: greenhouse gas (GHG) emissions and energy independence. Under the Baseline Scenario, annual GHG emissions in carbon dioxide equivalent (CO2eq) vary between 6.2 and 8.0 megatons (Mt) across 2024–2050. This growth is a result of a significant decrease in emissions from the power sector, while in all other sectors, emissions are projected to increase. GHG emissions from the power sector reach their lowest level in 2050, at 19 kilotons (kt), accounting for only 0.2 percent of total GHG emissions. This is due to RES's increasing share in the energy generation mix and the introduction of a new NPP. The highest emissions throughout the planning horizon come from the transport sector, followed by the residential sector; in 2050, they account for 35 percent and 27 percent of GHG emissions, respectively. Natural gas has the highest share of CO2 emissions over the planning period, followed by gasoline and diesel. These three pollutants account for around 98 percent of total CO2 emissions.

Energy independence is the share of domestic energy production in TPES supplied in the country. In 2024, this is expected to be 36.8 percent. After ANPP decommissioning in 2027, energy independence will drop by almost two-thirds to 12.9 percent. Widespread implementation of RES, mostly solar energy, and the construction of the new NPP will restore it to 38.3 percent in 2050.

SELECTED POLICY SCENARIOS

ECONOMIC GROWTH RATE SCENARIOS

The study analyzes Armenia's energy sector development for two GDP growth rate scenarios: a 50 percent increase (High Growth) and decrease (Low Growth) in the GDP growth rate compared with the Baseline Scenario. Two more scenarios analyze Armenia's energy sector development in case of a 200-MW increase in electricity demand from the industrial sector in 2027 (Increased

Demand in Industry) and conservative development in technological efficiency in the same sector (EE in Industry). None of the economic growth rate scenarios consider new fossil generation.

Total system cost in the High Growth scenario will amount to $81 billion; in the Low Growth scenario, $57.5 billion. These changes will both be proportional to the changes in GDP growth. For Increased Demand in Industry, total system cost is $69 billion; for EE in Industry, total system cost is $68.4 billion.

In the High Growth scenario, TPES shows a steady increase from 2030, which is mostly the result of additional use of nuclear energy and natural gas compared with the Baseline Scenario. Until 2027, there is a slight reduction in TPES as more efficient technologies meet the demand. In The Low Growth scenario, TPES shows a steady decrease until 2045, which is mostly the result of reduced use of nuclear energy, natural gas, and oil products. For 2045–2050, the slight increase in TPES is due to an increase in share of RES. In the Increased Demand in Industry scenario, TPES shows a steady increase from 2027, which is mostly a result of more nuclear energy use than in the Baseline Scenario. In the EE in Industry scenario, TPES follows the Baseline Scenario trends and increases slightly at the end of the planning period to cover increased demand due to the implementation of lower-efficiency technologies.

FEC increases in both GDP growth scenarios during the planning period, faster in the High Growth scenario than in the Low growth Scenario. In High Growth, electricity grows the fastest, followed by oil products and natural gas. The largest consumers at the end of the planning period are the commercial, transport, and residential sectors. In Low Growth, FEC increases more slowly, with the highest growth in electricity and natural gas. Oil products decline by 4 percent in 2024–2050. FEC projections for Increased Demand and EE in Industry show practically no change compared with the Baseline Scenario.

There are significant changes in generation capacity configuration for nuclear, RES, and storage technologies. In the High Growth scenario, increased energy demand is covered by the construction of a larger NPP (1,080 MW) in 2033. As a result, RES capacity for the 2033–2045 period is lower than in the Baseline Scenario. In 2050, however, RES capacity increases after the Yerevan Combined-Cycle Gas Turbine (CCGT)-2 comes to the end of its life. Storage capacity also increases during the planning horizon and this scenario foresees the implementation of Loriberd HPP in 2050, rather than 2024 as in the Baseline Scenario.

In the Low Growth scenario, there is no NPP in the capacity mix after the end of ANPP's life. An increased share of RES and storage capacities fill the gap it leaves behind. Compared to the Baseline Scenario, this scenario foresees the earlier than in the Baseline Scenario implementation of Shnokh HPP in 2033 but does not include Loriberd HPP.

The Increased Demand in Industry scenario foresees significant changes in generation capacity configuration for nuclear, RES, and storage technologies, while in the EE in Industry scenario, only the capacities of the solar and hydro pumped storage plants increased (by a small amount) between 2040 and 2050.

Changes in the generation technology mix result in significant changes in the total power sector investments for new generation. High Growth scenario implementation will require around $16.6 in investment, Low Growth around $10 billion, Increased Demand in Industry around $12 billion, and EE in Industry around $14 billion.

The main polluting energy carrier for both GDP growth scenarios remains natural gas with around 80 percent share in total GHG emissions in almost all milestone years. In High growth scenario transport and residential sectors together contribute to the total GHG emissions at most with 38.4 and 24.2 percent share for the end of planning period (2050). In Low growth scenario transport and residential sectors remain the sectors with the highest share of cumulative pollution with 32.7 and 30.5 percent share in total, followed by commercial (15.1 percent), industry (12.8 percent) and fuel supply system (8.0 percent) sectors. Significant increase in emissions in 2027 in the Increased Demand in Industry is a result of increased gas-fired generation. At the end of the planning horizon, emissions almost reach the Baseline Scenario level for the same year (7,992 kt). The EE in Industry scenario follows the same pattern as the Baseline Scenario, with slightly higher emissions.

In the High Growth scenario, Armenia will reach the highest energy independence in 2033 (48 percent), after which it will decrease to 40 percent by the end of the planning horizon as a result of increased fossil fuel use to cover higher demand. In the Low Growth scenario, with no NPP in the capacity mix, energy independence will reach its maximum in 2050 (31 percent) after a steady increase from 2027 (13 percent). After the decommissioning of the ANPP in 2026, the independence level in the Increase in Demand and EE in Industry scenarios drops due to higher imports of natural gas.

NATURAL GAS PRICE SCENARIOS

In the Baseline Scenario, Armenia relies heavily on natural gas throughout the planning horizon. To assess the impact of natural gas price changes on Armenia's least-cost energy system development, MLET modeled and analyzed three scenarios:

- For the EU Gas Price scenario, the natural gas price is equal to the current import price from Russia at $165/1,000m^3$ up to 2024; afterward, it is equal to the EU prices defined in the WEO 2021.
- For Unchanged Gas Price scenario, the natural gas price is $165/1,000m^3$ until 2033, then equal to the prices in the Baseline Scenario without a new TPP.
- The Extreme Gas Price scenario considers the 2022 changes in EU natural gas prices. It is expected that until 2033, the gas price in Armenia will follow the natural gas price in the EU ($1,000/1,000 m^3$), with no gas supply after that date. If this occurs, Armenia will require a new and different approach to:

  – Switch from natural gas to electricity, blends of biofuel with fossil fuel, and oil products;
  – Increase NPP and RES generation capacity to fill the gap from gas-fired generation; and
  – Increase transmission and distribution grid capacity to transfer increased electricity generation.

Considering that the occurrence of the assumptions in this scenario has low probability, its results are only discussed in the results section for that scenario.

In the EU Gas Price and Unchanged Gas Price scenarios, total system cost ($66.5 billion for EU Gas Price, $65.9 billion for Unchanged Gas Price) decreases as gas price decreases.

Changes in TPES are directly connected to the implementation of new NPPs. The EU Gas Price scenario adds new CCGT and gas turbine (GT) power plants, and no new NPP is foreseen because the gas price is lower than in all the Baseline Scenario's milestone years. The most economical solution is the use of natural gas over the whole planning horizon. In the Unchanged Gas Price scenario, after imported gas prices become equal to the baseline values in 2036, a new 600-MW

NPP is implemented in 2045 to cover increased demand. FEC in both scenarios is practically identical to the Baseline Scenario because there are no significant changes in FEC drivers.

The least-cost configuration of generation technologies shows significant changes in the generation mix for nuclear, RES, and gas-fired technologies. In the EU Gas Price scenario, three new CCGTs are introduced in 2027, 2033, and 2045 and one new GT in 2050. No new NPP is implemented in this scenario. The implementation of Loriberd HPP is shifted from 2045 (in the Baseline Scenario) to 2050 and there are no plans for Shnokh HPP. At the same time, 1,121 more MW of solar PV will be introduced at the end of the planning horizon than in the Baseline Scenario.

In the Unchanged Gas Price scenario, the power system requires that Armenia implement a 25-MW geothermal plant from 2033, move up the construction of Loriberd and Shnokh HPPs to 2023 (from 2045 in the Baseline Scenario), postpone the commissioning of a new 600-MW NPP to 2045 (from 2033 in the Baseline Scenario), build 210 MW of additional solar PV at the end of the planning period, fully utilize its modeled wind potential (500 MW), and construct two hydro pumped storage power plants in 2033 and 2040.

Investments in new capacities changes significantly between scenarios as a result of changes in the generation technology mix. The EU Gas Price scenario will require around $7 billion (42 percent lower than the Baseline Scenario) and the Unchanged Gas Price scenario will need $13 billion in investment.

In both scenarios, natural gas produces around 83 percent of total GHG emissions in almost all milestone years. The most polluting sectors in 2050 are the transport and residential sectors.

Armenia's energy independence strictly follows the TPES trend and decreases in parallel to the increase in imports of natural gas.

NUCLEAR DEVELOPMENT SCENARIOS

MLET analyzed five nuclear scenarios, considering an extension of ANPP's life and different options for small modular reactor (SMR) module implementation. The ANPP 2032 scenario considers extending ANPP's life until 2032; the ANPP 2037 scenario until 2037. Two more scenarios combine an ANPP extension until 2037 with the implementation of SMR-300 modules: one considers implementing one SMR-300, while the other considers adding one in 2037 and a second in 2045. A fifth scenario extends ANPP's life by 2026 and adds one SMR-300 in 2036.

Total system cost will vary between 0.4 and -2.3 percent compared with the Baseline Scenario, mostly due to the cost of implementing new nuclear unit(s).

Extending ANPP's operation results in the redistribution of electricity generation between nuclear and gas-fired power plants until 2030. In the ANPP 2032 and ANPP 2037 scenarios, TPES is higher than in the Baseline Scenario. In the scenarios that force new NPP implementation, the difference from the Baseline Scenario mostly depends on installed capacity and the year the new SMR-300 units(s) are implemented. FEC projections for all nuclear development scenarios are practically identical to that in the Baseline Scenario.

The main changes to generation capacity configuration in these scenarios are in the nuclear, RES, and storage technologies. In all scenarios, generation from ANPP and the new SMR-300 modules results in a redistribution of new solar PV capacities and a revised implementation schedule for wind farms compared with the Baseline Scenario. Generation in ANPP 2032 and ANPP 2037 corresponds directly to the selected generation capacities. The main differences in the generation mix compared with the Baseline Scenario are the result of the extended operation of ANPP, with almost 3.37 terawatt-hours (TWh) of electricity production from 2027 to 2030 replacing gas-fired production. In ANPP 2037, to cover a capacity gap of around 160 MW compared to the Baseline Scenario, the model adds more wind and solar capacities as well as gas-fired generation in 2033–2036. In the ANPP 2026 and one SMR-300 scenario, there is no nuclear generation in the power system in 2033–2036. During this period, demand is mostly covered by additional generation from gas-fired plants and solar PV, whereas forced implementation of new nuclear plants in the ANPP 2037 and One SMR and the ANPP 2037 and Two SMR scenarios, resulting in less RES generation.

The different generation technology mixes also require different investment for new generation. There are practically no differences in required investment between the ANPP life extension scenarios over the planning horizon ($12.7 billion for ANPP 2032 and $12.5 billion for ANPP 2037), only a reallocation of NPP investments from 2033 to 2040. However, more significant investments are required in the other three scenarios (ANPP 2026 and One SMR-300, ANPP 2037 and One SMR, ANPP 2037 and Two SMR) due to considerable differences in the new SMR-300 module implementation schedule and the amount of installed capacity compared with the Baseline Scenario. ANPP 2037 and One SMR will require around $13 billion; ANPP 2037 and Two SMR, around $14 billion; and ANPP 2026 and one SMR-300, $13.6 billion.

Cumulative GHG emissions depend directly on the volume of nuclear and RES use. Emissions are almost equal in all scenarios, except for ANPP 2026 and one SMR-300, in which emissions are similar to those in the Baseline Scenario in 2027 and 2030 and also differ from other nuclear scenarios in 2033 because of less nuclear power usage. GHG emissions for all scenarios are the same in 2024, reflecting an identical generation mix.

Energy independence will not exceed 40 percent in any milestone year and is lowest in the ANPP 2026 and One SMR-300 scenario due to increased gas-fired generation replacing nuclear and solar generation.

ENERGY EFFICIENCY SCENARIOS

The EE scenarios consider improvements in end-use technologies and a greater share of electric vehicles (EVs). They consider different levels of efficiency improvements for demand technologies: the EE-No Limit model removes all limitations on replacing demand technologies with advanced, better, or improved technology by 2050, and other scenarios consider 20, 50, and 90 percent forced use of more efficient end-use technologies by 2050 (EE-20, EE-50, and EE-90). To assess the impact of increased EV use, two scenarios consider that the share of EVs among total cars increases from 5 percent in 2030 to 50 percent (EV-50) and 100 percent (EV-100) in 2050. No EE scenarios consider new fossil fuel generation. EV scenarios consider only light-duty vehicles and does not include other transportation.

The total system cost in all scenarios is lower than in the Baseline Scenario. It decreases as EE penetration increases in end-use technologies, including EVs. Efficient technologies cost more, but this is offset by the savings from reduced energy consumption.

Implementing more EE technologies decreases TPES because Armenia can meet its end-use demand with less energy. As a result, in all EE scenarios and the EV-50 scenario, TPES is lower than in the Baseline Scenario—2.3 percent compared to almost 30 percent for the overall planning period. In the EV-100 scenario, demand for electricity increases and requires new generation capacity, such as the new 1,080-MW NPP, and lower fossil fuel consumption. Because NPPs are less efficient than TPPs, more primary energy must be supplied. FEC in all scenarios is lower than in the Baseline Scenario and varies between 84.1 million tons of oil equivalent (Mtoe) and 104.8 Mtoe (Baseline: 107.3 Mtoe).

Lower energy consumption also reduces the need for electricity generation technologies. Therefore, in all EE scenarios, there is less total installed capacity than in the Baseline Scenario; differences vary from -2.9 percent to -8.5 percent. At the same time, replacing a significant amount of fossil fuels with electricity in the transport sector results in 675 MW more installed capacity in the EV-50 scenario and 267 MW more in the EV-100 scenario than in the Baseline Scenario.

Different levels of demand technology efficiency and generation technology implementation schedules significantly affect total power sector investment for new generation. The main driver is the new 600-MW NPP in the EE-No Limit, EE-50, and EE-90 scenarios compared to the new 1,080-MW NPP in the EV-100 scenario and the additional solar PV capacity in the EV-50 scenario. The lowest investment is in the EE-No Limit scenario ($9.8 billion), and the highest is in the EV-100 scenario ($15 billion).

Due to the reduced fossil fuel use and the increased share of RES and NPP, GHG emissions are also lower than in the Baseline Scenario (a difference of between -3.7 percent and -34.4 percent).

In the EV-100 scenario, Armenia will reach a high level of energy independence in 2033 (52 percent), mainly by implementing a large NPP (1,080 MW), after which independence will fall to 51 percent until 2045 as it meets the increased demand with more fossil fuels. At the end of the planning horizon, the replacement of TPPs by RES will increase independence to its highest value—53 percent. In the EV-50 scenario, independence will reach 41 percent in 2033 and then continuously increase to 44 percent in 2050 because of the wide implementation of solar PVs and wind farms. As the use of fossil fuels makes Armenia less energy-independent, the projections for energy independence and GHG emissions are approximately mirror images of one another.

GHG EMISSIONS SCENARIO

This scenario considers the influence of a carbon tax equal to the EU's on energy carriers' supply options in Armenia. In the model, the carbon tax is equal to $50/ton in 2030 and $100/ton afterward based on estimates of expected EU carbon taxes in the coming decades.

The total system cost is $75.5 billion, more than 10 percent higher than in the Baseline Scenario. The increase in the carbon tax reflects the total system cost, even though this scenario's GHG emissions are 4.3 percent lower than in the Baseline Scenario.

TPES is different than in the Baseline Scenario because of the earlier introduction of the 600-MW NPP (2027 instead of 2033). To produce the same output, nuclear technology requires more primary sources than gas-fired plants. From 2033, there is no significant difference in TPES between the GHG and Baseline Scenarios. The FEC projection shows practically identical final energy consumption between the GHG emissions scenario and the Baseline Scenario.

Significant differences in generation capacity configuration relate to gas-fired power plants and RES, as well as the new NPP implementation schedule. The least-cost solution is to implement a 250-MW CCGT in 2050, a 234-MW GT plant in 2045, and 191 more MW of solar PV and 91 more MW of wind capacity than in the Baseline Scenario over the planning horizon. The construction of the Loriberd and Shnokh HPPs is not considered to be part of the least-cost solution in this scenario.

A different generation technology mix requires significantly different investment in new generation, especially the introduction of additional gas-fired plants with total installed capacities of 484 MW as well as 282 MW of RES. New capacity built in this scenario will cost $11.3 billion in investment.

The move of the new 600-MW NPP from 2033 to 2027 means gas-fired plants are replaced earlier and GHG emissions fall. After 2033, pollutants in this scenario almost duplicate the values in the Baseline Scenario.

Energy independence will reach its highest level in 2027 (41 percent) mainly due to the new 600-MW NPP, then fall to 37 percent at the end of the planning horizon.

GEORGIEA ELECTRICITY IMPORT/EXPORT SCENARIOS

These scenarios examine the effect of increasing exports on Armenia's least-cost development pathway: the first with 300 MW of electricity exports from 2027, and the second with 300 MW from 2027 and 1,050 MW from 2040, both from October-March period. For both scenarios, starting from 2027, 50 MW electricity import from Georgia during April-September period is considered. The load factor for both scenarios is 75 percent. Neither scenario considers adding new fossil generation.

The total system costs will amount to $68.6 billion for the Import/Export 300 MW scenario (1.3 percent more than the Baseline Scenario) and $70.2 billion for the Import/Export 1,050 MW scenario (3.6 percent more). In both scenarios, total system cost is higher because of additional generation costs for increased export capacity.

In TPES projections for both export scenarios, extra energy sources are needed to cover supplemental export demand proportional to the increase in export capacity. TPES is higher than in the Baseline Scenario as a result of additional use of natural gas until 2027 and nuclear energy from 2030. FEC remains almost the same as in the Baseline Scenario.

Both scenarios show significant changes in generation capacity configuration related to nuclear, RES, and storage technologies.

In the Import/Export 300 MW scenario, the least-cost configuration includes adding a 1,080-MW NPP in 2033, which leads to significantly lower RES capacity and a delay in the construction of large HPPs compared with the Baseline Scenario. In the Import/Export 1,050 MW scenario, the least-cost configuration adds a 1,080-MW NPP in 2033 and increases RES compared with the Baseline Scenario. To ensure the proper daily operation of a large number of variable renewables as well as large baseline production from the new NPP, the model also adds more hydro pumped storage plants and lithium-ion batteries. Total power system investments for new capacities will cost $12.4 billion in the Import/Export 300 MW scenario (3.9 percent lower than in the Baseline Scenario) and $17.8 billion in the Import/Export 1,050 MW scenario (38.4 percent higher).

Cumulative GHG emissions for these scenarios show insignificant differences compared with the Baseline Scenario. The main polluting energy carrier for both scenarios remains natural gas, with around 80 percent share in total GHG emissions in all milestone years. The transport and residential sectors contribute the most to total emissions.

In both scenarios, energy independence will reach its highest level in 2033 (around 51 percent), then fall slightly to 46 in Import/Export 300 MW scenario and 48 percent in Import/Export 1,050 MW scenario until 2040 due to increased demand, which will be met by fossil fuels. After that, energy independence in the Import/Export 1,050 MW scenario will increase up to 48 percent in 2050 due to the implementation of more RES, while it will fall to 46 percent in the Import/Export 300 MW scenario by the end of the planning period.

KEY CONCLUSIONS

- The results of the Armenia LCEDP 2024-2050 emphasize the importance of ensuring a policy and institutional environment to support the realization of new variable renewable generation to the maximum extent feasible. This would ensure the lowest cost generation, strengthen Armenia's energy security and competitiveness and reduce reliance on imported energy sources.
- Armenia could achieve a fully carbon-neutral power system by 2050 if renewable and nuclear generation are developed in parallel.
- Armenia's use of fossil fuels will be approximately 50% by 2050. This could be further reduced through the implementation of new technologies and demand side management.
- Natural gas is projected to contribute to more than 80% of pollutants in all the scenarios and would be the main source of GHG emissions from all the energy carriers.
- The transport and household sectors have highest share of energy use over total FEC in all considered scenarios (together - from 56% to 62%). The development of special policy measures ensuring more RES usage instead of natural gas in household and transport sectors, will strengthen Armenia's energy independence.
- In 16 of the 21 scenarios, the maximum capacity for new NPP does not exceed 600 MW. In five high demand growth scenarios, the new NPP capacity increase to 1,080 MW. These scenarios are:

  1. High GDP growth: 50 percent higher growth than in Baseline Scenario
  2. Increased Demand in Industry: Additional 200 MW of industrial capacity
  3. Import/Export 300 MW: Regular export to Georgia at 300 MW
  4. Import/Export 1,050 MW: Increased export to Georgia at 1050 MW
  5. EV-100: 100 percent share of EVs in Armenia

  This five high demand growth scenarios assume significant demand growth, which is unlikely based on historical data. To illustrate this point: during the last 20 years, Armenia's demand has grown by about 42%, while under the 5 high demand growth scenarios it is assumed that the demand will grow by 228%, 5.5 times more than the historical data.

  These scenarios add about 400 MW more demand in 2050 (from 2,200MW to 2,600MW), which would require Armenia to build generation capacity in the form of new 1,080-MW NPP in 2036. If Armenia builds a large (1,000 MW or more) NPP based on these assumptions, it would most likely bear the full cost of capital investment while only using a fraction of the full capacity.

- A large (1,000 MW or more) NPP would require the Yerevan CCGT and Yerevan CCGT-2 units to cease operation from 2036 since they would no longer be needed. Although, the Yerevan CCGT is a state-owned company, the Government of Armenia has a contractual commitment under a PPA with Yerevan CCGT-2 for 25-years, through 2046. As a result, the total electricity system cost would increase, as compensation of the fixed costs of at least one of two mentioned power generation units is an obligation for the Government of Armenia.
- From the operation/dispatch standpoint: a large (1,000 MW or more) NPP unit would be serving about 50% of the system peak demand and very close to 100% of the nightly minimum demand/consumption, this would require all other generating units (thermal, hydro and wind) to either be shut down overnight (6-8 hours), which would have significant technical/operational consequences, or their electricity output would need to be stored. Storing of such a volume of

electricity will require large battery systems, involving technologies that are still in their early stage of development and have not reach their maturity stage.

- Furthermore, if the capacity of one unit were to serve 50% of the peak demand, during annual maintenance and/or system emergency situations, the system would require a reserve capacity of the same size. This would create an additional economic burden to electricity consumers due to the high cost of reserved capacity. From the system dispatching standpoint, the best practice is to build a thermal unit that is not larger than 20% of the system peak demand.

Considering all developed scenarios and taking into account economic and energy security considerations, it is recommended to consider nuclear generation with a capacity of no more than 600 MW. To reduce the reserve capacity requirement, smaller modular reactors, with a maximum capacity of 300 MW, would enable the country to improve the security of the supply without placing an additional financial burden on the Armenian economy and electricity consumers.

SECTION 1. OVERVIEW OF BASE YEAR DATA FOR TIMES-ARMENIA MODEL CALIBRATION

Depicting an energy system in a TIMES model starts by entering the complete energy balance for the base year. When data collection for model calibration began in April 2021, the latest year for which all statistical data were available was 2019. Furthermore, COVID-19 and Armenia's political situation in 2020 resulted in unusual economic development and energy system operation, making 2019 a better base year for the model. The 2019 Armenia Energy Balance used for the model is presented in Annex 1.

To produce accurate scenario results, a Baseline Scenario needs to properly reflect the base year's fuel consumption and generation composition, as well as the amount of installed capacity for each plant type. This includes retirement year, existing capacity, fuel consumed, electricity generated, maximum availability, and general overall efficiency. Base year data used for model calibration is presented below.

OVERVIEW OF ARMENIA'S ENERGY SECTOR IN THE BASE YEAR

INSTALLED CAPACITIES

As of the end of 2019, the total installed capacity of Armenia's power system was approximately 2,916 megawatts (MW) (Table 1.1).

NUCLEAR ENERGY. The first unit of the Armenian nuclear power plant (ANPP) was put into operation in 1976, and the second unit in 1980. Two reactors of type VVER-440 (V-270) are installed, with aggregate capacity of 815 MW. In 1989, ANPP was shut down after the December 1988 earthquake in Spitak, although there were no technical problems. In 1995, after the country's severe energy crisis (1993–1995), the second unit was recommissioned with an installed capacity of 407.5 MW.[2] After renovation, available ANPP capacity in 2022 is 440 MW.

THERMAL ENERGY. The total installed capacity of thermal power plants (TPP) in Armenia is 1,113.6 MW, and their total available capacity is 1,038 MW. Hrazdan TPP and Hrazdan Unit 5 have dual firing capability and can burn either natural gas or fuel oil. The installed capacity of Hrazdan TPP is 410 MW, with 370 MW available; Hrazdan Unit 5 has 467 MW, of which 440 MW is available; and the Yerevan combined-cycle gas turbine (CCGT) has 229 MW, with 220 MW available. After renovation the installed capacity of Yerevan CCGT is increased to 234 MW.

As of the end of 2019, installed hydropower capacity was approximately 1,340.5 MW, including 374.9 MW of small hydropower plants (HPPs). There are also wind farms with 4.23 MW of total installed capacity and 49.4 MW of grid-connected solar photovoltaic (PV) capacity.[3]

TABLE 1.1: INSTALLED CAPACITY, MW	
TOTAL INSTALLED CAPACITY	2,915.27
ANPP (VVER-440)	407.5
Hrazdan TPP	410
Hrazdan Unit 5	467
Yerevan CCGT	228.6

[2] All nuclear power plant (NPP) and TPP data comes from http://mtad.am/u_files/file/energy/Energy Strategy _ Jan 14 2021_English.pdf

[3] https://psrc.am/uploads/files/Էլեկտրական Էներգիա/Մոնիթորինգ/Verlucakan2020.pdf

TABLE 1.1: INSTALLED CAPACITY, MW	
Local combined heat and power plant (CHP)	8
Sevan-Hrazdan cascade of HPPs	561.4
Vorotan cascade of HPPs	404.2
Small HPP (<30 MW)	374.9
Wind farm	4.23
Solar PV (commercial)	10[4]
Solar PV (autonomous power producer)	39.44[5]

HYDRO ENERGY. According to Armenia's Ministry of Territorial Administration and Infrastructure, the country's water-energy resource potential is 21.8 billion kilowatt-hours (kWh), including large and medium-sized rivers with 18.6 billion kWh potential as well as small rivers with 3.2 billion kWh potential.[6]

- The Sevan-Hrazdan cascade includes seven HPPs: Sevan (34 MW), Hrazdan (81 MW), Argel (224 MW), Arzni (71 MW), Kanaker (102 MW), Yerevan-1 (44 MW), and Yerevan-3 (5 MW), with 561.4 MW of total installed capacity. It is designed to produce up to 2.32 billion kWh annually. The HPPs are on the River Hrazdan and run on irrigation water flow from Lake Sevan as well as River Hrazdan stream waters.

- The Vorotan HPP cascade consists of three HPPs on the River Vorotan in Syunik region. They run on river and stream water. The HPPs are Spandaryan (76 MW), Shamb (171 MW), and Tatev (157 MW), with 404 MW of total installed capacity and 1.16 billion kWh of annual designed electricity generation.

- The construction of small HPPs in Armenia was an early contributor to the development of the renewable energy sector and energy independence. The majority are derivational stations running on natural water flows. As of January 1, 2020, electricity was generated by 189 small HPPs with 375 MW total installed capacity. In 2019, they produced around 956 million kWh, about 12.5 percent of total electricity generated in Armenia.[6]

WIND ENERGY. In December 2005, the first regional grid-connected wind farm with capacity of 2.64 MW was put into operation at Pushkin Pass, producing around 2.7 million kWh annually. Three more wind farms were constructed in 2015, 2016, and 2019 with an installed capacity of 250 kilowatts (kW), 20 kW, and 1.32 MW respectively. As of January 1, 2021, there were four wind power plants under operation with total installed capacity of 4.23 MW and annual generation of 16.4 million kWh.[7] Another wind farm with installed capacity of 4 MW is under construction.

SOLAR ENERGY. Construction of solar PV is increasing rapidly. At the beginning of 2021, there were 15 solar power plants operating with total installed capacity of 16.7 MW[8] and annual generation of 21.3 million kWh.[9] Another 29 with installed capacity of 117.05 MW are under construction.[8]

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[4] https://www.psrc.am/uploads/files/Տարեկան հաշվետվություններ/3.pdf
[5] http://mtad.am/u_files/file/energy/1_Armenia_Energy Balance 2019_ARM.pdf
[6] http://minenergy.am/page/448
[7] https://psrc.am/uploads/files/Էլեկտրական Էներգիա/Մոնիթորինգ/Verlucakan2020.pdf
[8] https://psrc.am/uploads/files/Էլեկտրական Էներգիա/Մոնիթորինգ/19.pdf
[9] https://psrc.am/uploads/files/Էլեկտրական Էներգիա/Հաշվետվություններ/2020/2. Հիմնական բնութագրեր/4 Eramsyak.pdf

ELECTRICITY GENERATION AND CONSUMPTION

Aggregate indicators for base year generation and consumption are presented in Table 1.2.

TABLE 1.2: ELECTRICITY GENERATION AND CONSUMPTION, MILLIONS OF KWH	
Generation	7,632.3
Power plant's own use	334.0 (4.4%)
Losses in transmission network relative to input	106.2 (1.6%)
Losses in distribution network relative to input	442.0 (7.1%)
Export	1,251.1
Import	292.6
Final consumption	5,802.0
Number of customers[10]	1,042,000

Figure 1.1 presents the share of electricity generation by energy source in 2019. Natural gas and nuclear power comprise around 70 percent of generation and renewable energy sources (RES) produce around 30 percent. Thus, the independence level of electricity supply is around 60 percent.[11]

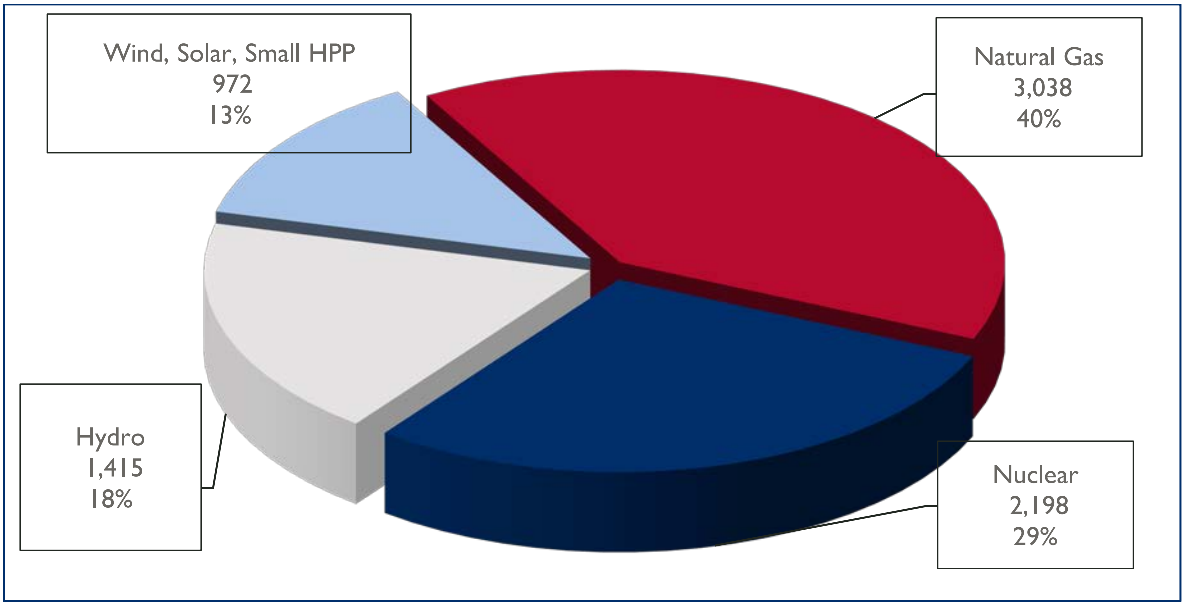


Figure 1.1: Share of total electricity generation by source, millions of kWh, %

The energy mix in electricity generation for domestic use is presented in Figure 1.2. Nuclear power plays a significant role in the base load electricity supply, meeting 35 percent of domestic electricity demand. Even though nuclear fuel is an imported energy source, the ANPP reactors are considered to be a domestic energy source because ANPP refuels only one-third of its total nuclear fuel volume each year as part of operations and maintenance (O&M). RES and ANPP ensure an energy independence level of around 72 percent for domestic use.

[10] https://www.ena.am/downloads/ENA_Annual_Report_2019_ARM.pdf

[11] Nuclear power is internationally considered an indigenous energy source.

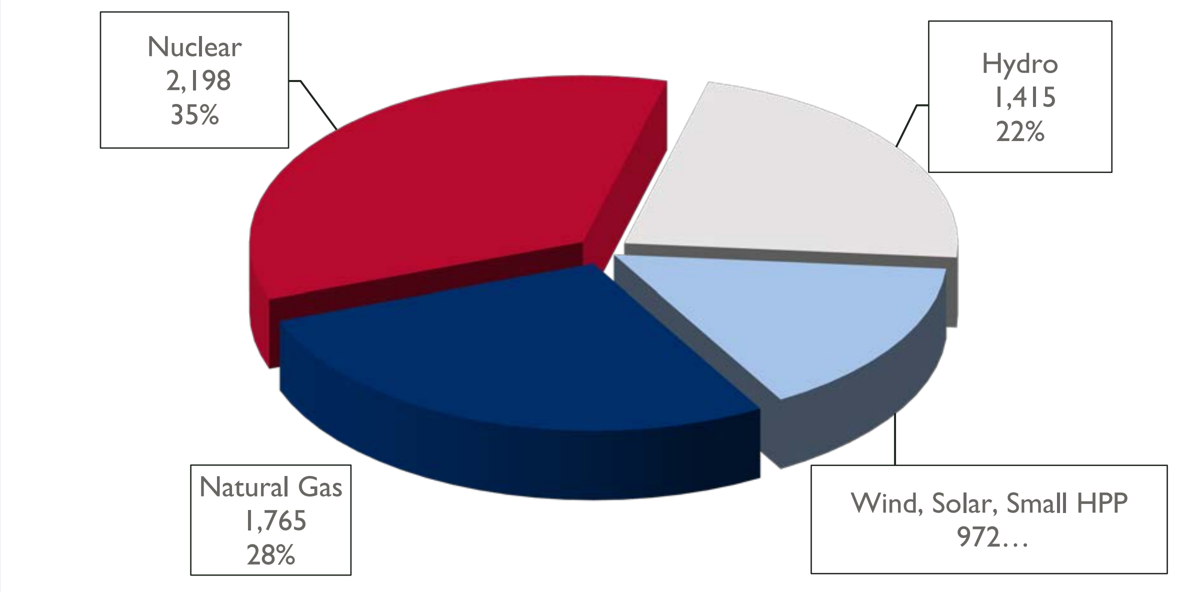


Figure 1.2: Share of electricity generation for domestic use by source, millions of kWh, %

Figure 1.3 presents historical electricity generation data by power plant for 2009–2019. It shows a significant increase in the share of electricity generated from RES and steady generation by ANPP.

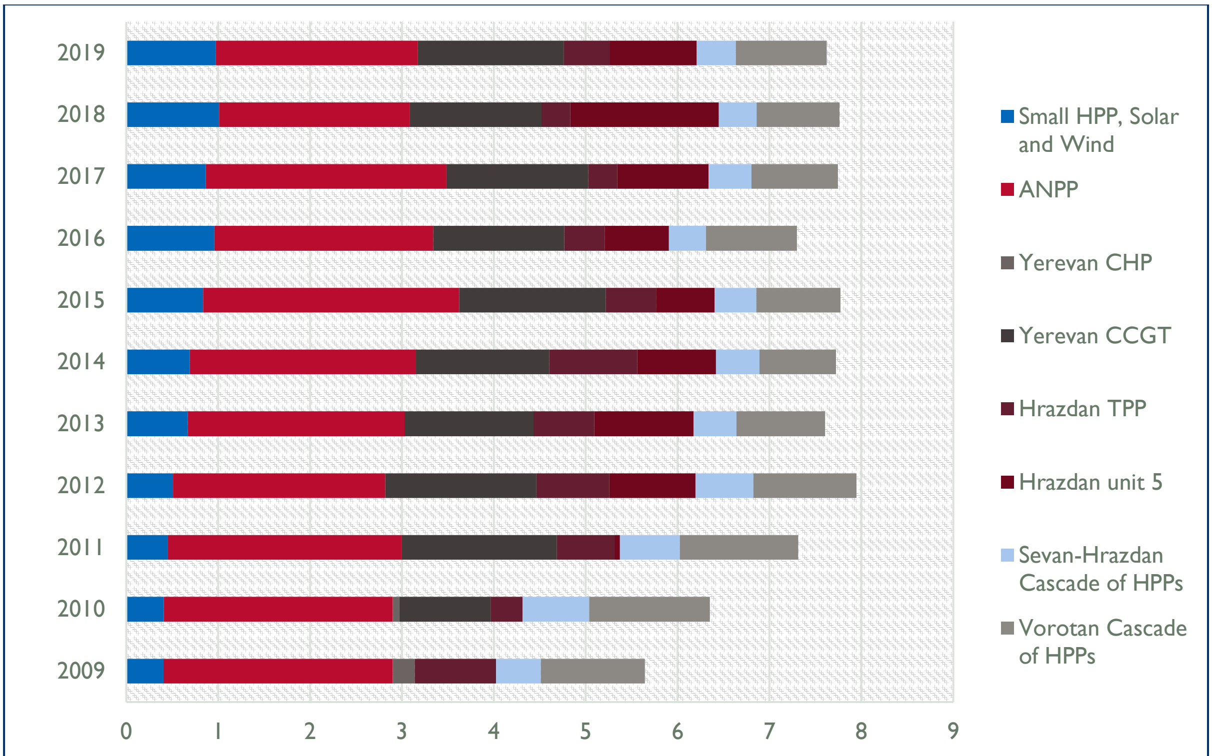


Figure 1.3: Electricity generation by power plant and year, billions of kWh

Figure 1.4 shows that the household (population), service, and industry sectors have the highest shares in total electricity consumption, which requires detailed modeling due to electricity consumption's sensitivity to development in these sectors.[12]

[12] The service sector is found in the graph under "others," the Public Services Regulatory Commission's terminology.

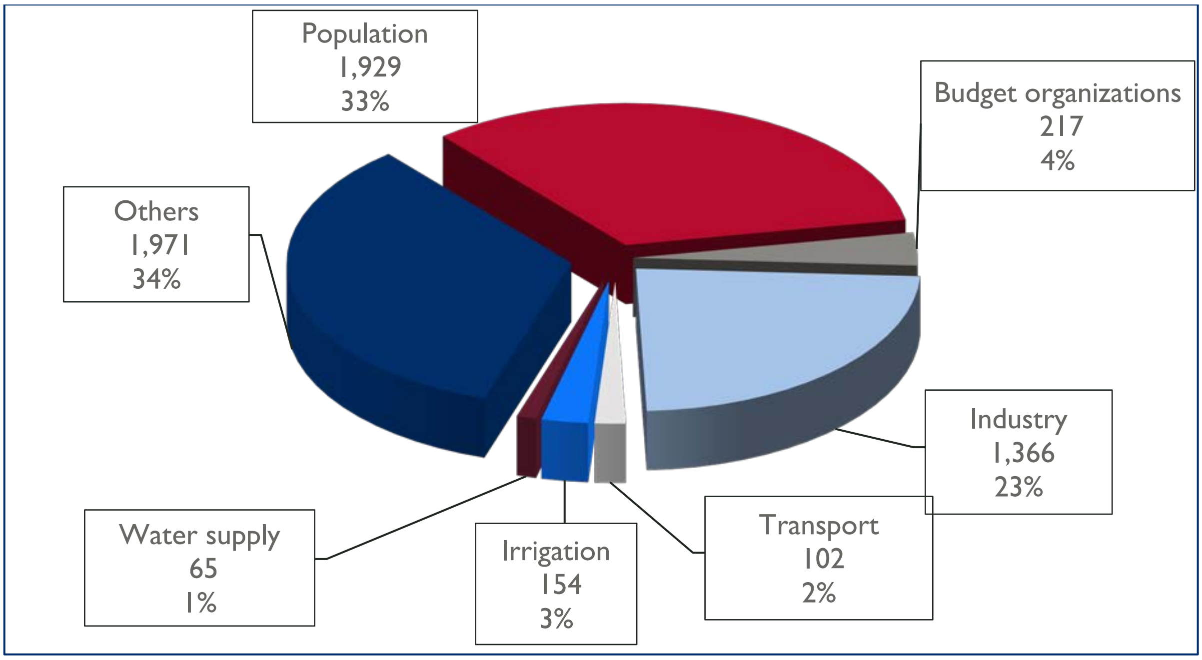


Figure 1.4: Share of electricity consumption by sector, millions of kWh, %

NATURAL GAS IMPORT AND CONSUMPTION

The main indicators of Armenia's natural gas supply system for 2019 are summarized in Table 1.3. The gasification level is almost 95 percent and most customers have nearby access to the gas system. Nevertheless, many households, especially in rural areas, are still use biofuels such as wood and manure for heating, cooking, and preparing hot water. An underground gas storage facility in the city of Abovian enables Armenia to regulate daily load fluctuations in winter and stores natural gas to provide uninterruptable supply in case of emergency. Armenia imports natural gas from Russia for domestic and industrial use and from its southern neighbor country under a swap agreement. According to the agreement, Armenia exchanges natural gas for electricity at a rate of 1 m^3 of gas per 3 kWh of electricity.

TABLE 1.3: MAIN INDICATORS OF NATURAL GAS SUPPLY SYSTEM, MILLIONS OF M^3

Imports:	2,545
from Russia	2,167
from the south	378
Losses in transmission network relative to input	86.8
Losses in distribution network relative to input	27.4
Abovian Underground Gas Storage Facility[13]	140
Number of consumers	713,606[14]

Natural gas consumption by economic sector is presented in Figure 1.5. The main consumers are the residential, transport, and power sectors. Since 2000, consumption in the transport sector has grown rapidly, as many vehicles have been converted to accept natural gas as fuel instead of gasoline or petroleum.

[13] https://armenia.gazprom.com/about/today/
[14] https://armenia-am.gazprom.com/press/news/2020/07/1607/

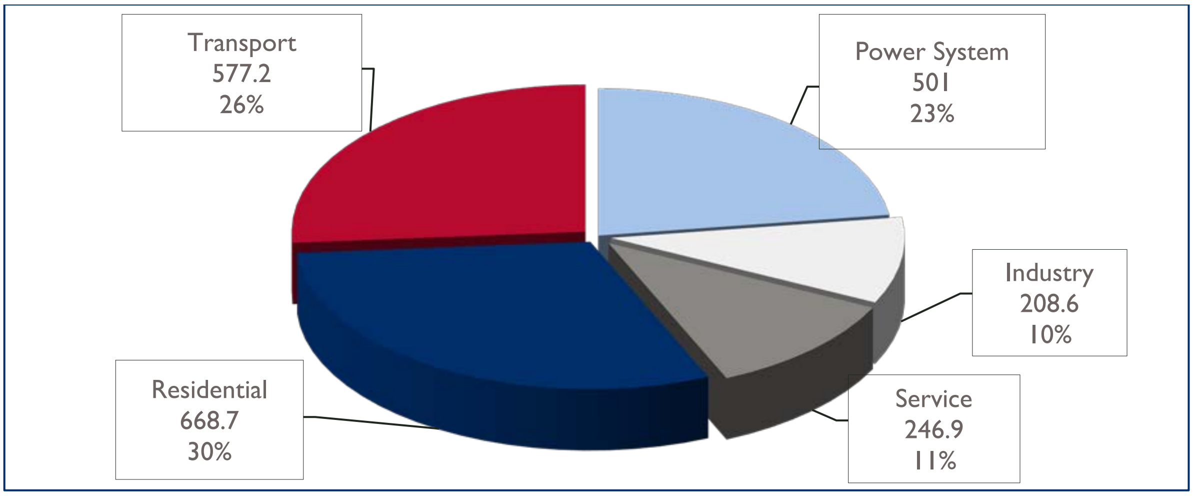


Figure 1.5: Gas consumption per sector, millions of m^3, %

ENERGY COSTS

ELECTRICITY GENERATION TARIFFS. Tariffs for utility-scale electricity generators are listed in Table 1.4.[15]

TABLE 1.4: ELECTRICITY GENERATION TARIFFS (NOT INCLUDING RES UNDER FEED-IN TARIFF (WITHOUT 20% VALUE ADDED TAX (VAT), EFFECTIVE FEBRUARY 1, 2021)

POWER PLANT		UNIT	TARIFF
ANPP			
	Capacity Tariff	AMD (USD[16])/kW/month	5,016.42 (9.608)
	Electricity Tariff	AMD (U.S. cents)/kWh	4.448 (0.8)
Hrazdan TPP			
	Capacity Tariff	AMD (USD)/kW/month	350.61 (0.671)
	Electricity Tariff	AMD (U.S. cents)/kWh	33.575 (6.4)
Hrazdan Unit 5			
	Capacity Tariff	AMD (USD)/kW/month	498.05 (1.018)
	Electricity Tariff	AMD (U.S. cents)/kWh	26.876 (5.49)
Yerevan CCGT			
	Capacity Tariff	AMD (USD)/kW/month	4,418.18 (8.463)
	Electricity Tariff	AMD (U.S. cents)/kWh	1.88 (0.4)
Sevan-Hrazdan HPP Cascade			
	Capacity Tariff	AMD (USD)/kW/month	1,021.84 (1.957)
	Electricity Tariff	AMD (U.S. cents)/kWh	4.913 (0.9)
Vorotan HPP Cascade			
	Capacity Tariff	AMD (USD)/kW/month	2694.09 (5.160)
	Electricity Tariff	AMD (U.S. cents)/kWh	8.446 (1.6)

[15] https://psrc.am/uploads/files/Էլեկտրական Էներգիա/Սակագներ/Electricity_Tariffs-2021-22.pdf
[16] Exchange rate: USD 1 = AMD 522.08

Tariffs for RES electricity benefit from feed-in tariff regimes. Feed-in tariffs by power plant are presented in Table 1.5.[17]

TABLE 1.5: ELECTRICITY GENERATION TARIFFS FOR RES (WITHOUT VAT 20%, EFFECTIVE FROM JULY 1, 2021)

POWER PLANT	TARIFF, AMD (US. CENT)/KWH
Small HPP:	
• Build on drinking water pipeline	11.637 (2.229)
• Build on irrigation system	17.454 (3.343)
• Build on natural water flow	26.185 (5.016)
Wind Power Plant	
• Licensed before Nov 1, 2018	47.013 (9.005)
• Licensed from Nov 2, 2018, to Dec 31, 2020	26.204 (5.016)
Biomass Power Plant	
• Licensed before Dec 31, 2020	47.013 (9.005)
• Up to 30 MW (inclusive) licensed from Jan 1, 2021, to Dec 31, 2021	26.185 (5.016)
Solar power plant	
• Up to 1 MW (inclusive) licensed up to November 1, 2018	47.013 (9.005)
• Up to 5 MW (inclusive) licensed from November 2, 2018, to December 31, 2020	26.204 (5.019)
• Up to 1 MW (inclusive) licensed to community non-profit organizations	23.584 (4.517)

NATURAL GAS TARIFFS. Starting in July/August 2020, Armenia implemented a new structure for natural gas customers (Table 1.6). It differentiates tariffs for vulnerable customers, greenhouse farms, and customers consuming less or more than 10,000 m^3 per month.

TABLE 1.6: NATURAL GAS TARIFFS (20% VAT INCLUDED, EFFECTIVE FROM JULY 19 AND AUGUST 1, 2020)

CONSUMER TYPE	MEASUREMENT UNIT	TARIFF
1. Vulnerable customer		
1.1 Up to 600 m^3 of natural gas	AMD/1,000m^3	100,000
1.2 More than 600 m^3 of natural gas	AMD/1,000m^3	139,000
2. Greenhouse farms in agriculture		
2.1 For November 1 to March 31, inclusive	$/1,000$m^3$	224
2.2 For April 1 to October 31, inclusive		
a. For consumption of up to 10,000 m^3 per month	AMD/1,000m^3	139,000

[17] https://www.arlis.am/DocumentView.aspx?DocID=153032

TABLE 1.6: NATURAL GAS TARIFFS (20% VAT INCLUDED, EFFECTIVE FROM JULY 19 AND AUGUST 1, 2020)		
CONSUMER TYPE	MEASUREMENT UNIT	TARIFF
b. For consumption of 10,000 m^3 per month or more	$/1,000$m^3$	255.91
3. For individuals performing agricultural produce processing: preserves, beverage, and dairy product producers	**$/1,000$m^3$**	**224**
4. TPPs		
4.1 Consumption of up to 10,000 m^3 per month	AMD/1,000m^3	139,000
4.2 Consumption of 10,000 m^3 per month or more	$/1,000$m^3$	255.91
5. Other than 1–4		
5.1 Consumption of up to 10,000 m^3 per month	AMD/1,000m^3	139,000
5.2 Consumption of 10,000 m^3 per month or more	$/1,000$m^3$	255.91

OTHER ENERGY CARRIERS. Energy carriers are selected based on the types of fuels listed in the Armenia Energy Balance (Table 1.7). Fuels and their prices have been included in the model and made available for future consideration as possible energy sources to cover projected demand.[18]

TABLE 1.7: FUEL PRICES	
FUEL TYPE	PRICE, $/TON
Coal	
Anthracite (hard coal)	152.8
Bituminous (brown coal)	113.6
Other coal product	166.0
Oil	
Aviation gasoline	1,341.6
Liquefied petroleum gases	561.7
Gasoline	560.7
Jet fuel	779.6
Kerosene	1,200.5
Diesel	663.4
Lubricants	1,949.8
Bitumen	353.3
RES	PRICE, $/M^3

[18] Statistical Committee of the Republic of Armenia (Armstat)

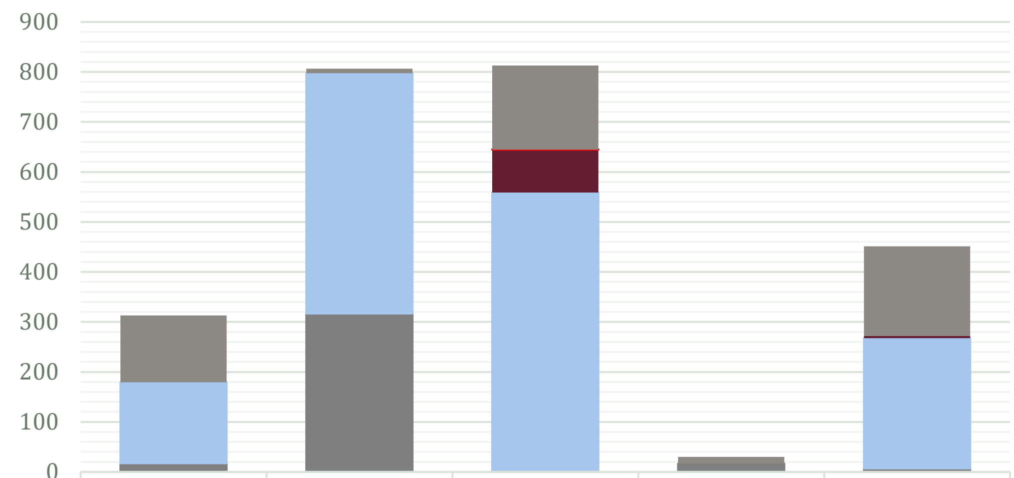
TABLE 1.7: FUEL PRICES

	Firewood	43.3
	Biomanures	26.0
Gas		PRICE, $/1,000M³
	Natural gas	165
Nuclear		PRICE, $/kg
	Uranium	91

FINAL ENERGY CONSUMPTION (FEC) OVERVIEW

In the base year, total FEC is 2,413 kilotons of oil equivalent (ktoe), of which the household and transport sectors account for around 1,620 ktoe. The largest final energy consumers are households, whereas agriculture has the smallest share. Natural gas has higher consumption than any other fuel type, amounting to 1,460 ktoe (60.5 percent of FEC). Figure 1.6 shows FEC by sector and type of fuel in 2019.

The transport sector is the second highest consumer, representing 33.4 percent of total FEC. The service and industry sectors make up 18.7 percent and 13.0 percent, respectively. Agriculture comprises only 1 percent of total FEC.



	Industry	Transport	Households	Agriculture	Services
Electricity	133.8	8.7	168	13.2	179.4
Heat			0.2		
Renewables			85.9		4.3
Natural Gas	161.7	480.8	557		260.8
Oil	17.5	317	0.8	16.6	5.1
Coal			0.8		1.8

Figure 1.6: Final energy consumption by sector and fuel type, ktoe

MODEL CALIBRATION[19]

The base year data were restructured to fit the model's specifications using the following process:

- Accumulating statistical data
- Reconfiguring statistical data and matching it with model requirements
- Carrying out intermediate calculations, producing a hypothesis, and completing the missing statistical data
- Determining the final energy for the base year using the model and comparing the results with the statistical consumption figures
- Improving the input data and producing new iterations in the model to achieve results similar to the true consumption.

After the data was collected and restructured, the model was calibrated with the base year data. This is an important task because the model must reflect the initial state of the economy in terms of labor, capital, and the links between the energy sector and the economy at large. The main variables to be calibrated were the capacities and operating levels of all technologies, as well as the quantities exported, imported, produced, and consumed by all energy carriers. The model runs for the base year showed that the transformed data and modeled parameters were adequate, meaning that the model was ready for Baseline Scenario development.

[19] http://www.iea-etsap.org/web/Documentation.asp

SECTION 2. BASELINE SCENARIO RESULTS AND ASSUMPTIONS

DEMAND DRIVERS

ECONOMIC INDICATORS

The goal of the model is to meet the future energy demand that underpins economic activity.[20] Therefore, a set of demand drivers were introduced to project economic development (Table 2.1).

TABLE 2.1: GROSS DOMESTIC PRODUCT (GDP) AND POPULATION

	2024	2027	2030	2033	2036	2040	2045	2050
GDP, millions of USD	15,254	17,159	19,301	21,711	24,422	28,570	34,760	42,291
Population, thousands of persons	2,977	2,976	2,967	2,952	2,934	2,905	2,865	2,816
Persons per household	3.4	3.3	3.3	3.2	3.2	3.1	3.1	3.0
GDP growth, %	4.2	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Population growth, %	0.08	-0.01	-0.10	-0.16	-0.21	-0.25	-0.28	-0.34
GDP per capita growth, %	4.2	4.0	4.1	4.2	4.2	4.3	4.3	4.4

International Monetary Fund data was used for GDP growth up to 2026.[21] For subsequent years, the growth rate is considered constant and equal to the 2026 growth rate.

Base year population data was drawn from Armstat yearbooks. As there is no national forecast for Armenia's population growth rate, the study used United Nations projections.[22]

The number of persons per household was calculated based on Armstat's housing stock data.[23]

Table 2.2 displays GDP growth by economic sector using ten-year retrospective data from Armstat yearbooks and standard trendlines in Microsoft Excel.[24]

TABLE 2.2: GDP AND GROWTH RATES BY SECTOR OF THE ECONOMY

GDP BY SECTOR, MILLIONS OF USD	2024	2027	2030	2033	2036	2040	2045	2050
Commercial/service	7,855	8,945	10,185	11,598	13,207	15,705	19,501	24,214
Growth rate, %	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
% of total GDP	51.5	52.1	52.8	53.4	54.1	55.0	56.1	57.3
Industry	3,186	3,673	4,195	4,751	5,343	6,186	7,327	8,563
Growth rate, %	5.2	4.9	4.5	4.2	4.0	3.7	3.4	3.2

[20] https://iea-etsap.org/index.php/etsap-tools/model-generators/times
[21] https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/ARM
[22] https://www.macrotrends.net/countries/ARM/armenia/population-growth-rate
[23] https://www.armstat.am/file/doc/99526853.pdf
[24] https://www.armstat.am/am/?nid=12&id=01001&submit

TABLE 2.2: GDP AND GROWTH RATES BY SECTOR OF THE ECONOMY								
GDP BY SECTOR, MILLIONS OF USD	2024	2027	2030	2033	2036	2040	2045	2050
% of total GDP	20.9	21.4	21.7	21.9	21.9	21.7	21.1	20.2
Construction	777	753	734	717	703	686	669	654
Growth rate, %	-1.2	-1.0	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4
% of total GDP	5.1	4.4	3.8	3.3	2.9	2.4	1.9	1.5
Agriculture	1,836	1,918	2,005	2,095	2,190	2,322	2,499	2,690
Growth rate, %	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
% of total GDP	12.0	11.2	10.4	9.7	9.0	8.1	7.2	6.4
Other	1,601	1,869	2,182	2,549	2,979	3,671	4,765	6,170
Growth rate, %	8.0	5.3	5.3	5.3	5.3	5.4	5.4	5.3
% of total GDP	10.5	10.9	11.3	11.7	12.2	12.8	13.7	14.6

FUEL PRICES

Forecasts for fuel prices are made based on World Energy Outlook (WEO) 2021 data for the European Union (EU).[25] In particular, WEO 2021 assumes that prices for natural gas will increase by 84 percent by 2030 and then another 8 percent (relative to 2030) by 2050. Prices for oil products will increase by 110 percent by 2050; coal prices will increase by 34 percent by 2030 and decrease by 6 percent by 2050 relative to 2030. Uranium prices are forecasted to increase by 43 percent by 2050.[26] The fuel price forecasts for Armenia are provided in Figures 2.1–2.4.

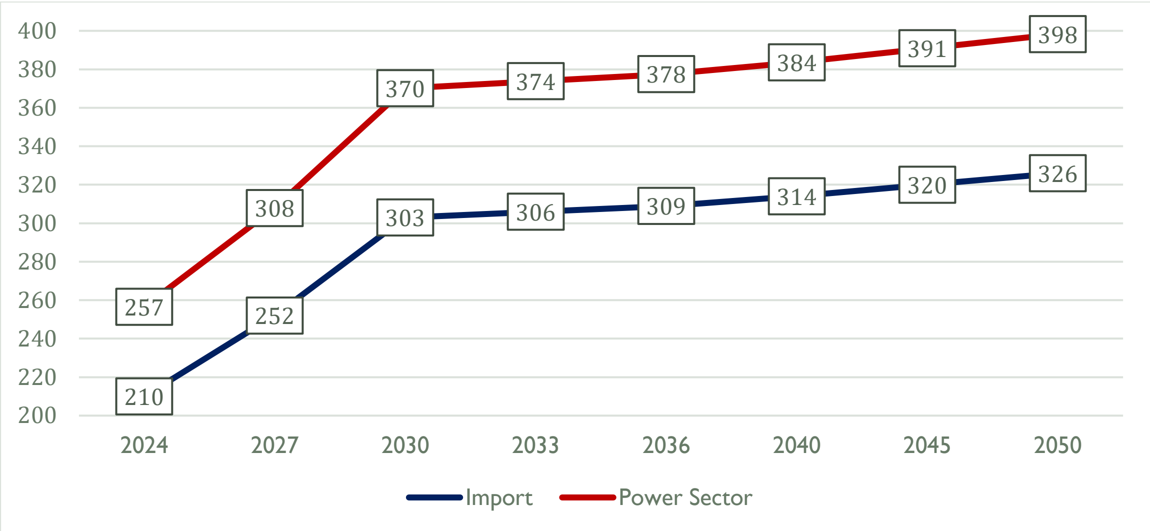
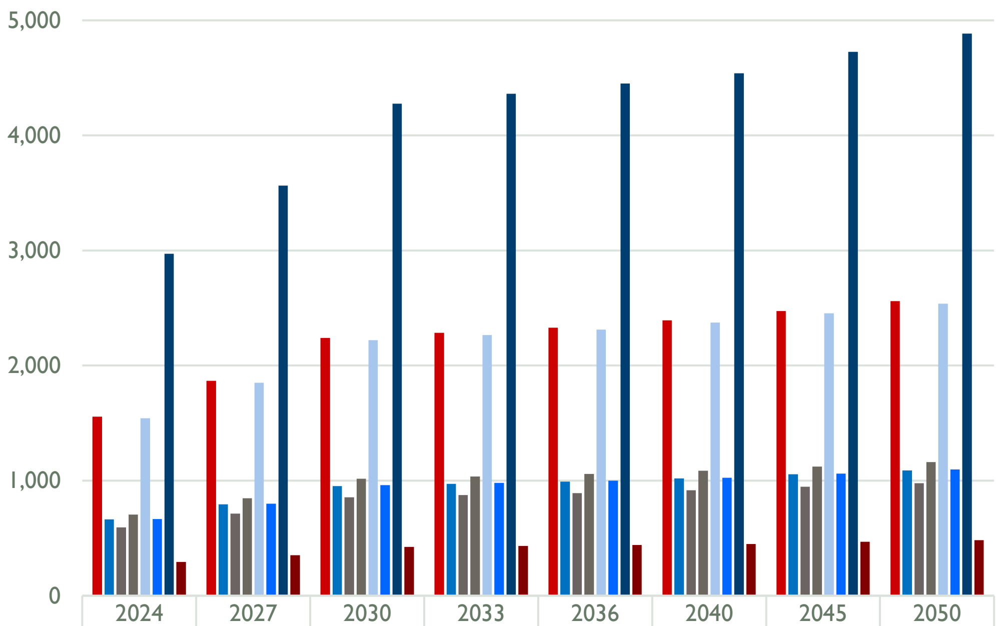


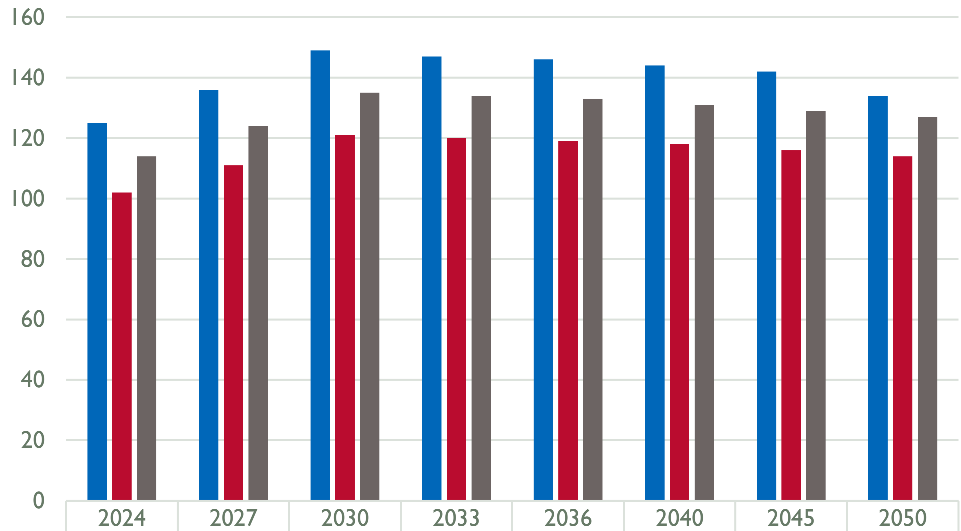
Figure 2.1: Natural gas price forecast, USD_{2019}/1,000 m^3

[25] https://iea.blob.core.windows.net/assets/888004cf-1a38-4716-9e0c-3b0e3fdbf609/WorldEnergyOutlook2021.pdf
[26] https://www.researchgate.net/publication/309020124_Forecasting_the_price_of_uranium_based_on_the_costs_of_uranium_deposits_exploitation



	2024	2027	2030	2033	2036	2040	2045	2050
Avia Gasoline	1,556	1,867	2,239	2,284	2,330	2,393	2,475	2,559
LPG	663	795	954	973	993	1,020	1,054	1,090
Gasoline	595	714	856	874	891	915	946	979
Jet Fuel	706	847	1,016	1,036	1,057	1,086	1,123	1,161
Kerosene	1,544	1,851	2,221	2,266	2,311	2,374	2,455	2,538
Diesel	667	800	960	979	999	1,026	1,061	1,097
Lubricants	2,972	3,564	4,275	4,362	4,450	4,540	4,726	4,886
Bitumen	294	353	423	432	440	449	468	484

Figure 2.2: Oil product price forecast, USD2019/ton



	2024	2027	2030	2033	2036	2040	2045	2050
Anthracite	125	136	149	147	146	144	142	134
Bituminous	102	111	121	120	119	118	116	114
Other coal product	114	124	135	134	133	131	129	127

Figure 2.3 Coal price forecast, USD2019/ton

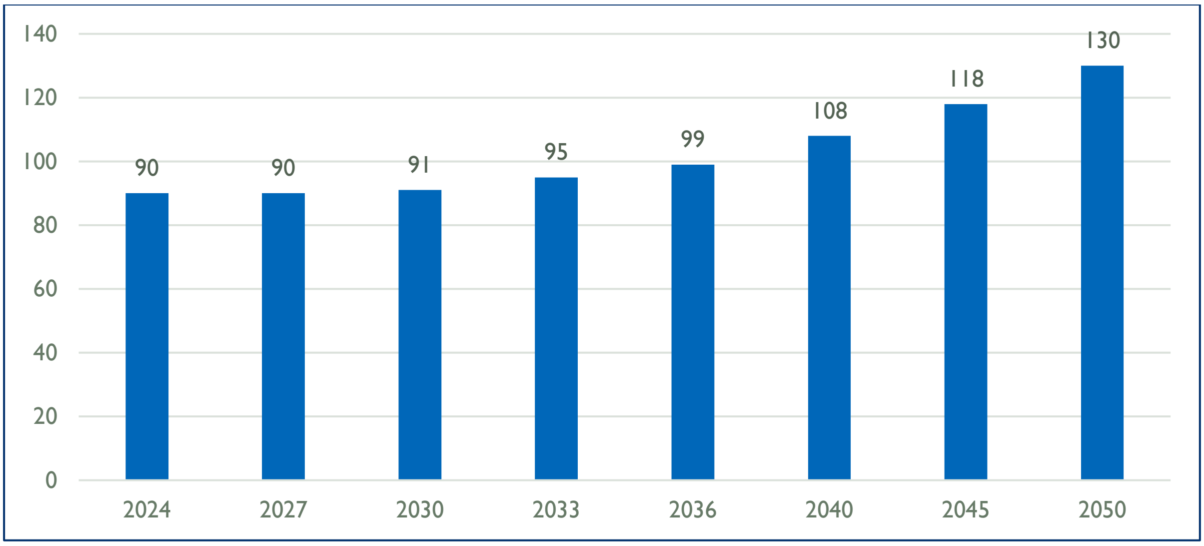


Figure 2.4: Uranium price forecast, USD_{2019}/kg

USEFUL ENERGY DEMAND PROJECTION

Demand projections driving the model were defined for useful energy services such as lighting, cooling, heating, food preparation, transportation of people and goods, etc. The model must meet projected levels of useful energy demand in all sectors and sub-sectors, choosing the fuels and technologies that do so at minimum costs for the entire energy system.[27]

Energy demand is mainly sensitive to changes in GDP and demographic parameters. The elasticity measures the change in useful energy relative to changes in GDP or GDP per capita and varies for different economic sectors and end-use applications. As the economy grows, the overall useful energy demand increases. End-use energy forecasts by sector were prepared based on analyses of available retrospective statistical data and defined elasticities.[28] Table 2.3 shows the structure of projected useful energy demand and its growth for 2024–2050.

TABLE 2.3: USEFUL ENERGY DEMAND PROJECTION

SECTOR, KTOE	2024	2027	2030	2033	2036	2040	2045	2050
Agriculture	9.6	9.7	9.7	9.8	9.9	10.0	10.1	10.3
Commercial	685	738	796	855	919	1,011	1,139	1,285
Industry	422	476	533	595	660	752	874	1,008
Residential	877	930	985	1,044	1,105	1,176	1,271	1,375
TRANSPORTATION, M[P/T]KM								
Air, international	2,296	2,513	2,750	3,009	3,293	3,714	4,316	5,015
Bus	5,483	5,759	6,049	6,353	6,673	7,125	7,732	8,391

[27] Useful energy is defined at the service level, such as required indoor temperature and boundary conditions, e.g., thermal heat losses and gains in space heating. https://ec.europa.eu/energy/sites/ener/files/documents/mapping-hc-final_report_wp1.pdf

[28] https://crawford.anu.edu.au/sites/default/files/publication/crawford01_cap_anu_edu_au/2016-07/understanding_the_energy-gdp_elasticity_a_sectoral_approach.pdf

TABLE 2.3: USEFUL ENERGY DEMAND PROJECTION								
SECTOR, KTOE	2024	2027	2030	2033	2036	2040	2045	2050
Commercial truck	1,749	1,956	2,187	2,446	2,736	3,176	3,827	4,612
Heavy-duty vehicles, short haul	3,066	3,355	3,672	4,018	4,397	4,959	5,763	6,697
Light-duty vehicles	11,077	11,896	12,796	13,781	14,855	16,431	18,659	21,228
Off-road	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Rail—freight	897	931	966	1,003	1,041	1,094	1,164	1,239
Rail—passenger	142	150	159	167	177	190	208	227

The residential sector has the highest share of useful energy demand until 2050 followed by the commercial sector. Agriculture accounts for less than 0.3 percent of useful energy demand, with industry and transportation accounting for the remainder.

The main drivers of energy demand growth in the agriculture, commercial, industry, and freight transport sectors are GDP and the elasticity of demand to GDP growth.[29] In the residential and passenger transportation sectors, the main drivers are GDP per capita and demand elasticity to GDP per capita growth. Some sectors use sector-specific demand drivers, such as degree-days[30] in the commercial sector or population and changes in the number of new and existing houses in the residential sector. The main sector-specific assumptions are:

AGRICULTURE

A slow growth rate is expected because it is unlikely that the sector will expand significantly. Throughout the planning period, the GDP elasticity of demand was set at 0.2 in all subsectors.

COMMERCIAL

It is assumed that commercial sector development will be based on the broad development of hotels, restaurants, shops, etc. This will result in fast demand growth for cooling and heating, lighting, cooking, and related services. For this sector, the elasticity of demand for the entire planning period was set at 0.51 in all subsectors.

INDUSTRY

It is assumed that the demand growth will be mainly driven by the non-metallic minerals and food and tobacco subsectors. The elasticity of demand for this sector was set as 0.86 for the entire planning period.

RESIDENTIAL

Due to the projected slight decrease in population, GDP per capita will still increase. For the model, this means that living conditions will improve, which will enable people to buy more appliances. More space in houses and apartments will be heated (today, many homes in Armenia are only

[29] https://veda-documentation.readthedocs.io/en/latest/index.html#

[30] A degree day compares the mean outdoor temperatures recorded for a location to a standard temperature, usually 65° Fahrenheit in the United States. The more extreme the outside temperature, the higher the number of degree days. A high number of degree days generally results in higher levels of energy use for space heating or cooling.

partially heated). The number of people per household is also projected to fall, which means that the number of apartments will increase, and more energy will be needed for space heating, cooling, and lighting, etc. The model also includes other drivers that are reducing energy consumption, such as the demolition rate of old buildings, more energy-efficient new buildings, and improved appliance efficiency. All these drivers are captured in the model, and the results show that net consumption will still increase. Elasticities of demand were set at 0.5 for space heating, at 0.42 for space cooling, and hot water preparation and at 0.2 for cooking and other appliances for the whole planning period.

TRANSPORT

It is assumed that improved living standards will require more differentiated types of passenger and freight vehicles, which will raise demand in the transportation sector. Demand elasticity for light-duty vehicles will decrease from 1.5 to 0.6 during the planning period, from 1.0 to 0.6 for buses, whereas it will remain at 0.51 for international passenger aviation during the planning horizon. For heavy-duty vehicles, international cargo aviation, and commercial trucks, demand elasticities will decrease from 1.1 to 0.95 during the planning period. Elasticity is set at 0.64 for passenger rail transportation and 0.5 for freight rail for the entire planning horizon.

ELECTRICITY GENERATION TECHNOLOGIES

To assess the least cost path of power sector development over the planning period, it is necessary to model all existing power plants and the range of possible generation technologies that are suitable for Armenia. The following three tables describe the technical and economic characteristics that the model requires for both existing power plants (Table 2.4) and for the proposed power technologies (Tables 2.5 and 2.6) that will be considered by the model.

TABLE 2.4: EXISTING POWER PLANTS AS OF 2019

POWER PLANT	INSTALLED CAPACITY, MW	LIFE YEAR	PARTICIPATION AT PEAK	EFFICIENCY	O&M COSTS[31] (U.S. CENTS/ KWH)	ANNUAL AVAILABILITY FACTOR		
						2019[32]	2020	2021
Hrazdan TPP	410	3	0.95	0.36	1.53	0.13	0.80	
Hrazdan Unit 5	467	13	0.95	0.42	1.36	0.22	0.80	
Yerevan CCGT	228.6	22	0.95	0.49	1.17	0.77	0.80	
Yerevan CCGT-2[33]	254	25	0.95	0.56	1.66			0.85
ANPP	407.5	7	0.95	0.27	0.71	0.57		
CHP	8	31	0.95	0.28	1.79	0.11	0.90	

[31] Includes both variable and fixed O&M costs.
[32] For 2019, figures represent actual utilization.
[33] Yerevan CCGT-2 is under operation starting in 2021. For modeling purposes, it is described as an existing power plant.

TABLE 2.4: EXISTING POWER PLANTS AS OF 2019

POWER PLANT	INSTALLED CAPACITY, MW	LIFE YEAR	PARTICIPATION AT PEAK	EFFICIENCY	O&M COSTS[31] (U.S. CENTS/ KWH)	ANNUAL AVAILABILITY FACTOR		
						2019[32]	2020	2021
Sevan-Hrazdan HPP Cascade	561.4	31	0.95	1	0.93	Availability factors are defined in Table 2.6		
Vorotan HPP Cascade	404.2	31	0.95	1	1.43			
Small HPP	374.9	31	0.28	1	4.60			
Solar PV commercial	10	25	0.15	1	5			
Solar PV residential	39.44	25	0.17	1	2.50			
Wind	4.2	31	0.09	1	5			

For existing power plants, variable and fixed O&M costs are the costs reflected in the Public Services Regulatory Commission (PSRC) power generation tariffs for 2019, excluding fuel costs. For modeling purposes, fuel costs included in the tariff calculations have been removed and variable costs recalculated following modeling requirements to provide each technology by fuel cost (if applicable), investment cost (if applicable), and O&M cost.

TECHNOLOGY	CAPACITY, MW	LIFE YEARS	PEAK	EFFICIENCY	INVESTMENT COST, USD2019/KW							VARIABLE COSTS U.S. CENTS /KWH	ANNUAL AVAILABILITY FACTOR
					2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**		
Gas-fired													
CCGT	250	30	0.95	0.56	988.0	988.0	988.0	988.0	988.0	988.0	988.0	0.67	0.85
Gas turbine	234	30	0.95	0.38	647.4	647.4	647.4	647.4	647.4	647.4	647.4	2.15	0.85
Nuclear													
Advanced Light Water Reactor (LWR)-1080	1,080	60	0.95	0.33	4,141.5	4,057.8	3,975.9	3,912.2	3,865.2	3,830.3	3,727.4	1.66	0.85
Advanced LWR (ALWR)-300 (small module reactor, SMR)	300	60	0.95	0.33	6,082.4	5,959.5	5,839.2	5,745.7	5,776.6	5,625.3	5,474.2	2.44	0.85
Advanced LWR (ALWR)-600	600	60	0.95	0.33	4,940.2	4,840.3	4,742.6	4,666.6	4,610.5	4,568.9	4,446.1	1.99	0.85
LWR (VVER)-1000	1,080	60	0.95	0.33	6,521.0	5,732.3	5,039.0	4,883.7	4,770.4	4,687.2	4,446.1	1.08	0.85
LWR (VVER)-300 (SMR)	300	60	0.95	0.33	9,576.9	8,418.6	7,400.3	7,172.4	7,006.0	6,883.8	6,529.7	1.59	0.85
LWR (VVER)-600	600	60	0.95	0.33	7,778.8	6,838.0	6,010.9	5,825.7	5,690.6	5,591.3	5,303.7	1.29	0.85
Molten salt reactor power plant	500	60	0.95	0.41	-	-	4,000.0	3,250.0	2,500.0	1,750.0	1,000.0	2.44	0.85
Natrium heat source	345	60	-	1	-	-	126.8	103.0	79.3	55.5	31.7	-	0.85
Natrium storage system	155	60	-	1	-	-	0.001	0.001	0.001	0.001	0.001	0.72	0.23
Renewable													
Geothermal	-	40	0.90	1	7,667.3	7,667.3	7,667.3	7,667.3	7,667.3	7,667.3	7,667.3	3.99	0.89
Hydro pumped storage	-	80	0.95	1	2,958.8	2,958.8	2,958.8	2,958.8	2,958.8	2,958.8	2,958.8	1.36	0.33
Solar–thermal concentrating–Six-hour storage	-	25	0.40	1	3,677.0	3,483.0	3,290.0	2,709.0	2,446.7	2,209.8	1,995.8	1.88	Availability factors are defined in Table 2.6
Solar–thermal concentrating–12-hour storage	-	25	0.50	1	5,046.0	4781.0	4,515.0	3,718.0	3,358.1	3,033.1	2,739.5	1.50	
Loriberd HPP	66	80	0.90	1	2,426.8	2,426.8	2,426.8	2,426.8	2,426.8	2,426.8	2,426.8	2.20	
Shnokh HPP	75	80	0.90	1	2,681.2	2,681.2	2,681.2	2,681.2	2,681.2	2,681.2	2,681.2	2.20	
Small HPP	-	80	0.35	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.75	
Solar PV Central	-	25	0.18	1	840.0	756.0	672.0	630.0	588.0	563.0	538.0	1.25	
Solar PV Masrik 1	55	25	0.18	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.19	
Solar PV commercial	-	25	0.18	1	1,031.0	969.0	825.0	709.0	650.0	588.0	526.0	1.38	
Solar PV residential	-	25	0.18	1	1,325.0	1,245.0	1,060.0	927.0	835.0	755.0	676.0	2.81	
Solar PV floating	-	20	0.18	1	1,000.0	900.0	800.0	750.0	700.0	670.2	640.5	1.74	
Wind	-	25	0.30	1	1,327.0	1,244.8	1,226.7	1,215.7	1,204.9	1,194.1	1,183.5	1.44	
Electricity storage													
Lithium-ion storage system	-	25	0.95	0.9	1,103.3	775.6	386.1	355.9	328.1	302.5	278.9	1.56	0.85

TABLE 2.6: AVAILABILITY PARAMETERS FOR RENEWABLE POWER PLANTS												
TECHNOLOGY/ PLANT	SP-D	SP-N	SP-P	SU-D	SU-N	SU-P	FA-D	FA-N	FA-P	WI-D	WI-N	WI-P
Sevan-Hrazdan HPP Cascade	0.15	0.17	0.29	0.10	0.10	0.13	0.01	0.02	0.07	0.03	0.04	0.12
Vorotan HPP Cascade	0.26	0.29	0.45	0.32	0.31	0.28	0.24	0.26	0.37	0.23	0.25	0.44
Loriberd HPP	0.60	0.61	0.62	0.31	0.32	0.31	0.24	0.24	0.25	0.25	0.25	0.26
Shnokh HPP	0.76	0.77	0.78	0.39	0.40	0.39	0.30	0.30	0.31	0.31	0.31	0.33
Small HPP	0.55	0.53	0.44	0.24	0.24	0.22	0.19	0.18	0.13	0.19	0.18	0.14
Solar PV	0.37	0.03	0.00	0.42	0.07	0.00	0.25	0.00	0.00	0.20	0.00	0.00
Solar–thermal concentrating–Six-hour storage	0.47	0.23	0.47	0.47	0.23	0.47	0.47	0.23	0.47	0.47	0.23	0.47
Solar–thermal concentrating–12-hour storage	0.65	0.33	0.65	0.65	0.33	0.65	0.65	0.33	0.65	0.65	0.33	0.65
Wind	0.40	0.28	0.53	0.38	0.36	0.55	0.22	0.16	0.17	0.26	0.24	0.22

SP – Spring, SU – Summer, FA – Fall, WI – Winter, D – Day, N – Night, P – Peak

MAIN ASSUMPTIONS FOR THE BASELINE SCENARIO

This section highlights key assumptions addressing Armenia's economy, power sector development options, new power generation and demand-side technology build-up rates, and potential energy sources in the country.

- The International Monetary Fund forecasts that Armenia's GDP will grow by 4.2 percent in 2024 and 4.0 percent in 2026. For years beyond 2026, the growth rate is considered constant and equal to the 2026 growth rate.
- Population shows small negative growth of -0.2 percent during the planning horizon.
- The industrial sector is one of the main contributors to demand for useful energy, with average annual growth rate of around 4 percent. The residential and commercial sectors contribute less, with average annual growth rates of around 2.2 percent and 2.7 percent, respectively.
- Fuel price projections are based on the International Energy Agency (IEA) forecast of prices for the EU in WEO 2021.
- Electricity losses in the transmission and distribution networks are assumed to be reduced from 8.6 percent in the base year to 8.1 percent at the end of the planning period.
- Considering 2020 geopolitical circumstances in Artsakh, electricity imports and exports have been modeled according to actual 2021 data. In the Baseline Scenario, Armenia's energy exchange is modeled without electricity exchange with Georgia. This enables the

study to assess the energy source and generation technology required to meet projected energy demand in Armenia.

- Based on existing available energy and technical resources in Armenia, capacity limitations have been applied to power generation capacities (Table 2.6).
- In the Armenia Energy Strategy the Government of Armenia stated its commitment to maintaining nuclear power in Armenia's power generation mix. The modeling of several options for the Baseline Scenario, shows that the only option, where the model chooses the construction of the new nuclear power plant, is where the limitation on TPP construction is set out. For the Baseline Scenario presented below it is assumed that no new TPP is constructed during the planning period.

BASELINE SCENARIO RESULTS

This section summarizes the main results of the Baseline Scenario, which depicts the future state of Armenian energy sector development considering the policies that are carried out today. It also demonstrates the least-cost deployment of power generation to meet future demand for energy in the country. Based on these results, additional policy scenarios and sensitivity analyses were conducted to provide inputs for policy and planning considerations (Section 3). The Baseline Scenario provides insight on total primary energy supply (TPES) and FEC by energy source, economic sector, and generation technology so that Armenia can meet projected demand at the lowest cost.

TOTAL PRIMARY ENERGY SUPPLY

Natural gas remains the dominant energy source throughout the planning horizon. Its share of TPES in 2024 is around 52 percent, increasing to 74 percent in 2027 due to the end of ANPP's life. The share of RES increases over the horizon from around seven percent to nearly 14 percent. The share of oil products remains approximately the same through the whole planning period (Table 2.7).

TABLE 2.7: TOTAL PRIMARY ENERGY SUPPLY (KTOE) AND SHARE (%)

COMMODITY	2024	2027	2030	2033	2036	2040	2045	2050
Biofuels	79.9	79.8	83.4	87.6	88.7	90.1	91.9	77.0
Coal	3.2	3.4	3.7	4.0	4.2	4.6	5.0	5.5
Electricity	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Natural gas	2,012.9	2,578.8	2,643.4	2,045.1	2,162.6	2,273.7	2,446.4	2,587.4
Nuclear	1,071.2	-	-	1,198.8	1,198.8	1,198.8	1,198.8	1,198.8
Oil products	439.0	450.0	461.5	475.8	492.1	520.5	570.1	629.5
Renewables	281.5	368.7	408.5	389.8	416.0	487.8	565.2	730.1
TOTAL	**3,893**	**3,485**	**3,605**	**4,206**	**4,367**	**4,580**	**4,882**	**5,233**
				SHARE OF TPES (%)				
Biofuels	2.1	2.3	2.3	2.1	2.0	2.0	1.9	1.5

TABLE 2.7: TOTAL PRIMARY ENERGY SUPPLY (KTOE) AND SHARE (%)

COMMODITY	2024	2027	2030	2033	2036	2040	2045	2050
Coal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Electricity	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Natural gas	51.7	74.0	73.3	48.6	49.5	49.6	50.1	49.4
Nuclear	27.5	-	-	28.5	27.4	26.2	25	23
Oil products	11.3	12.9	12.8	11.3	11.3	11.4	11.7	12.0
Renewables	7.2	10.6	11.3	9.3	9.5	10.7	11.6	14.0

Given natural gas' continuing large share in TPES, the Baseline Scenario assessed the capacities of existing natural gas pipelines to determine their availability to transport projected volumes. The results (Table 2.8) indicate that natural gas supply from Russia will reach its highest level in 2030, just under 76 percent of maximum pipeline capacity. Pipeline capacity to the south will be used at base year levels and only around 14 percent will be filled during the planning horizon.

TABLE 2.8: GAS PIPELINE CAPACITIES AND IMPORT

GAS PIPELINE	MAXIMUM CAPACITY, BILLION M³		IMPORT, BILLION M³	
	DAILY	ANNUAL	2019	2030 (MAX)
From Russia	0.010	3.65	2.17	2.77
From the south	0.008	2.92	0.40	0.40
Total	**0.018**	**6.57**	**2.57**	**3.17**

The level of independence on energy carrier imports is expected to be 36.8 percent in 2024. Energy independence is the share of domestic energy production in TPES supplied in the country. After ANPP decommissioning in 2027, energy independence will drop by more than half to 12.9 percent. Widespread implementation of RES, mostly solar energy, as well as the construction of the NPP, will restore this level to 38.3 percent in 2050. FEC distribution by sector and fuel type is presented in Table 2.9.

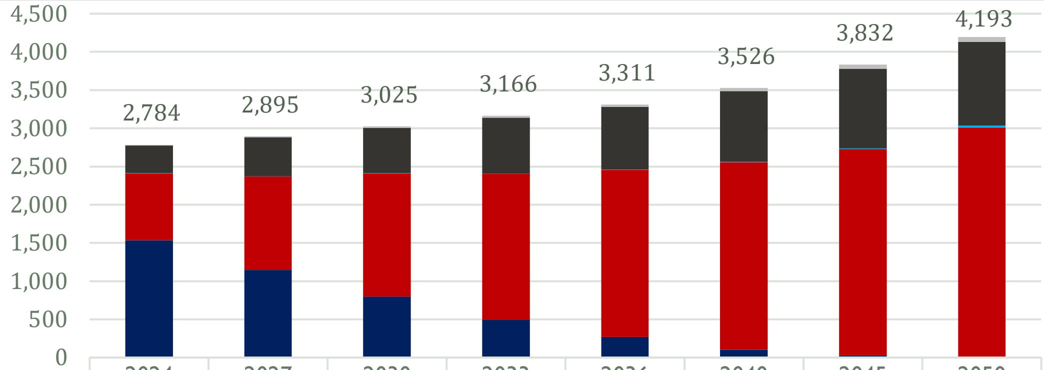
TABLE 2.9: FEC BY SECTOR AND FUEL, KTOE

SECTOR	COMMODITY	2024	2027	2030	2033	2036	2040	2045	2050
AGRICULTURE	Electricity	14.5	14.3	13.7	13.8	13.7	13.6	13.5	13.5
	Oil products	16.6	16.4	16.1	15.8	15.8	15.7	15.6	15.6
	Total	**31**	**31**	**30**	**30**	**29**	**29**	**29**	**29**
	% of grand total	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.7
COMMERCIAL	Coal	2.1	2.2	2.3	2.4	2.5	2.7	2.9	3.1

TABLE 2.9: FEC BY SECTOR AND FUEL, KTOE									
SECTOR	COMMODITY	2024	2027	2030	2033	2036	2040	2045	2050
	Electricity	198.3	208.7	220.3	233.4	248.8	272.1	304.2	340.9
	Natural gas	292.1	306.8	324.5	343.5	363.8	392.9	431.6	477.7
	Oil products	5.8	6.2	6.5	6.9	7.3	7.9	8.7	9.5
	Renewables	4.9	5.1	5.1	5.2	5.2	5.5	6.1	7.0
	Total	**503**	**529**	**559**	**591**	**628**	**681**	**753**	**838**
	% of grand total	18.1	18.3	18.5	18.7	19.0	19.3	19.7	20.0
INDUSTRY	Biofuels	0.004	0.004	0.004	0.5	0.005	0.005	0.006	2.4
	Electricity	157.5	170.3	184.8	200.9	215.7	236.1	251.4	276.1
	Natural gas	223.3	248.6	274.4	299.5	326.2	360.9	394.4	438.5
	Oil products	18.8	20.1	21.4	22.5	23.8	25.9	26.5	28.3
	Total	**400**	**439**	**481**	**523**	**566**	**623**	**672**	**745**
	% of grand total	14.4	15.2	15.9	16.5	17.1	17.7	17.5	17.8
RESIDENTIAL	Biofuels	79.9	79.8	83.4	87.1	88.7	90.1	91.9	74.6
	Coal	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.4
	Electricity	183.6	180.2	187.1	198.6	210.1	223.6	241.7	291.1
	Natural gas	695.2	728.6	758.9	785.8	811.0	843.3	884.5	901.7
	Low-temperature heat	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Oil products	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.1
	Renewables	3.9	3.6	3.2	3.0	2.6	2.2	1.5	0.6
	Total	**965**	**995**	**1,035**	**1,077**	**1,115**	**1,162**	**1,223**	**1,272**
	% of grand total	34.7	34.4	34.2	34.0	33.7	33.0	31.9	30.3
TRANSPORT	Electricity	8.9	9.1	9.3	11.1	11.7	12.5	13.7	13.7
	Natural gas	471.8	473.8	478.4	480.7	488.2	509.2	568.0	645.7
	Oil products	404.9	418.6	433.5	452.2	473.4	509.2	572.9	649.7
	Total	**886**	**901**	**921**	**944**	**973**	**1,031**	**1,155**	**1,309**
	% of grand total	31.8	31.1	30.4	29.8	29.4	29.2	30.1	31.2
	Grand total	**2,784**	**2,895**	**3,025**	**3,166**	**3,311**	**3,526**	**3,832**	**4,193**

FEC will increase by more than 50 percent during the planning period, but without any significant changes in shares by sector. The industrial and commercial sectors show increase of FEC, rising respectively three and two percentage points from 2024 to 2050. Natural gas, electricity, and oil products will provide around 98 percent of total FEC, with natural gas representing the highest share during the whole planning period.

The Baseline Scenario assumes that by the end of the planning period, 24 percent of FEC will be attributed to the improved technologies with higher efficiency (Figure 2.5). The remainder will be covered by the existing technologies subject to replacement by the same type of technology after the end of their useful lives.



	2024	2027	2030	2033	2036	2040	2045	2050
Advanced	10	13	19	25	32	42	52	64
Improved	361	510	593	733	821	924	1,044	1,095
Better	1	2	3	3	4	5	7	24
Standard	876	1,223	1,612	1,911	2,186	2,453	2,697	2,999
Existing	1,536	1,147	799	493	269	103	32	12
Total	2,784	2,895	3,025	3,166	3,311	3,526	3,832	4,193

Figure 2.5: Replacement of end-use technologies by types, ktoe [34]

TOTAL SYSTEM COST

The total projected system cost is $68 billion (in 2019 dollars) over the whole planning period (Figure 2.6). This comprises all costs associated with energy supply and end-use demands for energy across the agriculture, commercial, industry, residential, and transport sectors. In the investment category, the model's methodology includes not only the spending required to build new power plants or new industrial facilities, but also the costs associated with replacing existing facilities. For FEC by sector, the variable and fixed O&M costs include all costs (excluding fuel) required to ensure the safe and uninterrupted operation of all technologies and installations in the supply, transmission, and distribution systems as well as on the demand side.

Half of total system costs for the entire planning period is allocated to investments, and only 26 percent is for fuel. Fixed costs and variable costs (excluding fuel) account for 15 percent and 9 percent of overall costs, respectively. Within investment cost, only 6 percent is related to the power sector. The biggest share is accounting for the transport sector (31 percent).

[34] According to the IEA-ETSAP definitions, each type of energy demand technology has a level of efficiency (https://iea-etsap.org/index.php/energy-technology-data/energy-demand-technologies-data), namely Existing, Standard, Better, Improved, and Advanced (listed from less efficient to more efficient).

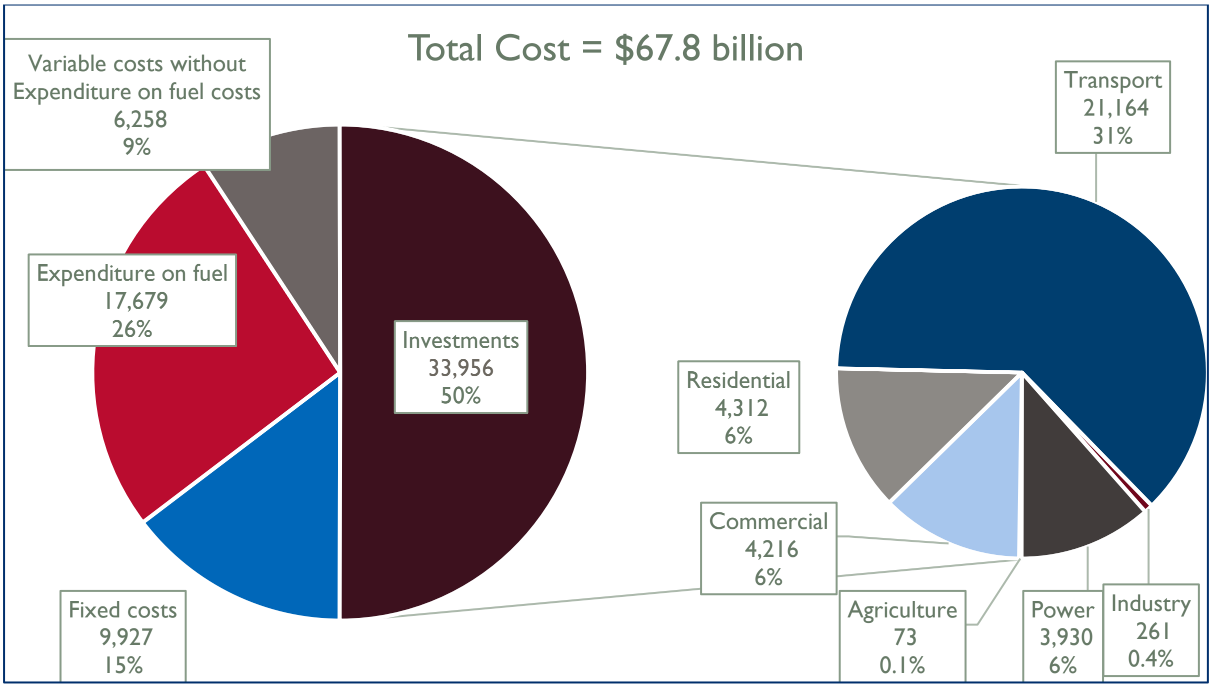


Figure 2.6: Structure of total discounted system cost to 2050 (millions of USD, %)

PROJECTED GENERATION MIX

The model's least-cost baseline configuration of the power sector is presented in Table 2.10. The volume of electricity generation by technology or power plant over the planning period is shown in Table 2.11.

TABLE 2.10: CAPACITY (BY PLANT/TYPE), MW

PLANT	2024	2027	2030	2033	2036	2040	2045	2050
Yerevan CCGT	234	234	234	234	234	234		
Yerevan CCGT-2	254	254	254	254	254	254	208	
Hrazdan Unit 5	467	467	467					
Local cogeneration plant	8	8	8	8	8	8	8	8
Vorotan HPP Cascade	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561
Loriberd HPP							66	66
Shnokh HPP							75	75
Small HPP (existing)	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64
ANPP (existing)	440							
NPP (new)				600	600	600	600	600

TABLE 2.10: CAPACITY (BY PLANT/TYPE), MW								
PLANT	2024	2027	2030	2033	2036	2040	2045	2050
Solar (existing)	49	49	49	49	49	49	49	
Solar (new)	369	845	982	1,026	1,130	1,452	1,727	2,630
Hydro pumped storage plant (new)							65	130
Lithium-ion storage (new)				0.02	0.02	0.02	0.02	0.06
Wind (existing)	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	409	409	371
Total	3,233	3,362	3,592	3,769	3,873	4,414	4,616	5,289

TABLE 2.11: GENERATION, GIGAWATT-HOURS (GWH)								
PLANT	2024	2027	2030	2033	2036	2040	2045	2050
Yerevan CCGT	71	1,672	1,672	22	59	60		
Yerevan CCGT-2	1,471	1,891	1,891	248	417	343	364	
Hrazdan Unit 5		591	510					
Local cogeneration plant	7	7	7	7	7	8	8	26
Vorotan HPP Cascade	984	984	984	979	984	984	984	598
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346
Loriberd HPP							203	203
Shnokh HPP							291	291
Small HPP (existing)	932	935	935	654	790	528	492	122
Small HPP (new)	159	159	159	159	159	159	159	159
ANPP (existing)	3,374							
NPP (new)				4,601	4,601	4,601	4,601	4,601
Solar (existing)	79	79	79	79	79	79	79	
Solar (new)	592	1,354	1,574	1,645	1,811	2,328	2,770	5,689
Hydro pumped storage plant (new)							188	376
Lithium-ion storage (new)				15	8	20	20	68
Wind (existing)	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	1,091	1,091	990

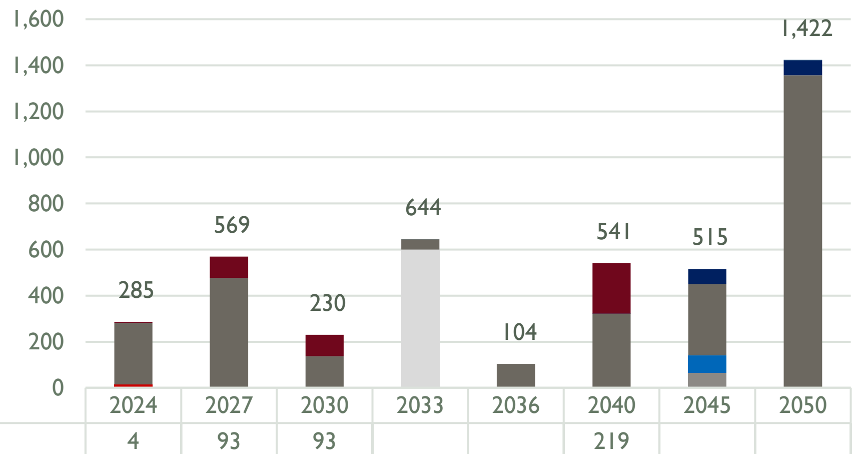
TABLE 2.11: GENERATION, GIGAWATT-HOURS (GWH)								
PLANT	2024	2027	2030	2033	2036	2040	2045	2050
Total	8,095	8,347	8,734	9,332	9,839	10,617	11,667	13,472

From a cost perspective and based on the minimum technical constraints assumed, extensive implementation of solar technologies is economically the most attractive option. However, such growth would create operational challenges for the power system. As large amounts of new grid-connected solar are introduced, the model shows a decline in the production of small HPPs due to the comparatively high cost of hydropower. Given the system operational constraints of such large amounts of variable renewable energy, this could imply the need for storage technologies, which are selected as the least-cost solutions. From 2033 onward, the lithium-ion and hydro pumped storage technologies are introduced in the generation mix. Moreover, at the end of the planning period, almost all thermal generation technologies will be phased out step by step. The model found the least-cost solution to cover the requested demand by implementing a 600 MW nuclear power plant in 2033.

NEW CAPACITY COSTS

Figures 2.7 and 2.8 present new generation added to the system by type and the associated total projected investment expenditures over the planning period. New built capacity will be 4,310 MW, which will require around $13 billion in investment.

Considering changes in technology prices, the model selects RES generation technologies such as whole hydro, solar and wind as the least-cost options. Their share in total installed capacity is expected to increase during the planning period, reaching 86 percent in 2050. That year, the share of storage technologies will be 2.5 percent.



	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93			219		
Lithium-ion storage				0.02		0.002		0.04
Hydro Pumped Storage Plant							65	65
Solar	266	476	137	44	104	322	309	1,357
NPP Advanced LWR-600				600				
Small HPP	15							
Shnokh HPP							75	
Loriberd HPP							66	
Total	285	569	230	644	104	541	515	1,422

Figure 2.7: New capacity implementation schedule, MW

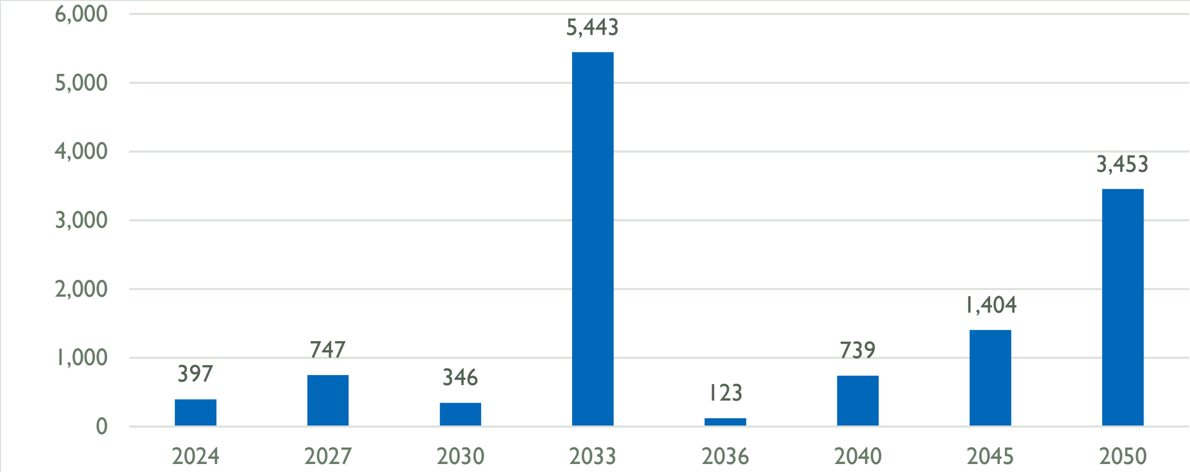
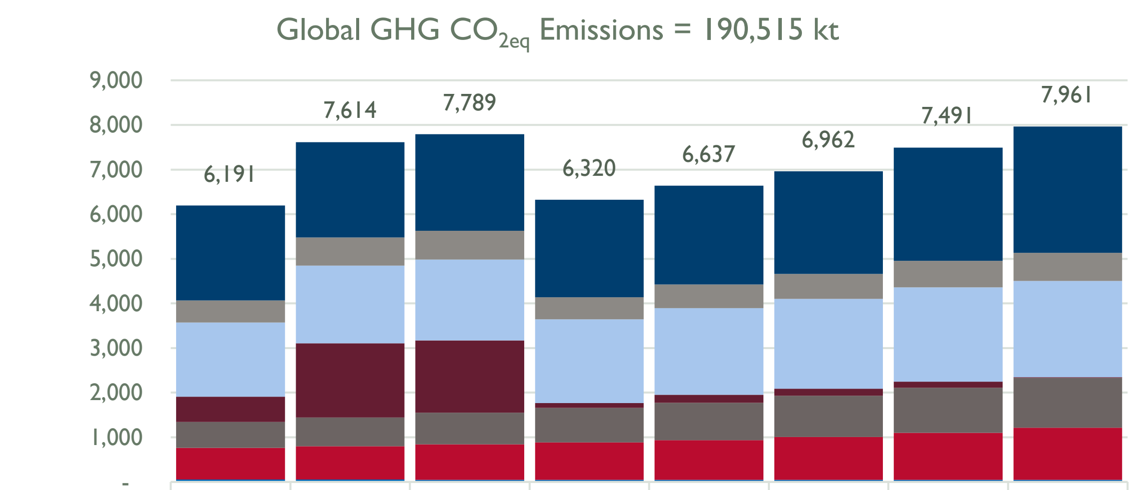


Figure 2.8: Total power sector investment for new capacity, millions of USD

GREENHOUSE GAS (GHG) EMISSIONS

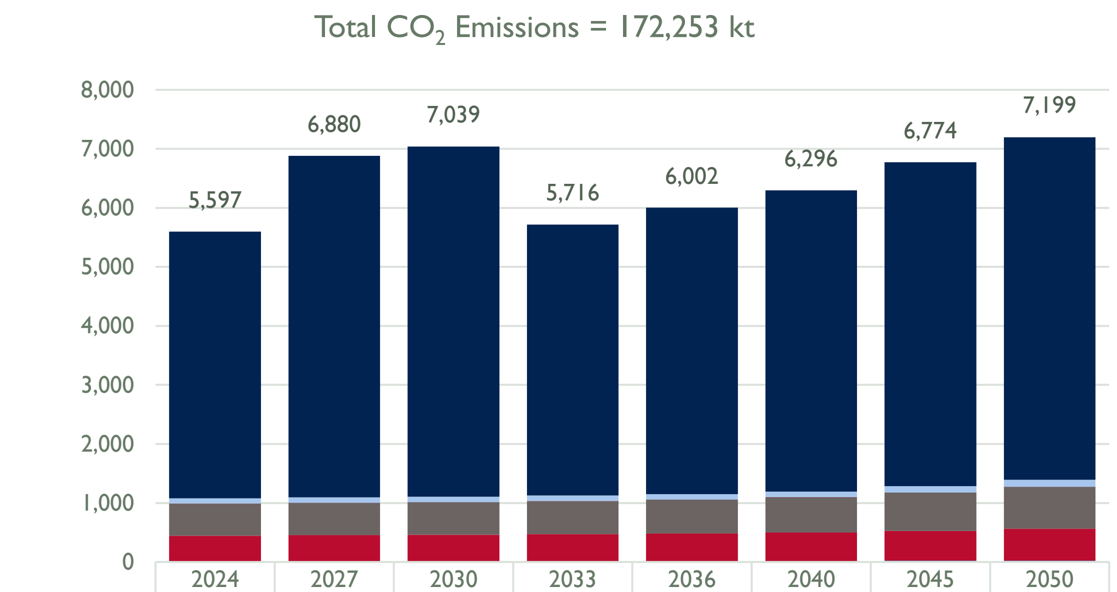
Annual GHG emissions in carbon dioxide equivalent (CO_{2eq}) for the Baseline Scenario vary between 6.2 and 8.0 megatons (Mt) across 2024–2050 (Figure 2.9). This is a result of a significant decrease in emissions from the power sector, while in all other sectors, emissions are projected to increase. GHG emissions from the power sector reach their lowest level in 2050, at 19 kilotons (kt), accounting for only 0.2 percent of total GHG emissions. This is due to RES' increasing share in the energy generation mix and introduction of a new nuclear power plant. The highest emissions throughout the planning horizon come from the transport sector, followed by the residential sector. In 2050, they account for 35 percent and 27 percent of GHG emissions, respectively.



	2024	2027	2030	2033	2036	2040	2045	2050
Transport	2,125	2,139	2,158	2,179	2,215	2,303	2,534	2,827
Supply	490	628	644	498	527	554	596	630
Residential	1,664	1,743	1,815	1,879	1,939	2,016	2,114	2,155
Power Sector	565	1,658	1,620	104	180	154	137	19
Industry	583	647	711	774	841	929	1,010	1,119
Commercial	712	748	791	837	886	957	1,051	1,163
Agriculture	52	51	50	49	49	49	49	49
Total	6,191	7,614	7,789	6,320	6,637	6,962	7,491	7,961

Figure 2.9: GHG emissions in CO_{2eq} by sector, kt

Emissions by fuel type are presented in Figure 2.10. Natural gas has the highest share of CO_2 emissions over the planning period, followed by gasoline and diesel. These three pollutants account for around 98 percent of total CO_2 emissions.



	2024	2027	2030	2033	2036	2040	2045	2050
Natural Gas	4,516	5,786	5,931	4,588	4,852	5,101	5,489	5,805
LPG	90	91	91	92	93	96	105	117
Kerosene	2	2	2	2	2	2	2	2
Gasolline	542	548	555	563	573	597	651	709
Diesel fuel	433	440	444	454	464	480	505	543
Coal	13	14	15	16	17	19	21	22
Total	5,597	6,880	7,039	5,716	6,002	6,296	6,774	7,199

Figure 2.10: GHG emissions (CO_2) by fuel, kt

SECTION 3. POLICY SCENARIOS' RESULTS AND ASSUMPTIONS

SELECTED SCENARIOS

MLET considered a set of policy scenarios covering socioeconomic and technical developments to provide vital information for Armenia's energy sector decision makers and decrease the uncertainty of demand driver projections.

ECONOMY GROWTH RATE SCENARIOS. Armenia's energy sector development is analyzed under two GDP growth rate scenarios with 50 percent greater (High Growth) and lower (Low Growth) GDP growth rates than those in the Baseline Scenario. Two more scenarios analyze sector development if there is a 200-MW increase in electricity demand from the industry sector in 2027 (Increased Demand in Industry) and conservative development in technological efficiencies in the industry sector (EE in Industry). None of the economy growth rate scenarios consider new TPP implementation.

NATURAL GAS PRICE SCENARIOS. Analysis of the Baseline Scenario shows that Armenia relies heavily on natural gas for the planning horizon. To mitigate the uncertainty of possible changes in the natural gas price, three alternative scenarios were selected. The first scenario (EU Gas Price) posits that natural gas price will remain \$165/1,000m^3 until 2024, then reach the EU prices defined in the WEO 2021. For the second scenario (Unchanged Gas Price), natural gas prices remain \$165/1,000m^3 until 2033, then equalize with the Baseline Scenario, and no new TPPs are implemented. One more scenario (Extreme Gas Price) considers the changes in the natural gas prices in the EU in 2022. This scenario posits that until 2033, the gas price in Armenia will follow the natural gas price in the EU (\$1,000/1,000 m^3) with no gas supply afterward.

NUCLEAR POWER DEVELOPMENT SCENARIOS. Five scenarios were developed to assess Armenia's energy sector development least-cost pathway in case ANPP's lifetime is extended and a new NPP is constructed. One scenario extends ANPP's lifetime to 2032 (ANPP 2032); another to 2037 (ANPP 2037). Two additional scenarios extend ANPP to 2037 and add more equipment: one adds a SMR-300 module in 2037 (ANPP 2037 and One SMR) and the other adds the first SMR-300 module in 2037 and the second in 2045 (ANPP 2037 and Two SMR). One final scenario analyzes energy sector development if ANPP's lifetime is extended by 2026 and an SMR-300 is implemented from 2036 (ANPP 2026 and One SMR-300). Neither scenario considers new TPP implementation.

ENERGY EFFICIENCY SCENARIOS. These scenarios consider different levels of improvements in end-use technologies and an increase in share of electric vehicles (EVs). EE-No Limit places no limitations in the model on replacing new demand technologies with advanced, better, or improved technology by 2050. Three other scenarios consider 20, 50, and 90 percent forced use of more efficient end-use technologies by 2050 (EE-20, EE-50, and EE-90). To assess the impact of a possible increase in EVs, scenarios posit that EVs increase from 5 percent of total cars in 2030 to 50 percent in 2050 in one scenario (EV-50) and 100 percent in 2050 in the second (EV-100). No EE scenarios consider new TPP implementation. EV scenarios consider only light-duty vehicles and does not include other transportation.

GHG EMISSIONS SCENARIO. One scenario considers the influence of a carbon tax equal to that in the EU on energy carriers' supply options in Armenia. The tax is modeled to be \$50/ton in 2030 and \$100/ton afterwards.

GEORGIA ELECTRICITY IMPORT/EXPORT SCENARIOS. These scenarios examine an expansion of electricity export to Georgia: first with 300 MW of electricity export from 2027

(Import/Export 300 MW), and the second with 300 MW from 2027 and 1,050 MW from 2040 (Import/Export 1,050 MW), both from October-March period. For both scenarios, starting from 2027, 50 MW electricity import from Georgia during April-September period is considered. For both scenarios load factor is 75 percent. Neither scenario considers new fossil generation.

ECONOMY GROWTH SCENARIOS GROUP

GDP GROWTH RATE SCENARIOS

Two GDP growth scenarios have been modeled to analyze the influence of GDP growth rates on Armenia energy system's least cost development pathway. For the Low Growth scenario, it is assumed that the GDP growth rate will be 50 percent lower than in the Baseline Scenario and for the High Growth scenario, 50 percent higher. No new TPP implementation is considered (Table 3.1, Figure 3.1).

TABLE 3.1: GDP GROWTH RATE, %

SCENARIO	2024	2027	2030	2033	2036	2040	2045	2050
Baseline	4.25	4.0	4.0	4.0	4.0	4.0	4.0	4.0
High Growth	6.37	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Low Growth	2.12	2.0	2.0	2.0	2.0	2.0	2.0	2.0

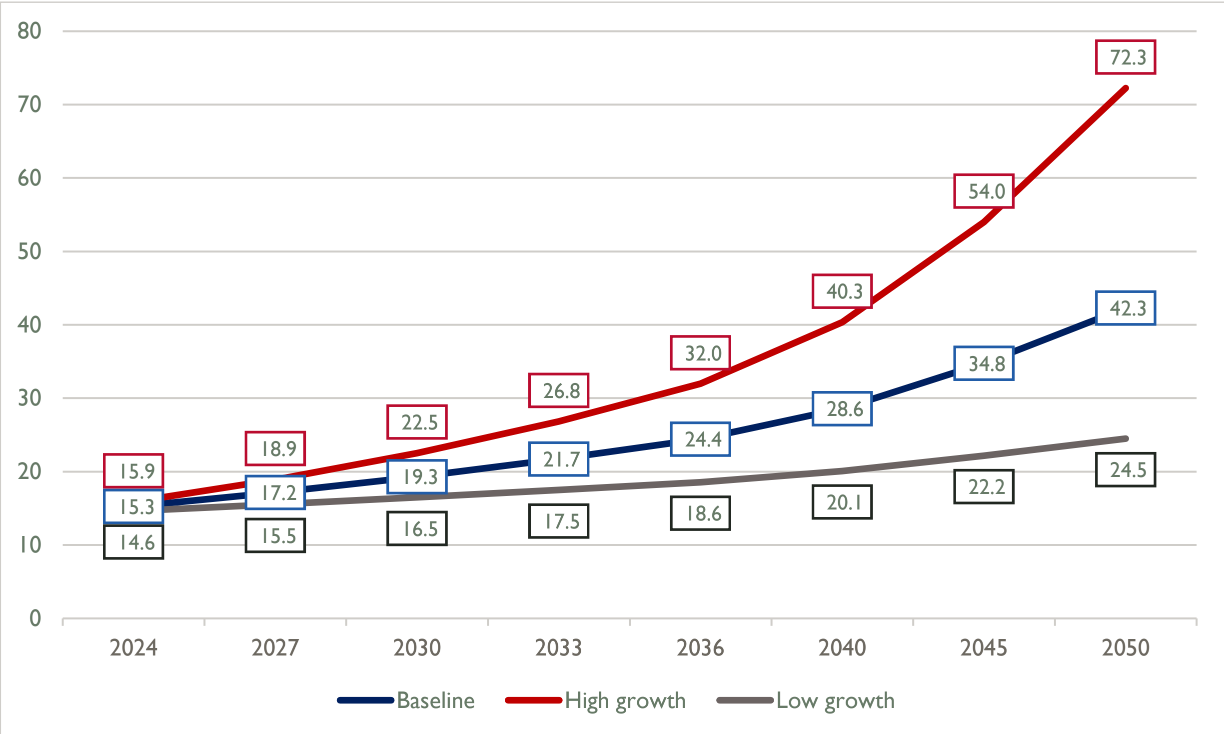


Figure 3.1: GDP growth scenarios, billions of USD

TOTAL SYSTEM COST will amount to $80.7 billion for the High Growth scenario and $57.5 billion for the Low Growth scenario. A comparison with the Baseline Scenario is presented in Table 3.2.

TABLE 3.2: TOTAL SYSTEM COST FOR GDP GROWTH SCENARIOS		
SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	67,763	-
High growth	80,660	+19
Low growth	57,507	-15

Total system cost changes proportional to the changes in GDP growth. For the High Growth scenario, it increases by 4.2 times for the planning horizon ($2.53 billion in 2024, $10.72 billion in 2050) compared with GDP's 4.5-times increase ($15.9 billion in 2024, $72.3 billion in 2050).

For the Low Growth scenario, total system cost increases by 2.4 times for the planning horizon ($2.3 billion in 2024, $5.5 billion in 2050) compared with GDP's 1.7-times increase ($14.6 billion in 2024, $24.5 billion in 2050).

TPES projections for High and Low Growth scenarios are presented in Figure 3.2.

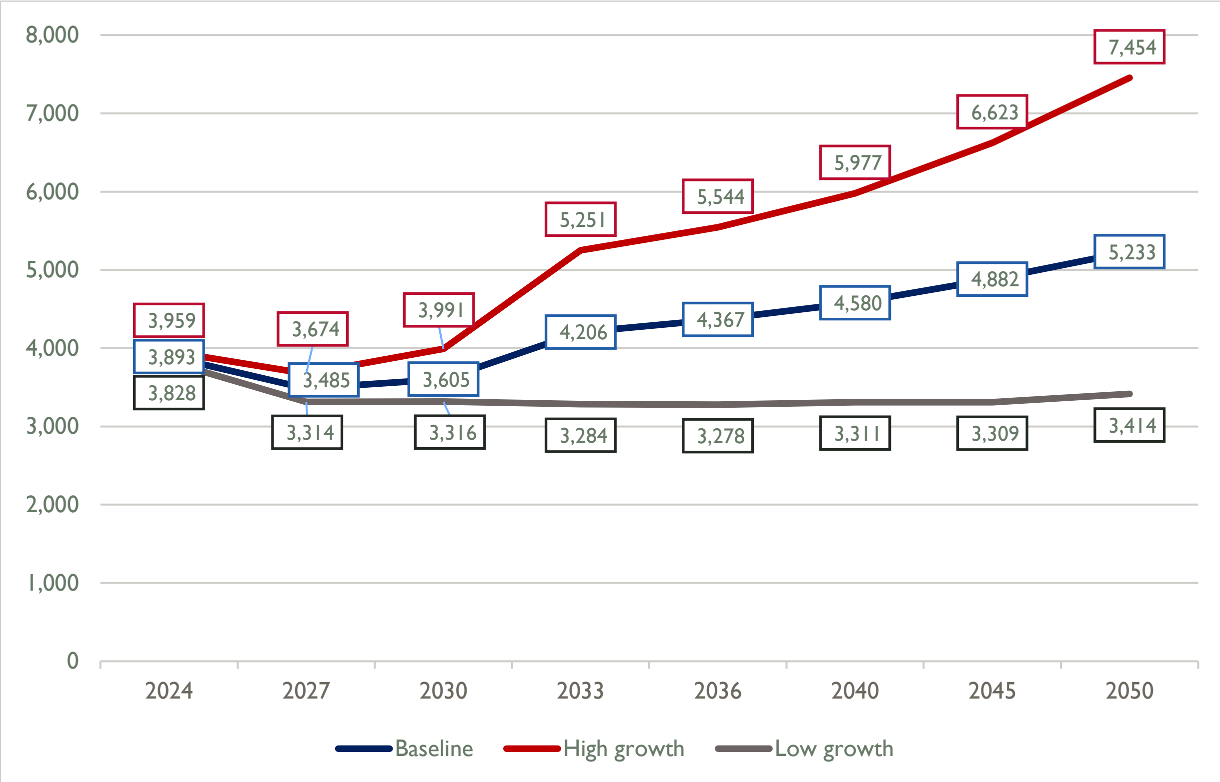


Figure 3.2: TPES for GDP growth scenarios, ktoe

In the High Growth scenario, TPES shows a steady increase from 2030, which is mostly a result of additional use (compared with the Baseline Scenario) of nuclear energy and natural gas. Until 2027, there is slightly lower TPES use because more efficient technologies are covering the demand.

In the Low Growth scenario, TPES shows a steady decrease until 2045, which is mostly the result of lower use of nuclear energy, natural gas, and oil products. For 2045–2050, the slight increase in TPES is a result of RES' increased share. TPES by fuel type is presented in Figure 3.3.

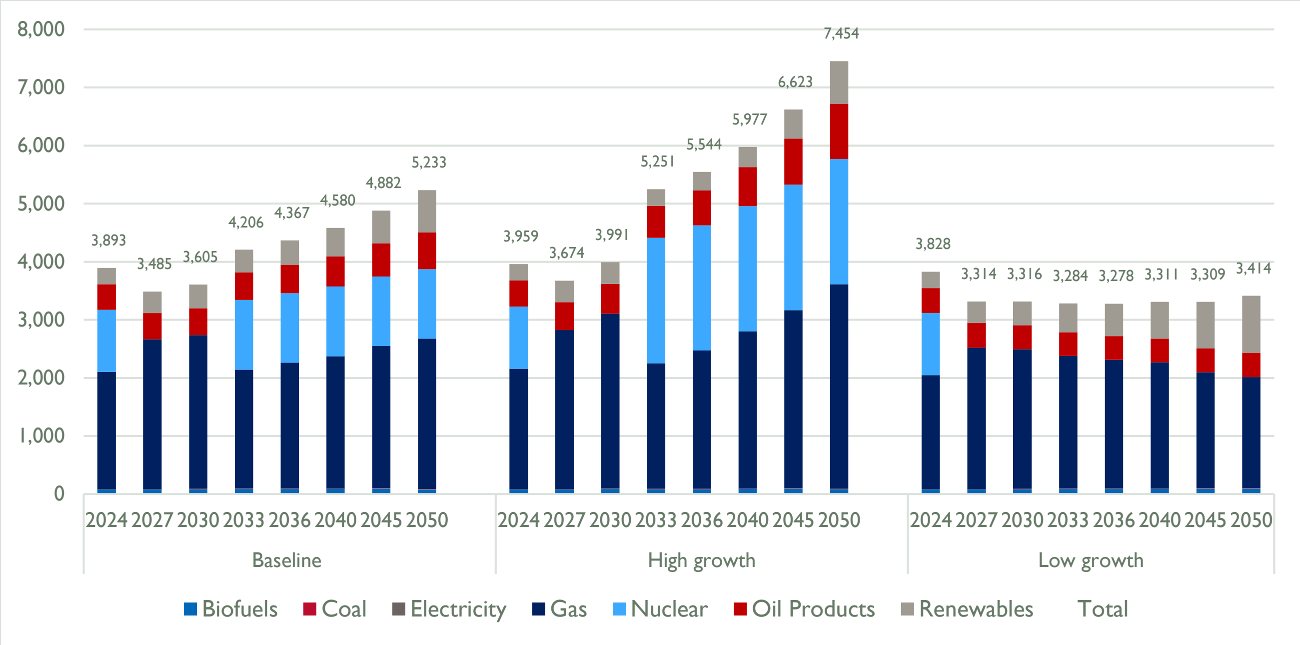
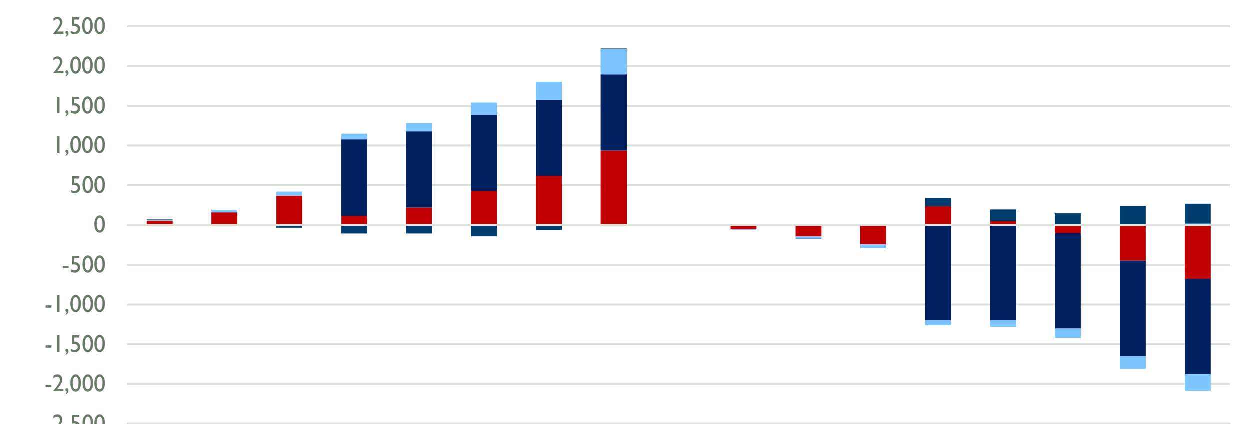


Figure 3.3: TPES by fuel type for GDP growth scenarios, ktoe

Figure 3.4 illustrates the changes in composition of TPES in the two GDP growth scenarios compared to the Baseline Scenario.



	2024	2027	2030	2033	2036	2040	2045	2050		2024	2027	2030	2033	2036	2040	2045	2050
	High growth									Low growth							
Renewables	0.4	0.3	-35	-101	-98	-143	-63	6		-1	-0.3	-1	106	142	149	235	250
Oil Products	11	30	51	76	105	152	226	321		-11	-27	-45	-64	-85	-116	-159	-208
Nuclear	0	0	0	959	959	959	959	959		0	0	0	-1,199	-1,199	-1,199	-1,199	-1,199
Gas	54	158	366	117	218	428	619	931		-52	-143	-242	235	52	-103	-450	-679
Electricity	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Biofuels	0.4	1	3	-6	-7	0	0	4		-0.4	-1	-2	0	0	0	0	17

Figure 3.4: Comparison of TPES by fuel type for GDP growth scenarios and Baseline Scenario, ktoe

FEC projections for High and Low Growth scenarios are presented in Figure 3.5.

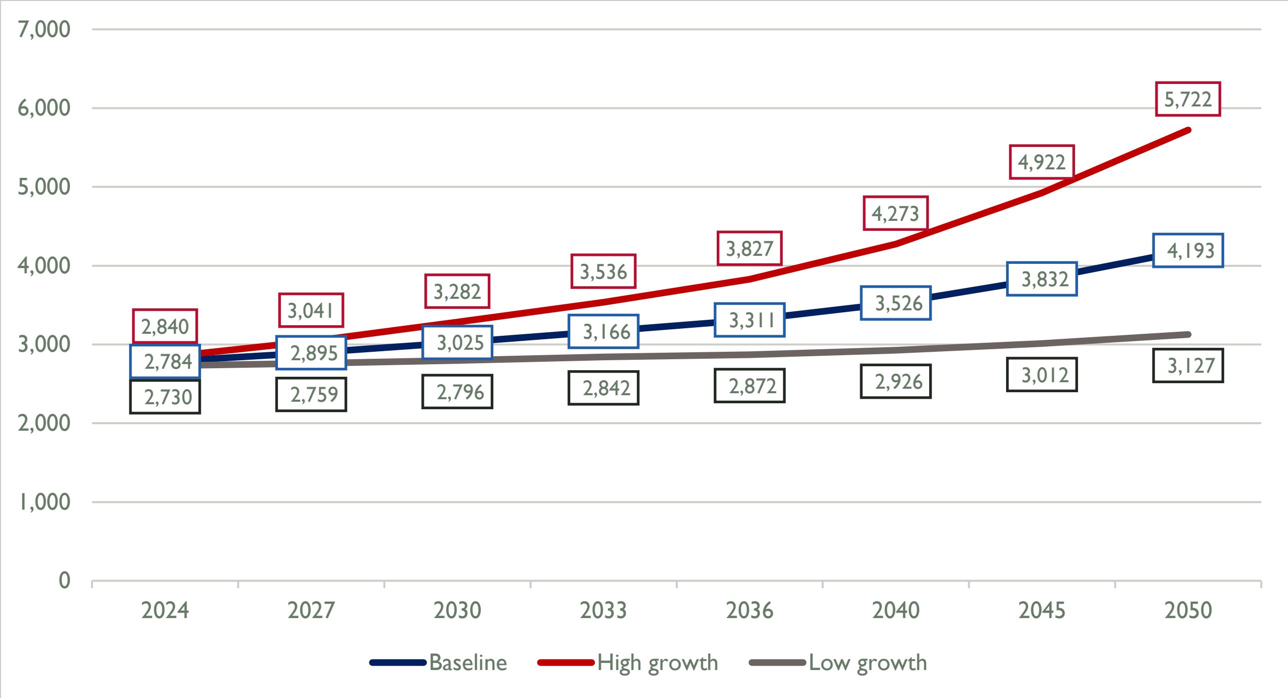


Figure 3.5: FEC for GDP growth scenarios, ktoe

FEC shows an increase in both GDP growth scenarios during the planning period. In the High Growth scenario, it increases faster than in the Low Growth scenario. Electricity grows the fastest in the High Growth scenario (112 percent increase for 2024 to 2050), followed by oil products (106 percent) and natural gas (95 percent). The large consumers at the end of the planning period are in the commercial (471 ktoe), transport (861 ktoe), and residential (1,112 ktoe) sectors.

In the Low Growth scenario, FEC shows a slower pace of increase, with the highest growth in electricity (32 percent) and natural gas (10 percent). Oil products have 4 percent negative growth for the period of 2024–2050.

A comparison of FEC with the Baseline Scenario is presented in Figure 3.6.

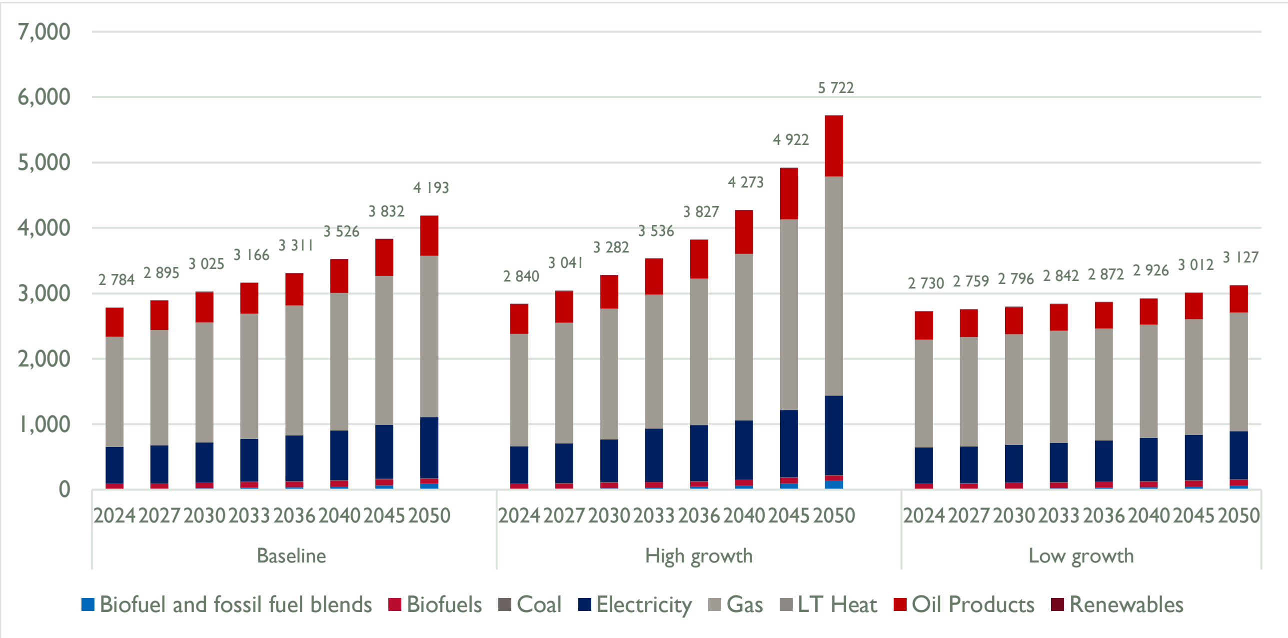
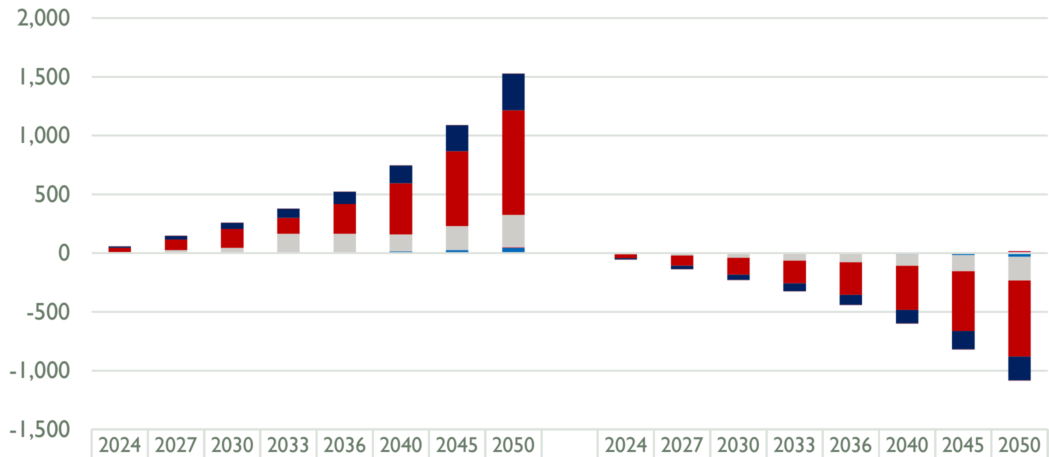


Figure 3.6: FEC by fuel type for GDP growth scenarios, ktoe

Figure 3.7 illustrates the changes in FEC's composition in the GDP growth scenarios compared to the Baseline Scenario.



	High growth								Low growth							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	0.1	0.3	1	1	1	1	2	2	-0.1	-0.3	-0.5	-0.7	-1	-1	-2	-2
Oil Products	11	30	50	75	104	149	221	312	-11	-27	-45	-64	-84	-114	-155	-201
LT Heat	0.001	0.006	0.03	0.02	0.02	0.03	0.05	0.07	-0.003	-0.01	-0.01	-0.01	-0.02	-0.03	-0.04	-0.05
Gas	35	91	161	138	252	437	638	889	-34	-88	-145	-195	-277	-376	-510	-646
Electricity	9	23	39	159	157	145	203	277	-9	-19	-36	-60	-72	-98	-135	-204
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biofuels	0.4	1	3	-6	-7	0	0	4	-0.4	-1	-2	0	0	0	0	17
Biofuel and fossil fuel blends	0.3	1	2	5	8	14	26	45	-0.3	-1	-2	-4	-6	-11	-19	-30

Figure 3.7: Comparison of FEC by fuel type for GDP growth scenarios and Baseline Scenario, ktoe

ELECTRICITY GENERATION TECHNOLOGIES. The least-cost configuration of the power sector for the GDP growth scenarios is presented in Table 3.3. Significant changes in generation capacity configuration occur for nuclear, RES, and storage technologies.

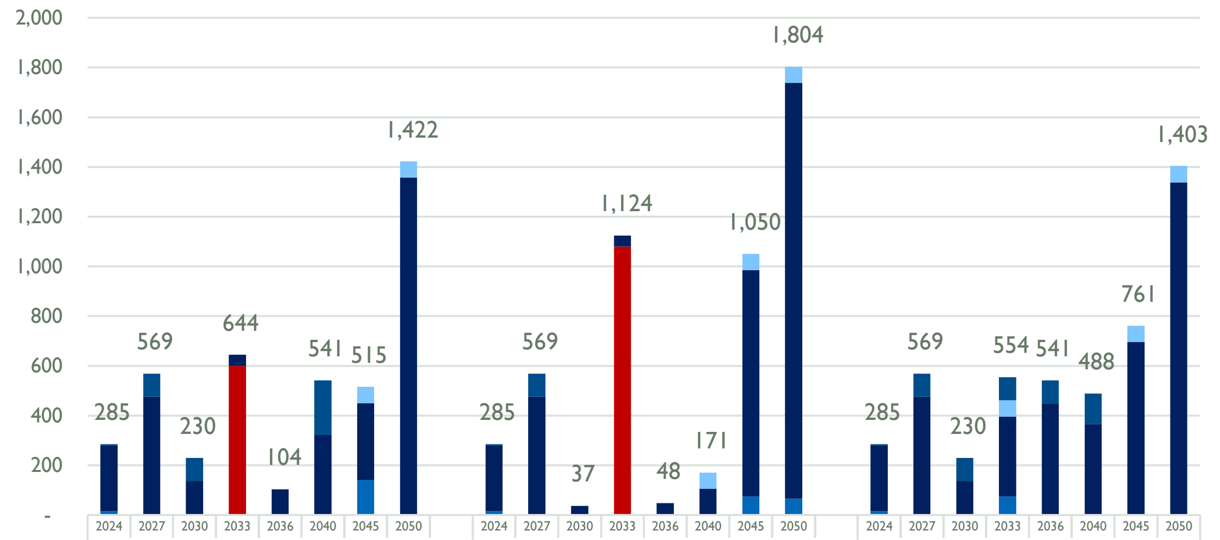
In the High Growth scenario, increased energy demand is covered by the construction of an NPP that is larger than in the Baseline Scenario (1,080 MW) in 2033. As a result, RES capacity is lower for the 2033–2045 period than in the Baseline Scenario. In 2050, RES capacity increases when the Yerevan CCGT-2 comes to the end of its life. Storage capacity also increases during the planning horizon. Implementation of the Loriberd HPP in this scenario is foreseen in 2050, compared to 2045 in the Baseline Scenario.

In the Low Growth scenario, there is no NPP in the capacity mix after the end of ANPP's lifetime. The absence of NPP is covered by an increased share of RES and relevant storage capacities. This scenario foresees earlier implementation of the Shnokh HPP (compared with the Baseline Scenario) in 2033 and does not foresee the implementation of the Loriberd HPP during the planning period.

TABLE 3.3: CAPACITY BY PLANT/PLANT TYPE FOR GDP GROWTH SCENARIOS, MW

SCENARIO	BASELINE								HIGH GROWTH								LOW GROWTH							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	66	-	-	-	-	-	-	-	-
Shnokh HPP	-	-	-	-	-	-	75	75	-	-	-	-	-	-	75	75	-	-	-	75	75	75	75	75
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-
NPP (new)	-	-	-	600	600	600	600	600	-	-	-	1,080	1,080	1,080	1,080	1,080	-	-	-	-	-	-	-	-
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,026	1,130	1,452	1,727	2,630	369	845	882	926	974	1,080	1,957	3,176	369	845	982	1,303	1,751	2,116	2,778	3,657
Hydro pumped storage plant	-	-	-	-	-	-	65	130	-	-	-	-	-	65	130	195	-	-	-	65	65	65	130	195
Lithium-ion storage	-	-	-	0.02	0.02	0.02	0.02	0.06	-	-	0.01	0.02	0.03	0.03	0.03	0.03	-	-	-	-	0.0002	0.1	0.1	0.2
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	409	409	371	4	97	97	97	97	97	97	59	4	97	190	283	376	500	500	462
Total	**3,233**	**3,362**	**3,592**	**3,769**	**3,873**	**4,414**	**4,616**	**5,289**	**3,233**	**3,362**	**3,399**	**4,056**	**4,105**	**4,275**	**5,013**	**6,068**	**3,233**	**3,362**	**3,592**	**3,679**	**4,221**	**4,709**	**5,157**	**5,806**

Figures 3.8 and 3.9 below show the results of new capacity implementation schedules for the GDP growth scenarios over the planning horizon.

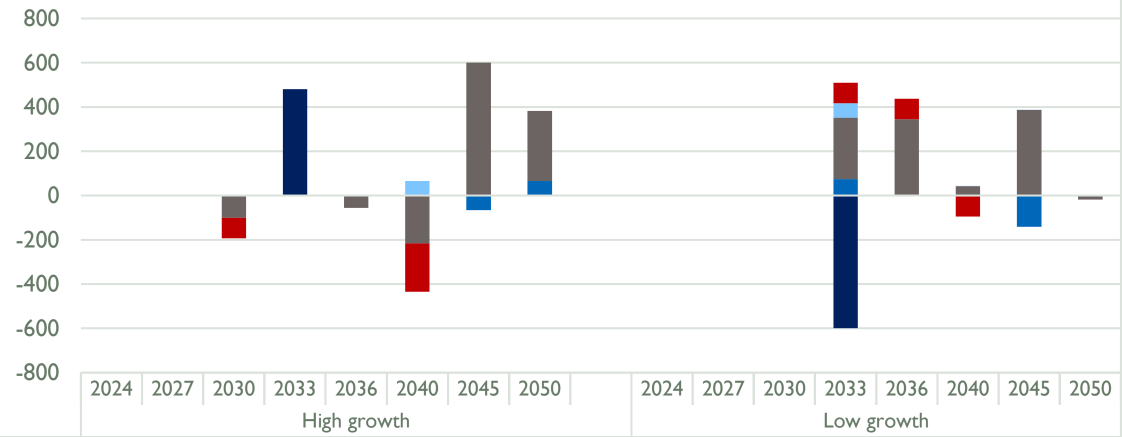


	Baseline 2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	-	219	-	-
Lithium-ion storage	-	-	-	0.02	-	0.002	-	0.04
Hydro pumped storage plant	-	-	-	-	-	-	65	65
Solar	266	476	137	44	104	322	309	1,357
Nuclear	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-
Total	285	569	230	644	104	541	515	1,422

	High growth 2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	-	-	-	-	-	-
Lithium-ion storage	-	-	0.01	0.01	0.01	-	-	-
Hydro pumped storage plant	-	-	-	-	-	65	65	65
Solar	266	476	37	44	48	106	910	1,673
Nuclear	-	-	-	1,080	-	-	-	-
Hydro	15	-	-	-	-	-	75	66
Total	285	569	37	1,124	48	171	1,050	1,804

	Low growth 2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	93	93	124	-	-
Lithium-ion storage	-	-	-	-	0.0002	0.1	0.1	0.1
Hydro pumped storage plant	-	-	-	65	-	-	65	65
Solar	266	476	137	321	448	364	696	1,338
Nuclear	-	-	-	-	-	-	-	-
Hydro	15	-	-	75	-	-	-	-
Total	285	569	230	554	541	488	761	1,403

Figure 3.8: New capacity implementation schedule in GDP growth scenarios, MW



	High growth 2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	-93	0	0	-219	0	0
Lithium-ion storage	0	0	0.01	-0.01	0.01	-0.002	0	-0.04
Hydro pumped storage plant	0	0	0	0	0	65	0	0
Solar	0	0	-100	0	-56	-216	601	316
Nuclear	0	0	0	480	0	0	0	0
Hydro	0	0	0	0	0	0	-66	66

	Low growth 2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	93	93	-95	0	0
Lithium-ion storage	0	0	0	-0.02	0.0002	0.1	0.05	0.06
Hydro pumped storage plant	0	0	0	65	0	0	0	0
Solar	0	0	0	277	344	42	387	-19
Nuclear	0	0	0	-600	0	0	0	0
Hydro	0	0	0	75	0	0	-141	0

Figure 3.9: Comparison of New Power Plant construction for GDP growth scenarios and Baseline Scenario, MW

Generation by power plant for the two scenarios is presented in Table 3.4.

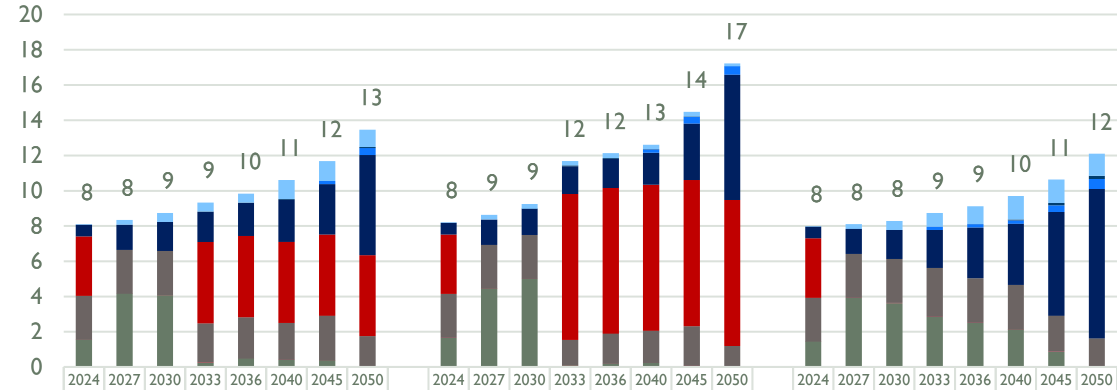
TABLE 3.4: GENERATION BY PLANT/PLANT TYPE FOR GDP GROWTH SCENARIOS, GWH

SCENARIO	BASELINE							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	71	1,672	1,672	22	59	60	-	-
Yerevan CCGT-2	1,471	1,891	1,891	248	417	343	364	-
Hrazdan Unit 5	-	591	510	-	-	-	-	-
Local cogeneration plant	7	7	7	7	7	8	8	26
Vorotan HPP Cascade	984	984	984	979	984	984	984	598
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346
Loriberd HPP	-	-	-	-	-	-	203	203
Shnokh HPP	-	-	-	-	-	-	291	291
Small HPP (existing)	932	935	935	654	790	528	492	122
Small HPP (new)	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	4,601	4,601	4,601	4,601	4,601
Solar (existing)	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	1,645	1,811	2,328	2,770	5,689
Hydro pumped storage plant	-	-	-	-	-	-	188	376
Lithium-ion storage	-	-	-	15	8	20	20	68
Wind (existing)	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	1,091	1,091	990
Total	**8,095**	**8,347**	**8,734**	**9,332**	**9,839**	**10,617**	**11,667**	**13,472**

SCENARIO	HIGH GROWTH							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	116	1,672	1,672	19	32	41	-	-
Yerevan CCGT-2	1,533	1,891	1,891	79	156	182	58	-
Hrazdan Unit 5	-	882	1,428	-	-	-	-	-
Local cogeneration plant	7	7	8	8	8	9	10	29
Vorotan HPP Cascade	984	984	984	508	721	779	829	290
Sevan-Hrazdan HPP Cascade	414	414	414	338	338	408	414	219
Loriberd HPP	-	-	-	-	-	-	-	203
Shnokh HPP	-	-	-	-	-	-	291	291
Small HPP (existing)	935	935	935	429	476	490	557	-
Small HPP (new)	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	8,281	8,281	8,281	8,281	8,281
Solar (existing)	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,413	1,484	1,562	1,732	3,138	7,119
Hydro pumped storage plant	-	-	-	-	-	188	376	458
Lithium-ion storage	-	-	5	42	43	8	21	15
Wind (existing)	3	3	3	3	3	3	3	3
Wind (new)	11	259	259	259	259	259	259	158
Total	**8,204**	**8,638**	**9,250**	**11,689**	**12,118**	**12,618**	**14,474**	**17,225**

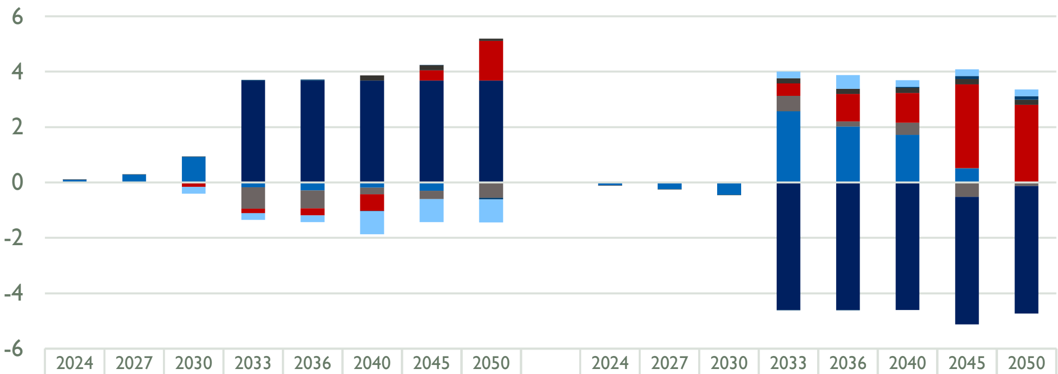
SCENARIO	LOW GROWTH							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	61	1,665	1,485	1,042	821	675	-	-
Yerevan CCGT-2	1,382	1,891	1,891	1,804	1,680	1,453	870	-
Hrazdan Unit 5	-	358	248	-	-	-	-	-
Local cogeneration plant	7	7	7	17	7	7	17	17
Vorotan HPP Cascade	984	984	984	984	984	984	745	651
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	307	240
Loriberd HPP	-	-	-	-	-	-	-	-
Shnokh HPP	-	-	-	291	291	291	291	291
Small HPP (existing)	924	935	935	902	673	673	516	262
Small HPP (new)	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	-	-	-	-	-
Solar (existing)	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	2,089	2,808	3,392	5,802	8,491
Hydro pumped storage plant	-	-	-	188	188	188	376	564
Lithium-ion storage	-	-	-	-	0.1	52	130	189
Wind (existing)	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	755	1,003	1,334	1,334	1,233
Total	**7,987**	**8,107**	**8,284**	**8,725**	**9,108**	**9,703**	**10,628**	**12,100**

Figures 3.10 and 3.11 show projected generation capacity by power plant and generation technology for each GDP growth scenario and the Baseline Scenario over the planning horizon.



	Baseline								High growth								Low growth							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0	0.01	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.01	0.3	0.5	0.8	1.0	1.3	1.3	1.2
Lithium-ion storage	-	-	-	0.02	0.01	0.02	0.02	0.07	-	-	0.005	0.04	0.04	0.01	0.02	0.01	-	-	-	-	0.000	0.05	0.1	0.2
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4	-	-	-	-	-	0.2	0.4	0.5	-	-	-	0.2	0.2	0.2	0.4	0.6
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7	0.7	1.4	1.5	1.6	1.6	1.8	3.2	7.1	0.7	1.4	1.7	2.2	2.9	3.5	5.9	8.5
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6	3.4	-	-	8.3	8.3	8.3	8.3	8.3	3.4	-	-	-	-	-	-	-
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7	2.5	2.5	2.5	1.4	1.7	1.8	2.2	1.2	2.5	2.5	2.5	2.7	2.5	2.5	2.0	1.6
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-	1.6	4.4	5.0	0.1	0.2	0.2	0.06	-	1.4	3.9	3.6	2.8	2.5	2.1	0.9	-
Total	8	8	9	9	10	11	12	13	8	9	9	12	12	13	14	17	8	8	8	9	9	10	11	12

Figure 3.10: Electricity generation by power plant/plant type for GDP growth scenarios, terawatt-hours (TWh)



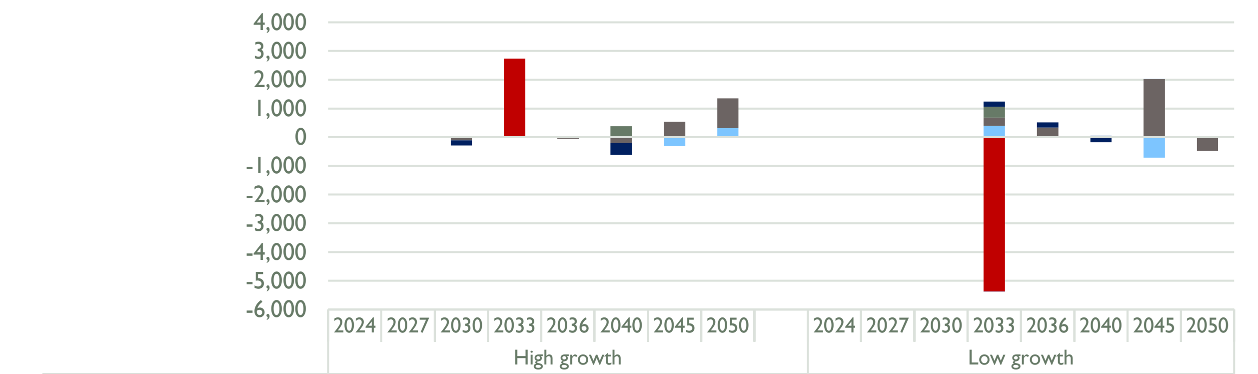
	High growth								Low growth							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	-0.2	-0.2	-0.2	-1	-1	-1	0	0	0	0.2	0.5	0.2	0.2	0.2
Lithium-ion storage	0	0	0.005	0.03	0.04	-0.01	0.001	-0.05	0	0	0	-0.02	-0.01	0.03	0.1	0.1
Hydro pumped storage plant	0	0	0	0	0	0.2	0.2	0.1	0	0	0	0.2	0.2	0.2	0.2	0.2
Solar	0	0	-0.2	-0.2	-0.2	-1	0.4	1	0	0	0	0.4	1	1	3	3
Nuclear	0	0	0	4	4	4	4	4	0	0	0	-5	-5	-5	-5	-5
Hydro	0.003	0	0	-1	-1	-0.2	-0.3	-1	-0.01	0	0	1	0.2	0.4	-1	0
Gas-fired CHPs	0	0	0.001	0.001	0.001	0.001	0.002	0.003	0	0	-0.001	0.01	-0.001	-0.001	0.01	-0.01
Gas-fired	0.1	0.3	1	-0.2	-0.3	-0.2	-0.3	0	-0.1	-0.2	-0.4	3	2	2	1	0

Figure 3.11: Comparison of electricity generation by power plant/type for GDP growth scenarios and Baseline Scenario, TWh

Investments in new capacity in the Powe system. Changes in the generation technology mix significantly change the total power sector investment in new generation. Table 3.5 and Figure 3.12 compare the investments in new power system capacity under the GDP growth and Baseline Scenarios. The main driver of differences is the existence of a new NPP 1,080 MW in the High Growth scenario and the absence of nuclear generation in the Low Growth scenario.

TABLE 3.5: TOTAL POWER SECTOR INVESTMENTS IN NEW CAPACITY FOR GDP GROWTH SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	12,854	-
High Growth	16,587	+29
Low Growth	9,938	-23



	High growth								Low growth							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	-178	0	0	-412	0	0	0	0	0	177	176	-178	0	0
Lithium-ion storage	0	0	0.01	-0.004	0.01	-0.001	0	-0.02	0	0	0	-0.01	0.0001	0.04	0.02	0.02
Hydro pumped storage plant	0	0	0	0	0	377	0	0	0	0	0	377	0	0	0	0
Solar	0	0	-107	0	-54	-203	540	1,034	0	0	0	293	337	48	2,022	-478
Nuclear	0	0	0	2,736	0	0	0	0	0	0	0	-5,375	0	0	0	0
Hydro	0	0	0	0	0	0	-314	314	0	0	0	395	0	0	-709	0

Figure 3.12: Comparison of investments in new power system capacity in GDP growth scenarios and Baseline Scenario, millions of USD

GHG EMISSIONS changes by GDP growth scenario are presented in Figure 3.13.

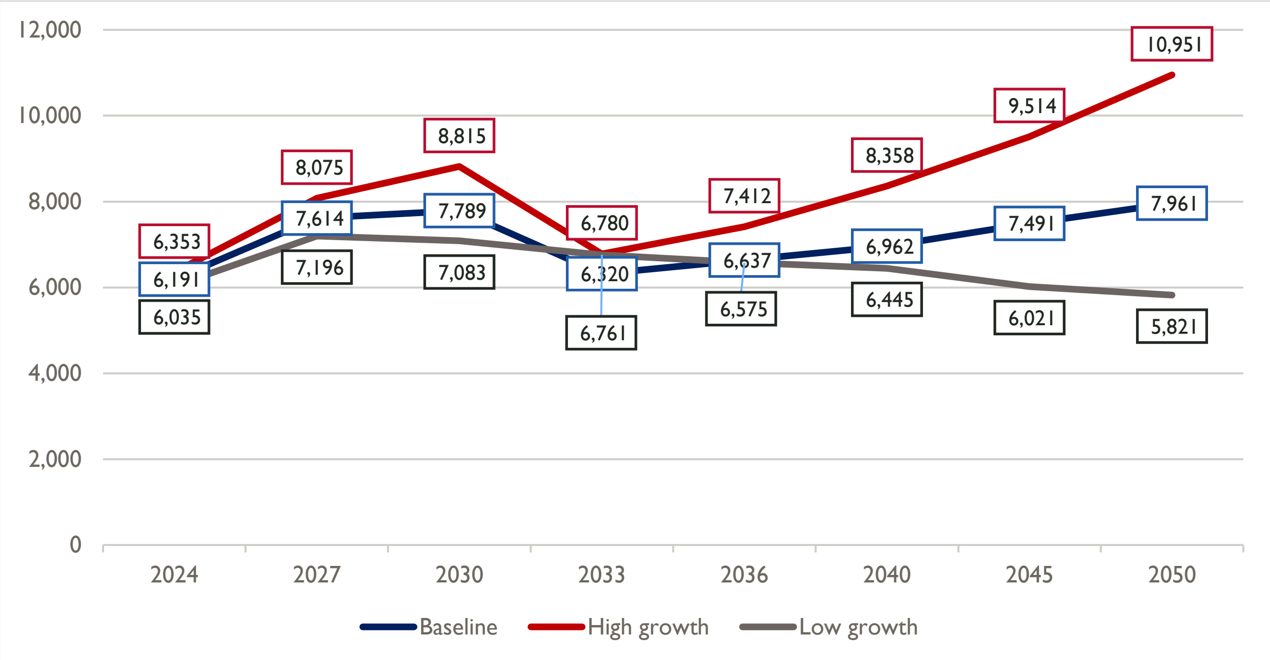


Figure 3.13: GHG emissions (CO_{2eq}) for GDP growth scenarios, kt

The main polluting energy carrier for both GDP growth scenarios remains natural gas, with around 80 percent share in total GHG emissions in almost all milestone years.

In the High Growth scenario, the transport and residential sectors contribute to total GHG emissions the most, with 38.4 and 24.2 percent share at the end of the planning period (2050). The next highest pollution comes from the industrial and commercial sectors with 15.4 and 13.6 percent, then fuel transportation (7.8 percent), and finally agriculture and the power sector with less than 0.7 percent combined.

In the Low Growth scenario, the transport and residential sectors have the highest share of cumulative pollution (32.7 and 30.5 percent respectively), followed by the commercial (15.1 percent), industrial (12.8 percent), and fuel supply system (8.0 percent) sectors. The lowest share comes from the agriculture and power sectors, with around 1.0 percent cumulatively for both.

ENERGY INDEPENDENCE levels for the GDP growth scenarios are presented in Figure 3.14.

In the High Growth scenario, energy independence will reach its highest level in 2033 (48 percent), mainly due to the implementation of a large NPP (1,080 MW), then fall to 40 percent at the end of the planning horizon as a result of increase of fossil fuel use to cover increased demand.

In the Low Growth scenario, where no NPP is available in the capacity mix, energy independence will reach its maximum in 2050 (31 percent) after a steady increase from 2027 (13 percent).

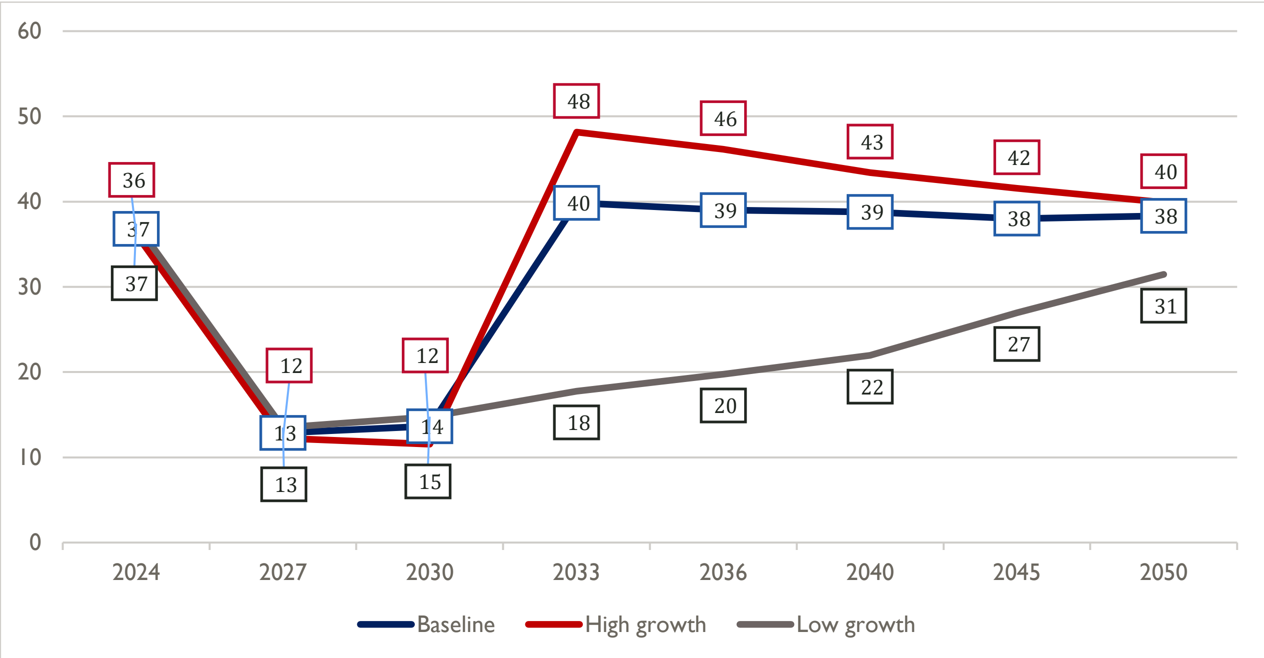


Figure 3.14: Energy independence levels for GDP growth scenarios, %

SCENARIOS WITH INCREASED ELECTRICITY DEMAND AND ENERGY EFFICIENCY IN INDUSTRY

The Increased Demand in Industry scenario considers a 200-MW increase in electricity demand in this sector in 2027. The EE in Industry scenario addresses the situation where the efficiency of demand technologies in this sector mostly remains at the level of the base year, with slow improvement during the planning period. Neither scenario considers new TPP implementation.

TOTAL SYSTEM COST. For the Increased Demand in Industry scenario is 2 percent higher than that for the Baseline Scenario, at $69.0 billion; for EE in Industry, $68.4 billion.

Covering the additional 200 MW of demand in the Increased Demand in Industry scenario will require more energy sources, which will result in a total system cost that is 2 percent higher than that for the Baseline Scenario, at $69 billion. In the EE in Industry scenario, costs are 1 percent higher than in the Baseline Scenario, as lower efficiency in the industrial sector leads to more energy demand and more energy carriers used. Table 3.6 compares the three.

TABLE 3.6: TOTAL SYSTEM COST FOR INCREASED DEMAND AND EE IN INDUSTRY SCENARIOS		
SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	67,763	-
Increased Demand in Industry	69,009	+2
EE in Industry	68,391	+1

TPES projection for the two scenarios is presented in Figure 3.15. In the Increased Demand in Industry scenario, TPES shows a steady increase from 2027, which is mostly a result of greater use of nuclear energy than in the Baseline Scenario. In the EE in Industry scenario, TPES follows the Baseline Scenario trends and slightly increases its growth rate at the end of the planning period to cover increased demand due to implementation of technologies with lower efficiency (compared with the Baseline Scenario).

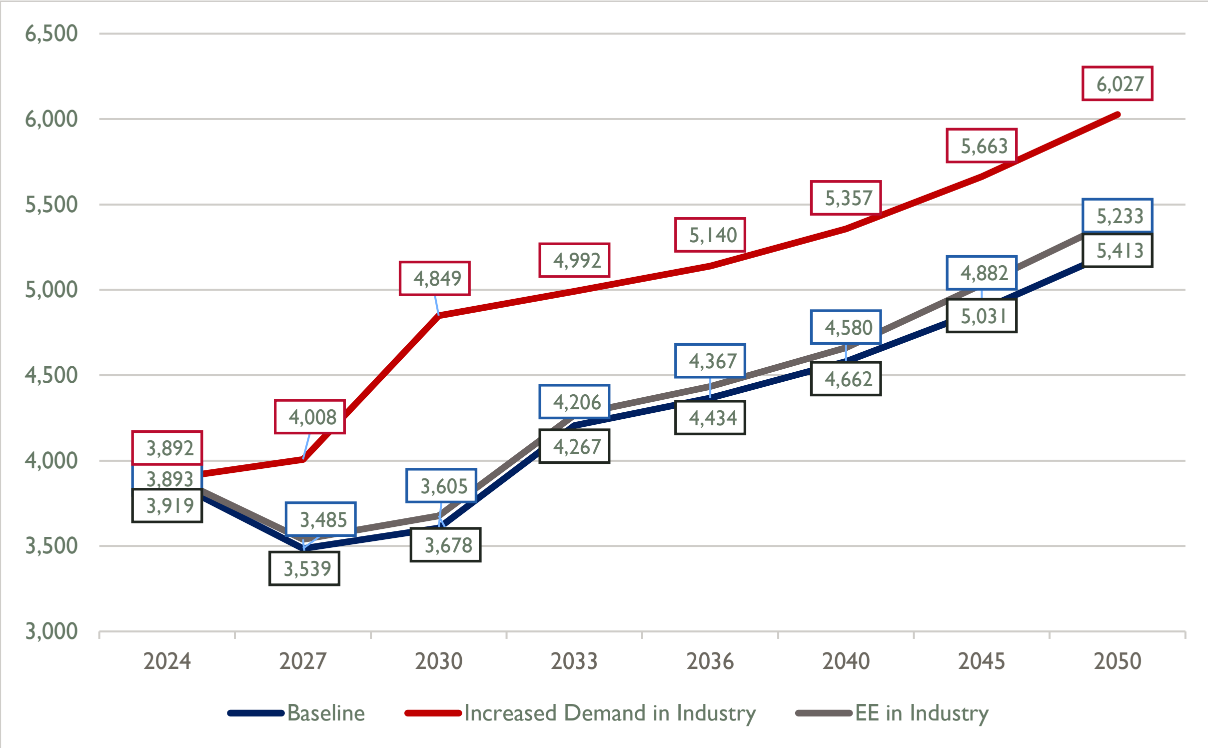


Figure 3.15: TPES for Increased Demand and EE in Industry scenarios, ktoe

TPES by fuel type is presented in Figure 3.16 and Figure 3.17.

FEC projection for the Increased Demand and EE in Industry scenarios shows practically no difference from the Baseline Scenario.

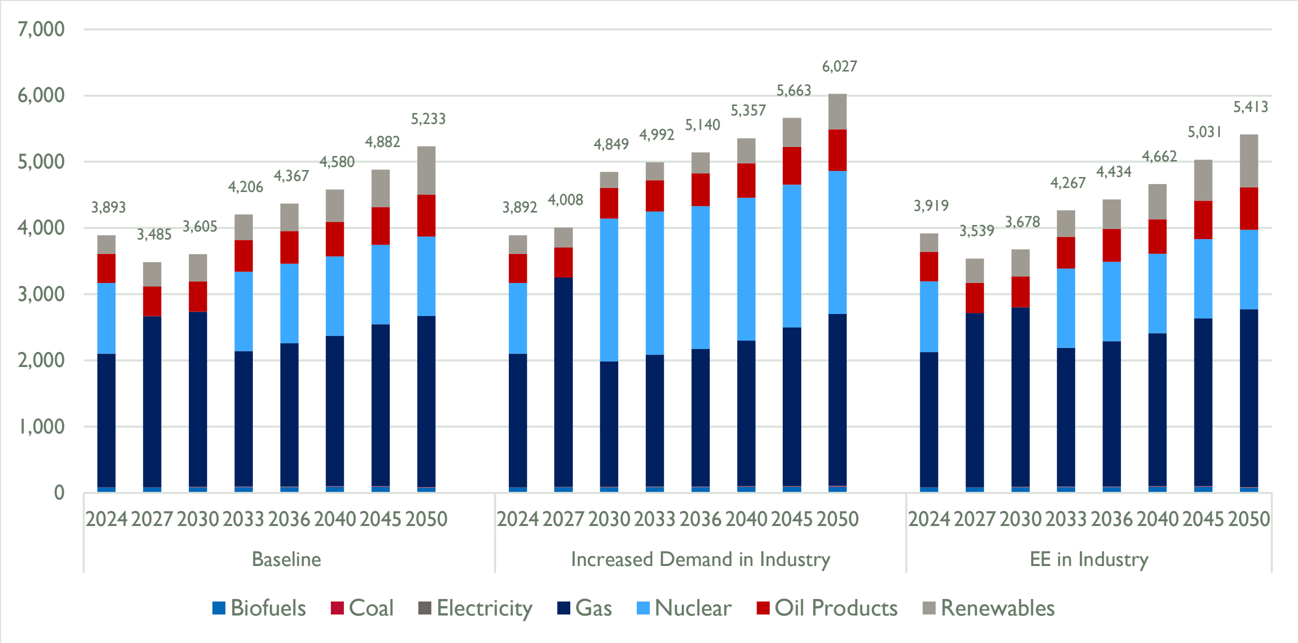
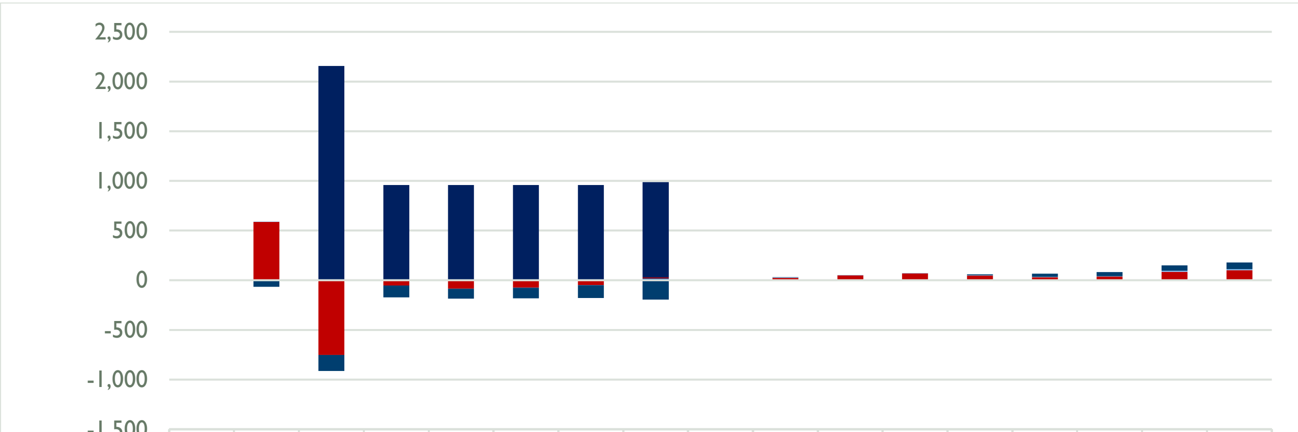


Figure 3.16: TPES by fuel type for Increased Demand and EE in Industry scenarios, ktoe



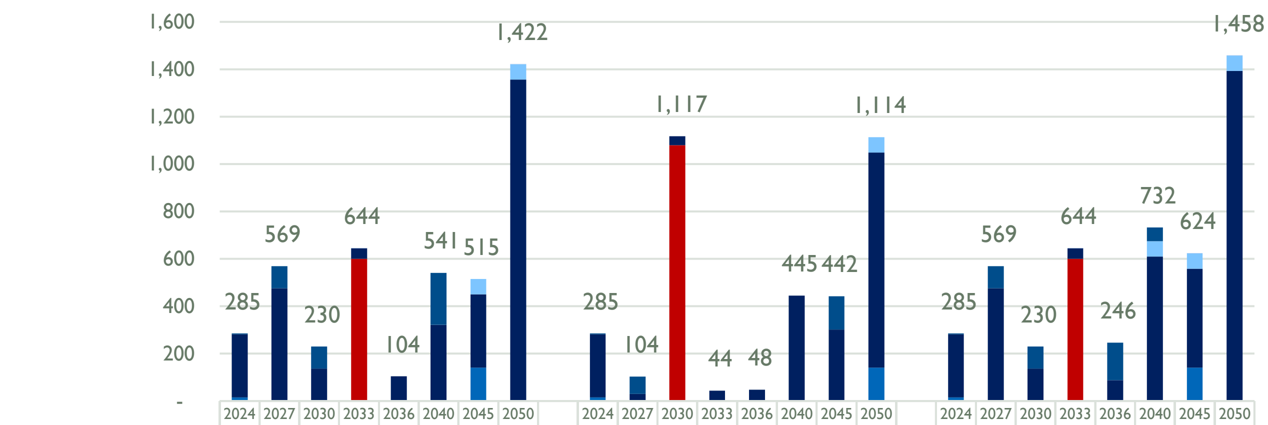
	Increased Demand in Industry								EE in Industry							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	-0.002	-66.3	-163	-120	-99	-107	-128	-194	0.3	0	0	12	33	42	55	69
Oil Products	0	1	-0.2	0	0	-0.4	-0.4	0	2	2	3	3	3	3	9	10
Nuclear	0	0	2,158	959	959	959	959	959	0	0	0	0	0	0	0	0
Gas	-0.2	582	-749	-53	-87	-75	-50	12	24	51	69	46	31	37	85	101
Electricity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biofuels	0	6	-2	0	0	0	0	17	0	0	0	0	0	0	0	0

Figure 3.17: Comparison of TPES by fuel type for Increased Demand and EE in Industry scenarios and Baseline Scenario, ktoe

Figures 3.18 and 3.19 below provide the results for new capacity implementation schedules for the Increased Demand and EE in Industry scenarios over the planning horizon.

TABLE 3.7: CAPACITY BY PLANT/PLANT TYPE FOR INCREASED DEMAND AND EE IN INDUSTRY SCENARIOS, MW

SCENARIO	BASELINE								INCREASED DEMAND IN INDUSTRY								EE IN INDUSTRY							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	66	-	-	-	-	-	-	66	66
Shnokh HPP	-	-	-	-	-	-	75	75	-	-	-	-	-	-	-	75	-	-	-	-	-	-	75	75
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-
NPP (new)	-	-	-	600	600	600	600	600	-	-	1,080	1,080	1,080	1,080	1,080	1,080	-	-	-	600	600	600	600	600
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,026	1,130	1,452	1,727	2,630	369	400	437	481	529	974	1,243	1,861	369	845	982	1,026	1,114	1,724	2,108	3,047
Hydro pumped storage plant	-	-	-	-	-	-	65	130	-	-	-	-	-	-	-	65	-	-	-	-	-	65	130	195
Lithium-ion storage	-	-	-	0.02	0.02	0.02	0.02	0.06	-	-	-	-	-	-	0.02	0.02	-	-	-	0.01	0.01	0.01	0.04	0.07
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	409	409	371	4	77	77	77	77	77	217	187	4	97	190	190	348	405	405	367
Total	**3,233**	**3,362**	**3,592**	**3,769**	**3,873**	**4,414**	**4,616**	**5,289**	**3,233**	**2,897**	**4,014**	**3,591**	**3,640**	**4,084**	**4,213**	**4,751**	**3,233**	**3,362**	**3,592**	**3,769**	**4,015**	**4,747**	**5,058**	**5,767**

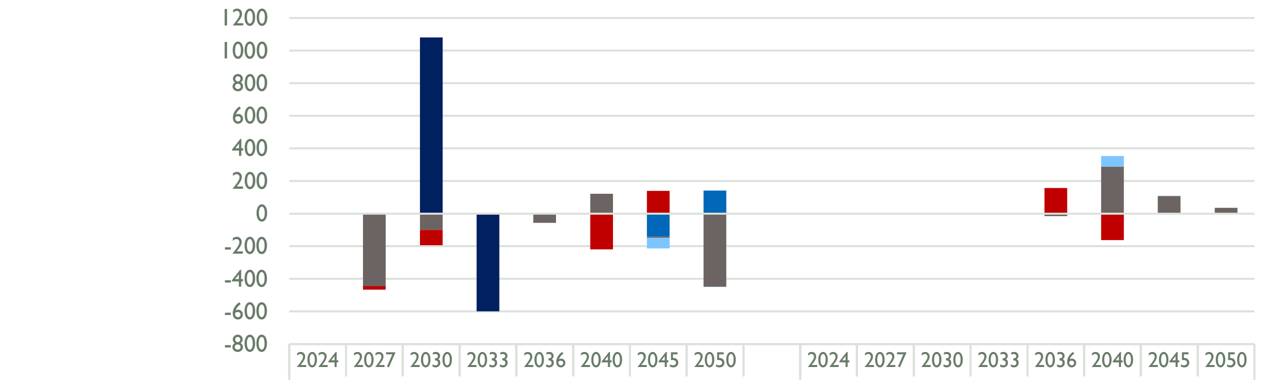


	Baseline 2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	-	219	-	-
Lithium-ion storage	-	-	-	0.02	-	0.00	-	0.04
Hydro pumped storage plant	-	-	-	-	-	-	65	65
Solar	266	476	137	44	104	322	309	1,35
Nuclear	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-
Total	285	569	230	644	104	541	515	1,42

	Increased Demand in Industry 2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	73	-	-	-	-	140	-
Lithium-ion storage	-	-	-	-	-	-	0.02	-
Hydro pumped storage plant	-	-	-	-	-	-	-	65
Solar	266	31	37	44	48	445	302	908
Nuclear	-	-	1,08	-	-	-	-	-
Hydro	15	-	-	-	-	-	-	141
Total	285	104	1,11	44	48	445	442	1,11

	EE in Industry 2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	158	57	-	-
Lithium-ion storage	-	-	-	0.01	0.00	-	0.03	0.02
Hydro pumped storage plant	-	-	-	-	-	65	65	65
Solar	266	476	137	44	88	610	417	1,39
Nuclear	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-
Total	285	569	230	644	246	732	624	1,45

Figure 3.18: New capacity implementation schedule in Increased Demand and EE in Industry scenarios, MW



	Increased Demand in Industry 2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	-20	-93	0	0	-219	140	0
Lithium-ion storage	0	0	0	-0.02	0	-0.002	0.02	-0.04
Hydro pumped storage plant	0	0	0	0	0	0	-65	0
Solar	0	-445	-100	0	-56	123	-7	-449
Nuclear	0	0	1,080	-600	0	0	0	0
Hydro	0	0	0	0	0	0	-141	141

	EE in Industry 2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0	158	-162	0	0
Lithium-ion storage	0	0	0	-0.01	0.002	-0.002	0.03	-0.02
Hydro pumped storage plant	0	0	0	0	0	65	0	0
Solar	0	0	0	0	-16	288	108	36
Nuclear	0	0	0	0	0	0	0	0
Hydro	0	0	0	0	0	0	0	0

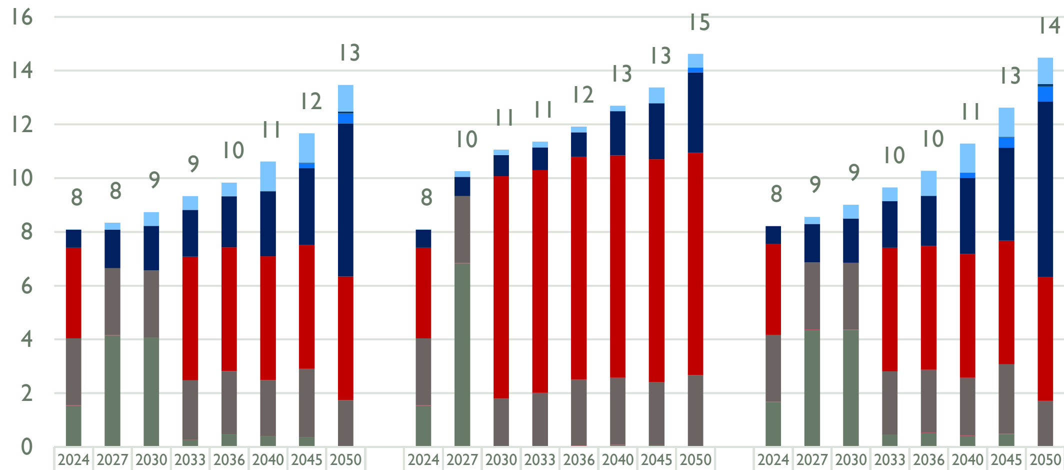
Figure 3.19: Comparison of new power plant construction for Increased Demand and EE in Industry scenarios and Baseline Scenario, MW

Generation by power plant for the Increased Demand and EE in Industry scenarios is presented in Table 3.8.

Figures 3.20 and 3.21 show projected generation capacity by power plant and generation technology for the Increased Demand and EE in Industry scenarios and their difference from the Baseline Scenario over the planning horizon.

TABLE 3.8: GENERATION BY PLANT/PLANT TYPE FOR INCREASED DEMAND AND EE IN INDUSTRY SCENARIOS, GWH

SCENARIO	BASELINE								INCREASED DEMAND IN INDUSTRY								EE IN INDUSTRY							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	71	1,672	1,672	22	59	60	-	-	71	1,672	-	-	-	6	-	-	120	1,672	1672	43	52	62	-	-
Yerevan CCGT-2	1,471	1,891	1,891	248	417	343	364	-	1,471	1,891	17	23	38	65	70	-	1,552	1,891	1,891	417	479	357	482	-
Hrazdan Unit 5	-	591	510	-	-	-	-	-	-	3,273	-	-	-	-	-	-	-	805	790	-	-	-	-	-
Local cogeneration plant	7	7	7	7	7	8	8	26	7	8	7	7	7	8	8	8	7	7	7	7	7	8	8	26
Vorotan HPP Cascade	984	984	984	979	984	984	984	598	984	984	984	984	984	984	945	829	984	984	984	984	984	984	953	590
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346	414	414	414	414	414	414	414	346	414	414	414	414	414	414	414	346
Loriberd HPP	-	-	-	-	-	-	203	203	-	-	-	-	-	-	-	203	-	-	-	-	-	-	203	203
Shnokh HPP	-	-	-	-	-	-	291	291	-	-	-	-	-	-	-	291	-	-	-	-	-	-	291	291
Small HPP (existing)	932	935	935	654	790	528	492	122	932	935	216	428	899	935	828	828	935	935	935	790	775	591	566	104
Small HPP (new)	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-	3374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	4,601	4,601	4,601	4,601	4,601	-	-	8,281	8,281	8,281	8,281	8,281	8,281	-	-	-	4,601	4,601	4,601	4,601	4,601
Solar (existing)	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	1,645	1,811	2,328	2,770	5,689	592	641	700	771	848	1,561	1,992	2,985	592	1,354	1,574	1,645	1,786	2,764	3,380	6,523
Hydro pumped storage plant	-	-	-	-	-	-	188	376	-	-	-	-	-	-	-	188	-	-	-	-	-	188	376	564
Lithium-ion storage	-	-	-	15	8	20	20	68	-	-	-	-	-	-	15	-	-	-	-	7	9	-	31	98
Wind (existing)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	1,091	1,091	990	11	205	205	205	205	205	579	498	11	259	507	507	927	1,079	1,079	979
Total	**8,095**	**8,347**	**8,734**	**9,332**	**9,839**	**10,617**	**11,667**	**13,472**	**8,095**	**10,263**	**11,065**	**11,354**	**11,918**	**12,700**	**13,373**	**14,620**	**8,228**	**8,561**	**9,014**	**9,655**	**10,275**	**11,287**	**12,625**	**14,487**

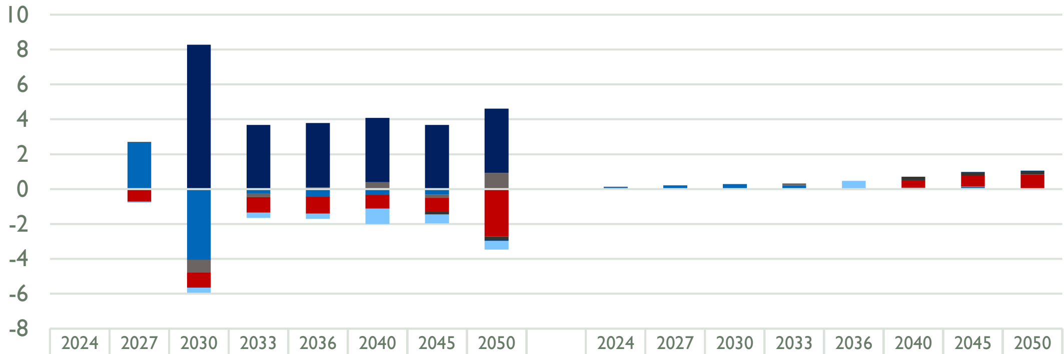


Baseline	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0
Lithium-ion storage	-	-	-	0.02	0.01	0.02	0.02	0.07
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-
Total	8	8	9	9	10	11	12	13

Increased Demand in Industry	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.2	0.2	0.2	0.2	0.2	0.6	0.5
Lithium-ion storage	-	-	-	-	-	-	0.02	-
Hydro pumped storage plant	-	-	-	-	-	-	-	0.2
Solar	0.7	0.7	0.8	0.9	0.9	1.6	2.1	3.0
Nuclear	3.4	-	8.3	8.3	8.3	8.3	8.3	8.3
Hydro	2.5	2.5	1.8	2.0	2.5	2.5	2.3	2.7
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gas-fired	1.5	6.8	0.02	0.02	0.04	0.1	0.1	-
Total	8	10	11	11	12	13	13	15

EE in Industry	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.5	0.5	0.9	1.1	1.1	1.0
Lithium-ion storage	-	-	-	0.01	0.01	-	0.03	0.1
Hydro pumped storage plant	-	-	-	-	-	0.2	0.4	0.6
Solar	0.7	1.4	1.7	1.7	1.9	2.8	3.5	6.5
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6
Hydro	2.5	2.5	2.5	2.3	2.3	2.1	2.6	1.7
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03
Gas-fired	1.7	4.4	4.4	0.5	0.5	0.4	0.5	-
Total	8	9	9	10	10	11	13	14

Figure 3.20: Comparison of electricity generation by power plant/type for Increased Demand and EE in Industry scenarios, TWh



Increased Demand in Industry	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	-0.05	-0.3	-0.3	-0.3	-1	-1	-0.5
Lithium-ion storage	0	0	0	-0.02	-0.01	-0.02	-0.005	-0.1
Hydro pumped storage plant	0	0	0	0	0	0	-0.2	-0.2
Solar	0	-1	-1	-1	-1	-1	-1	-3
Nuclear	0	0	8	4	4	4	4	4
Hydro	0	0	-1	0	0	0.4	-0.2	1
Gas-fired CHPs	0	0	0	0	0	0	0	-0.02
Gas-fired	0	3	-4	-0.2	-0.4	-0.3	-0.3	0

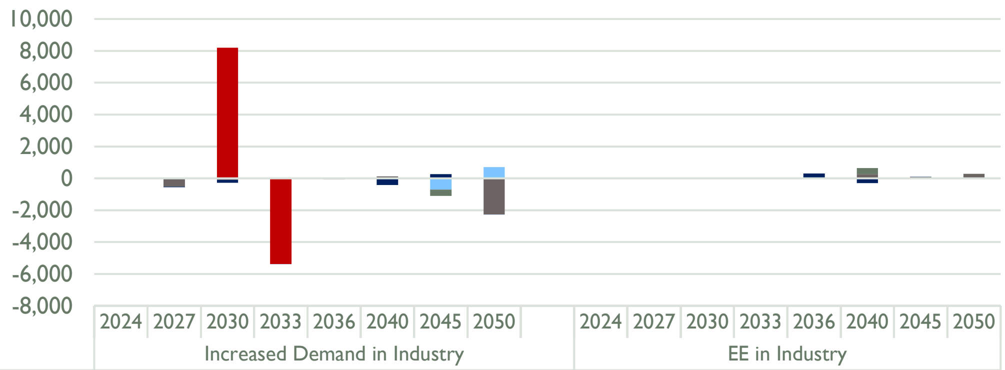
EE in Industry	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0	0.4	-0.01	-0.01	-0.01
Lithium-ion storage	0	0	0	-0.01	0.001	-0.02	0.01	0.03
Hydro pumped storage plant	0	0	0	0	0	0.2	0.2	0.2
Solar	0	0	0	0	-0.03	0.4	1	1
Nuclear	0	0	0	0	0	0	0	0
Hydro	0.003	0	0	0.1	-0.01	0.1	0.04	-0.03
Gas-fired CHPs	0	0	0	0	0	0	0	0
Gas-fired	0.1	0.2	0.3	0.2	0.1	0.02	0.1	0

Figure 3.21: Comparison of electricity generation by power plant/type for Increased Demand and EE in Industry scenarios, TWh

INVESTMENTS IN NEW POWER SYSTEM CAPACITY. A different generation technology mix results in different total power sector investments in new generation. Table 3.9 and Figure 3.22 compare investments in the three scenarios. The main drivers of differences are the existence of a new 1,080 MW NPP in the Increased Demand in Industry scenario and low-efficiency technologies in the EE in Industry scenario.

TABLE 3.9: TOTAL POWER SECTOR INVESTMENTS IN NEW CAPACITY FOR INCREASED DEMAND AND EE IN INDUSTRY SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	12,854	-
Increased Demand in Industry	12,096	-5.9
EE in Industry	13,865	+7.9



	Increased Demand in Industry								EE in Industry							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	-39	-178	0	0	-412	261	0	0	0	0	0	298	-304	0	0
Lithium-ion storage	0	0	0	-0.01	0	-0.001	0.01	-0.02	0	0	0	-0.01	0.001	-0.001	0.01	-0.01
Hydro pumped storage plant	0	0	0	0	0	0	-377	0	0	0	0	0	0	377	0	0
Solar	0	-511	-107	0	-54	115	-14	-2,263	0	0	0	0	-15	271	106	279
Nuclear	0	0	8,197	-5,375	0	0	0	0	0	0	0	0	0	0	0	0
Hydro	0	0	0	0	0	0	-709	709	0	0	0	0	0	0	0	0

Figure 3.22: Comparison of investments in new power system capacity in Increased Demand and EE in Industry scenarios and Baseline Scenario, millions of USD

GHG EMISSIONS differences in the Increased Demand and EE in Industry scenarios are presented in Figure 3.23. The peak in 2027 emissions in the Increased Demand in Industry scenario is a result of greater gas-fired power plant generation. Introducing a new 1,080 MW NPP results in a significant reduction in emissions, from 9,066 kt in 2027 to 5,924 kt in 2030. At the end of the planning horizon, emissions almost reach the Baseline Scenario level (7,992 kt). The EE in Industry scenario follows the same pattern as the Baseline Scenario, with slightly higher emissions.

ENERGY INDEPENDENCE for the two scenarios is presented in Figure 3.24. After the decommissioning of ANPP in 2026, independence in both scenarios drops due to the need to import more natural gas. By adding a new 1,080-MW NPP in 2030 in the Increased Demand in Industry scenario and a new 600-MW NPP in 2033 in the EE in Industry scenario (as in the Baseline Scenario), energy independence rises to 46 percent in the Increased Demand in Industry scenario and to the level of the Baseline Scenario in the EE in Industry scenario.

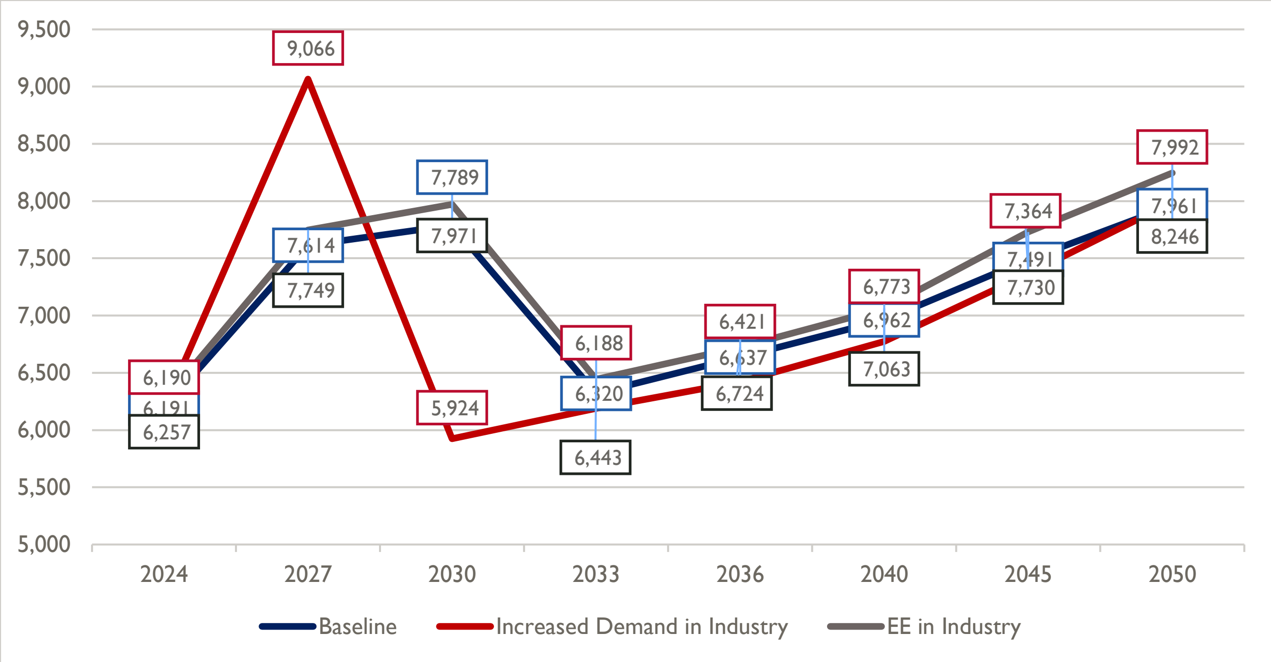


Figure 3.23: GHG emissions (CO_{2eq}) for Increased Demand and EE in Industry scenarios, kt

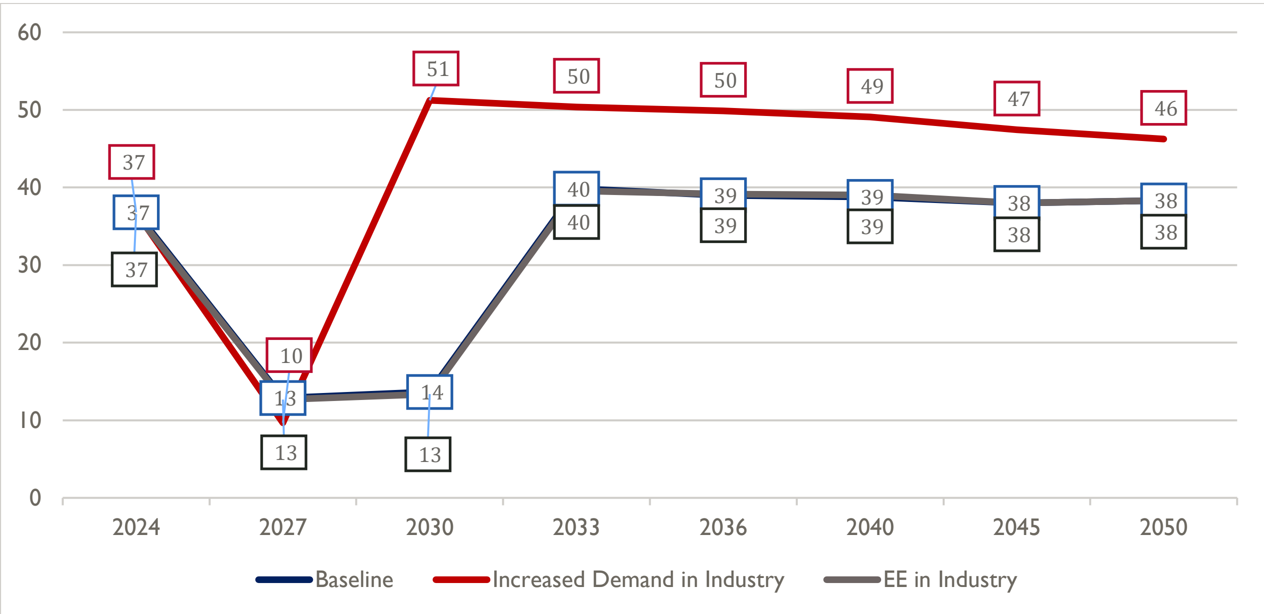


Figure 3.24: Energy independence levels for Increased Demand and EE in Industry scenarios, %

NATURAL GAS PRICE SCENARIOS

Three scenarios assess the impact of natural gas price changes on Armenia's least-cost energy system development pathways. In the EU Gas Price scenario, the natural gas price is equal to the current import price from Russia at $165/1,000m³ up to 2024, then rises to the EU prices defined in the WEO 2021. In the Unchanged Gas Price scenario, the natural gas price remains at the current level of $165/1,000m³ up to 2033, then rises to meet the prices in the Baseline Scenario without new fossil fuel generation. In the third Extreme Gas Price scenario, natural gas prices are equal to the EU gas prices in spring 2022 ($1,000/1,000m³) from 2024 to 2033; afterward, there is no natural gas supply. As this last scenario is extremely unlikely, its results are confined to a separate segment at the end of this section. Natural gas prices for the rest of the scenarios are presented in Figure 3.25.

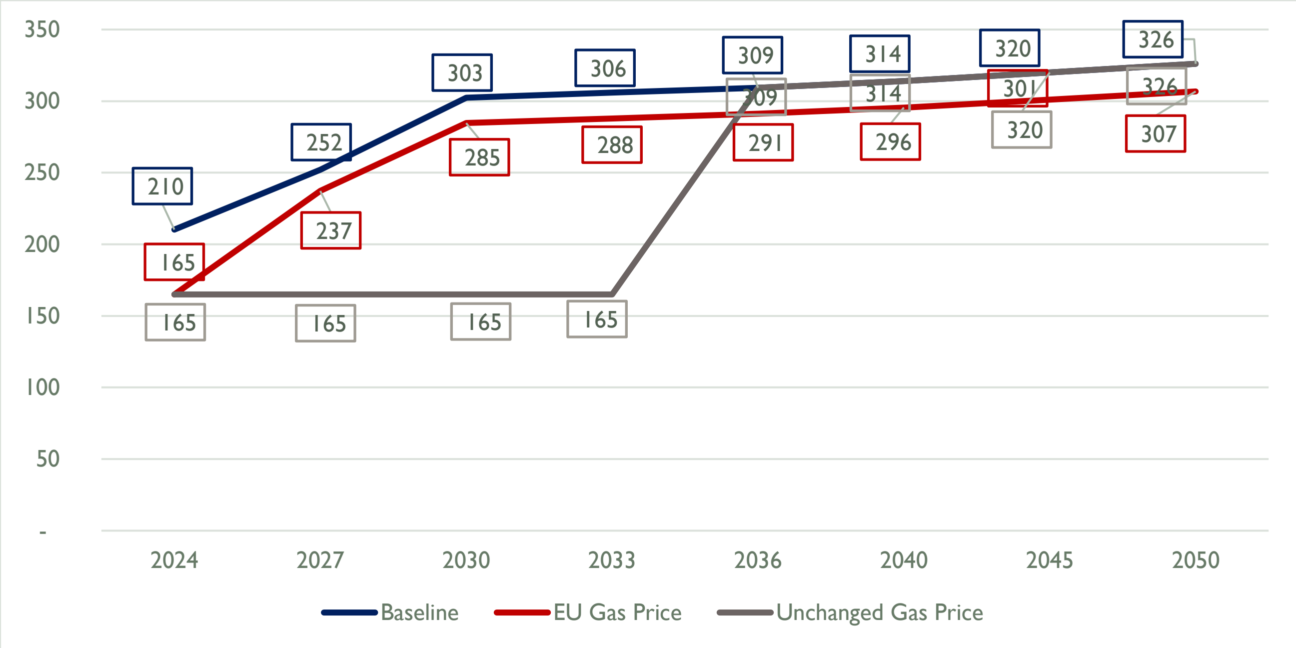


Figure 3.25: Natural gas price scenarios, $/1,000m^3

TOTAL SYSTEM COST decreases as the natural gas price decreases. For the EU Gas Price scenario, total system cost amounts to $66.5 billion, and for the Unchanged Gas Price scenario it is $65.9 billion (Table 3.10).

TABLE 3.10: TOTAL SYSTEM COST FOR NATURAL GAS PRICE SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	67,763	-
EU Gas Price	66,451	-1.9
Unchanged Gas Price	65,846	-2.8

TPES projections for the natural gas price scenarios are presented in Figure 3.26. Changes in TPES are directly connected to the implementation of new NPPs. The EU Gas Price scenario adds new CCGTs and GTs but no new NPP. In the Unchanged Gas Price scenario, a new 600-MW NPP is introduced in 2045 to cover increased demand. TPES projections by fuel type are presented in Figure 3.27.

Figure 3.28 illustrates the changes in the composition of TPES in these two scenarios compared to the Baseline Scenario.

FEC in the natural gas price scenarios is projected in Figure 3.29. Both scenarios show FEC that is practically identical to that of the Baseline Scenario because there is no significant changes in FEC drivers. Figure 3.30 and Figure 3.31 compare FEC by fuel type in the natural gas price scenarios with the Baseline Scenario.

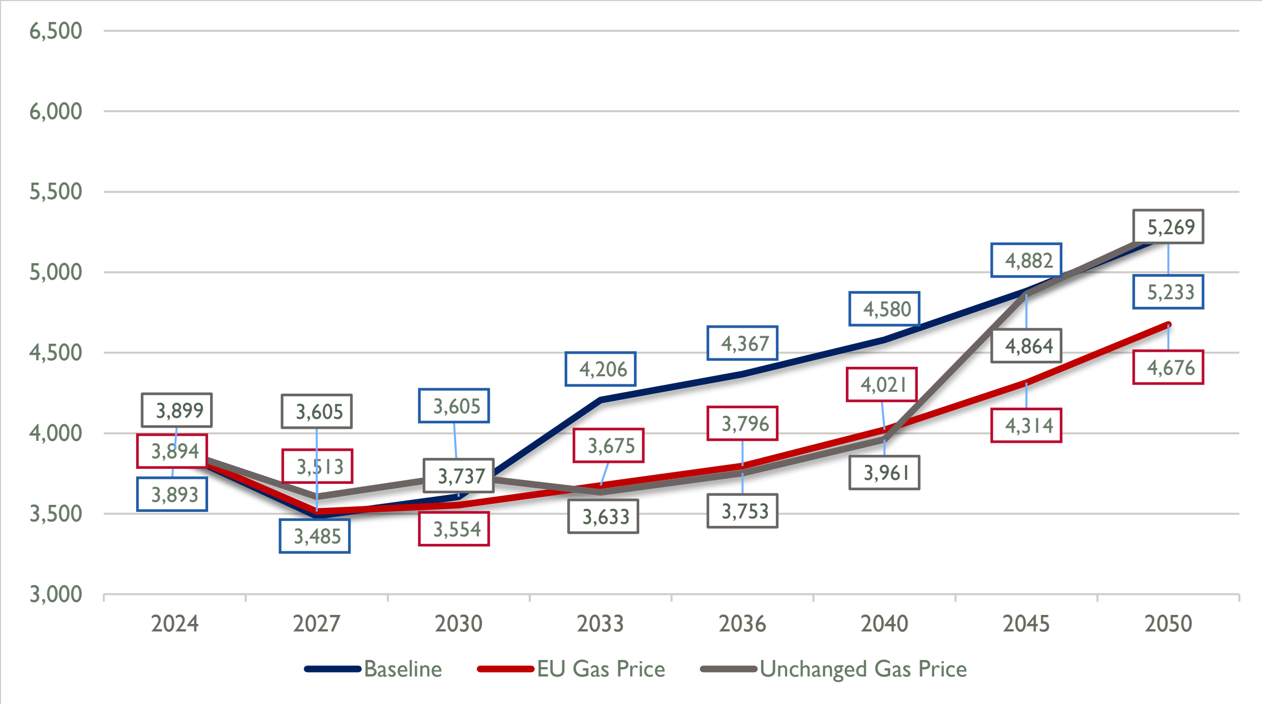
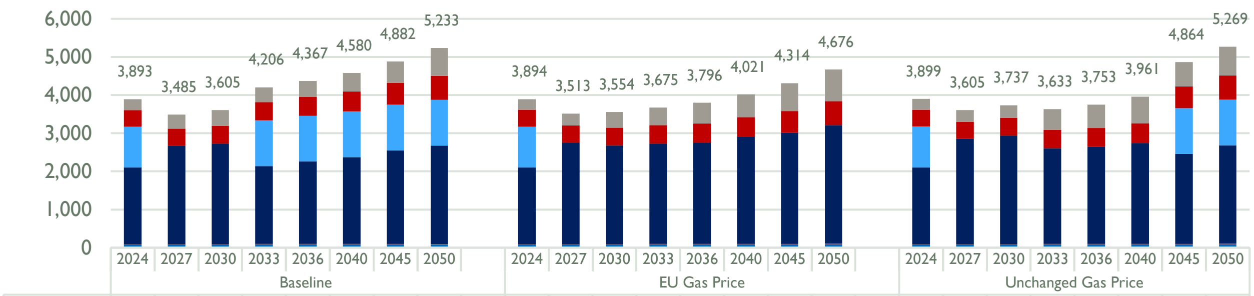


Figure 3.26: TPES for natural gas price scenarios, ktoe



Baseline	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	281.	368.	408.	389.	416.	487.	565.	730.
Oil Products	439.	450.	461.	475.	492.	520.	570.	629.
Nuclear	1,07	-	-	1,19	1,19	1,19	1,19	1,19
Gas	2,01	2,57	2,64	2,04	2,16	2,27	2,44	2,58
Electricity	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Coal	3.2	3.4	3.7	4.0	4.2	4.6	5.0	5.5
Biofuels	79.9	79.8	83.4	87.6	88.7	90.1	91.9	77.0
Total	3,89	3,48	3,60	4,20	4,36	4,58	4,88	5,23

EU Gas Price	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	281.	307.	408.	463.	542.	600.	734.	830.
Oil Products	439.	448.	461.	476.	492.	520.	570.	629.
Nuclear	1,07	-	-	-	-	-	-	-
Gas	2,01	2,66	2,59	2,63	2,66	2,80	2,90	3,11
Electricity	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Coal	3.2	3.4	3.7	4.0	4.2	4.6	5.0	5.5
Biofuels	79.9	79.8	83.4	87.6	88.7	90.1	91.9	93.6
Total	3,89	3,51	3,55	3,67	3,79	4,02	4,31	4,67

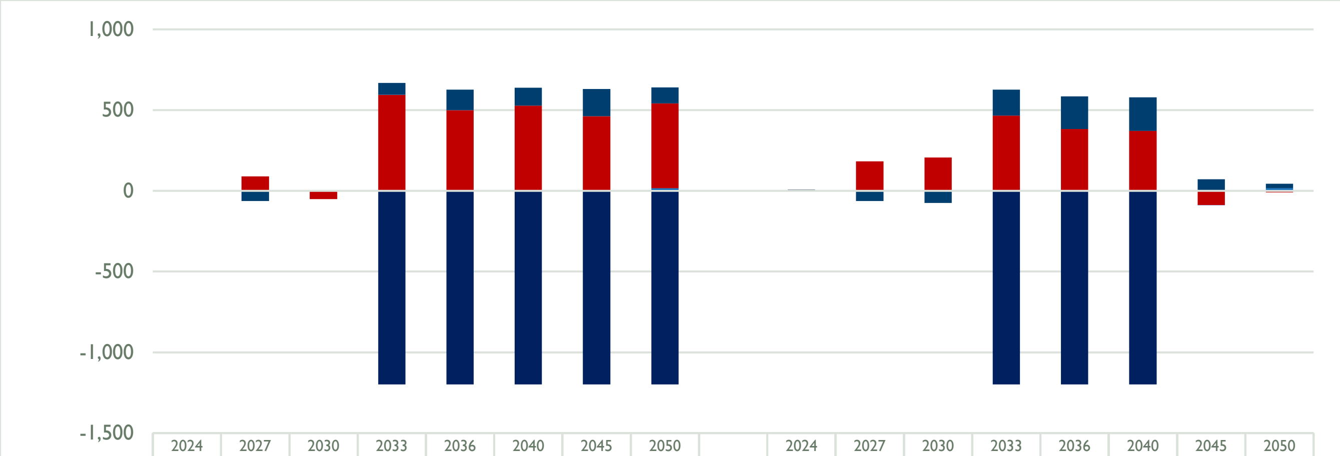
Unchanged Gas Price	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	281.	306.	333.	550.	616.	695.	636.	757.
Oil Products	439.	448.	461.	476.	492.	520.	569.	629.
Nuclear	1,07	-	-	-	-	-	1,19	1,19
Gas	2,01	2,76	2,84	2,51	2,54	2,64	2,35	2,57
Electricity	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Coal	3.2	3.4	3.7	4.0	4.2	4.6	5.0	5.5
Biofuels	79.9	79.8	83.4	87.6	88.7	90.1	91.9	93.6
Total	3,89	3,60	3,73	3,63	3,75	3,96	4,86	5,26

Biofuels Coal Electricity Gas Nuclear Oil Products Renewables Total

Figure 3.27: TPES by fuel type for natural gas price scenarios, ktoe

ELECTRICITY GENERATION TECHNOLOGIES. The least-cost configuration of Armenia's power sector for the natural gas price scenarios is presented in Table 3.11. There are significant changes in generation capacity configuration for nuclear, RES, and gas-fired technologies.

In the EU Gas Price scenario, three new CCGTs are introduced into the system in 2027, 2033, and 2045, and one new GT is introduced in 2050. No new NPP is implemented in this scenario. The implementation of the Loriberd HPP is shifted from 2045 (in the Baseline Scenario) to 2050. Hydro pump storage capacity reduces from 130 MW to 65 MW, and the scenario does not include the Shnokh HPP. At the same time, 1,121 MW more solar PV will be introduced at the end of the planning horizon than in the Baseline Scenario.



	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
	EU Gas Price								Unchanged Gas Price							
Renewables	0.002	-61	0	73	127	113	169	100	0.005	-62	-75	160	201	208	71	28
Oil Products	0	-1	0	0.3	0.3	0	0	0	0	-1	0.0	0.3	0.3	0	-0.5	0
Nuclear	0	0	0	-1,199	-1,199	-1,199	-1,199	-1,199	0	0	0	-1,199	-1,199	-1,199	0	0
Gas	1.74	91	-52	595	501	527	461	525	7	183	206	465	383	372	-88	-9
Electricity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	17

Figure 3.28 Comparison of TPES by fuel type for natural gas price scenarios and Baseline Scenario, ktoe

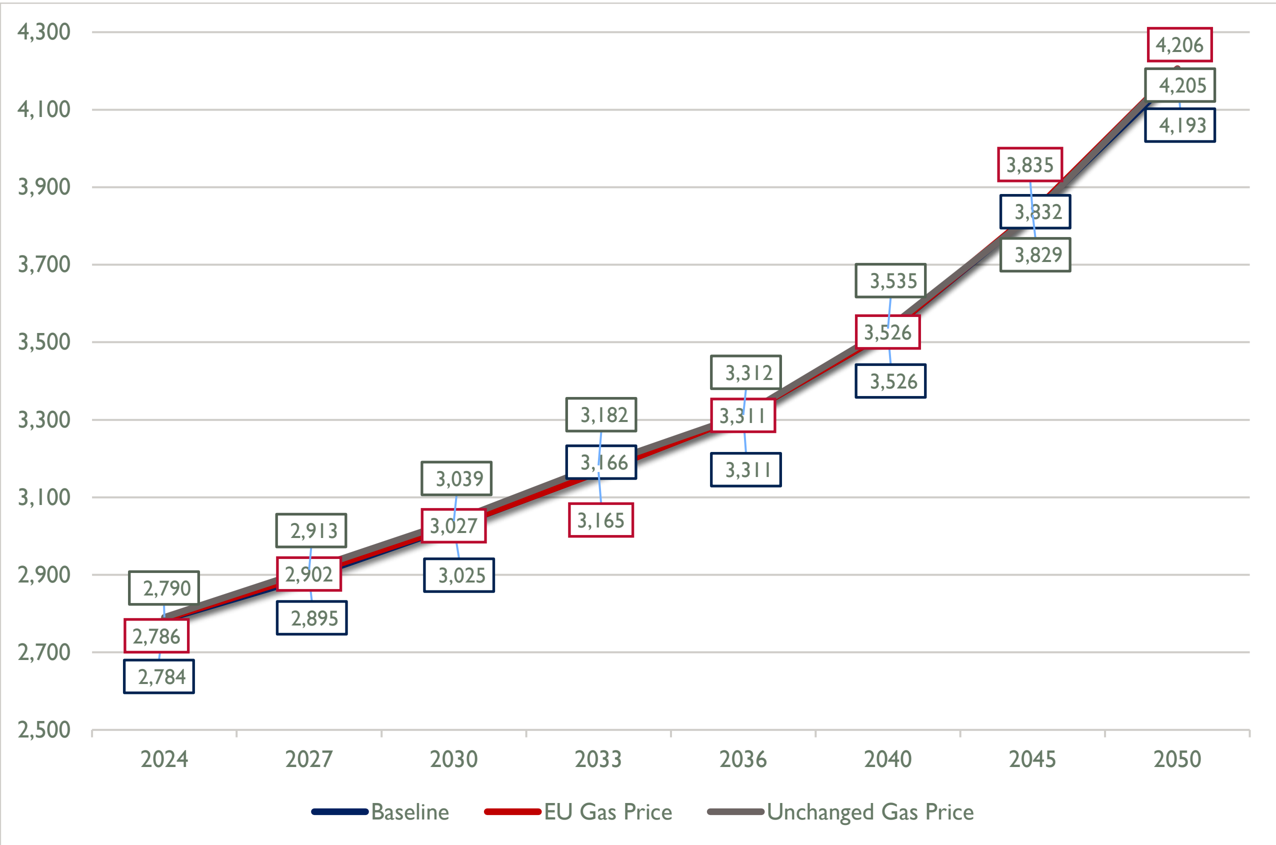
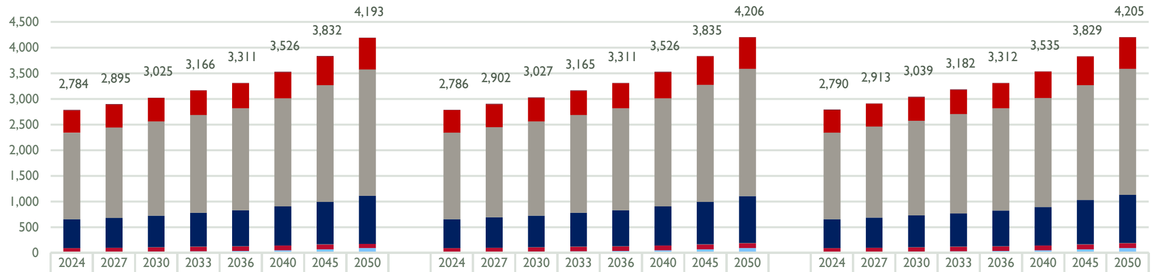


Figure 3.29 FEC for natural gas price scenarios, ktoe



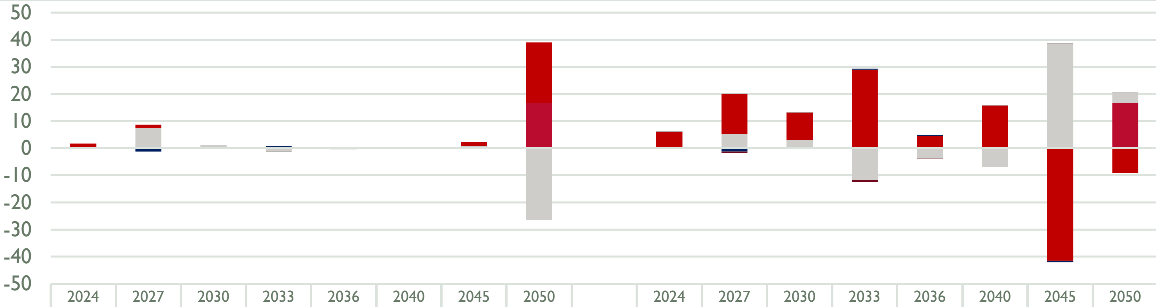
	Baseline 2024	2027	2030	2033	2036	2040	2045	2050
Renewables	8.77	8.70	8.38	8.13	7.88	7.62	7.58	7.67
Oil Products	437.00	446.94	457.24	470.17	484.87	510.65	556.48	610.88
LT Heat	0.17	0.18	0.18	0.19	0.19	0.20	0.20	0.21
Gas	1,682.	1,757.	1,836.	1,909.	1,989.	2,106.	2,278.	2,463.
Electricity	562.78	582.63	615.09	657.84	700.05	757.90	824.43	935.31
Coal	3.18	3.44	3.70	3.97	4.23	4.58	5.02	5.46
Biofuels	79.91	79.76	83.45	87.63	88.69	90.10	91.87	77.00
Biofuel and fossil fuel blends	10.09	15.27	21.27	28.25	36.35	49.04	68.28	93.33
Total	2,784	2,895	3,025	3,166	3,311	3,526	3,832	4,193

	EU Gas Price 2024	2027	2030	2033	2036	2040	2045	2050
Renewables	8.8	8.7	8.4	8.1	7.9	7.6	7.6	7.7
Oil Products	437.0	445.7	457.2	470.4	485.2	510.7	556.5	610.9
LT Heat	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Gas	1,684.	1,759.	1,836.	1,910.	1,989.	2,106.	2,279.	2,485.
Electricity	562.8	590.2	616.3	656.8	699.7	757.9	825.4	908.8
Coal	3.2	3.4	3.7	4.0	4.2	4.6	5.0	5.5
Biofuels	79.9	79.8	83.4	87.6	88.7	90.1	91.9	93.6
Biofuel and fossil fuel blends	10.1	15.3	21.3	28.2	36.3	49.0	68.3	93.3
Total	2,786	2,902	3,027	3,165	3,311	3,526	3,835	4,206

	Unchanged Gas Price 2024	2027	2030	2033	2036	2040	2045	2050
Renewables	8.8	8.3	8.3	7.4	7.9	7.6	7.6	7.7
Oil Products	437.0	445.7	457.2	470.4	485.2	510.7	556.0	610.9
LT Heat	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Gas	1,688.	1,772.	1,846.	1,938.	1,993.	2,122.	2,237.	2,454.
Electricity	563.2	587.8	618.2	646.1	696.2	750.9	863.0	939.2
Coal	3.2	3.4	3.7	4.0	4.2	4.6	5.0	5.5
Biofuels	79.9	79.8	83.4	87.6	88.7	90.1	91.9	93.6
Biofuel and fossil fuel blends	10.1	15.3	21.3	28.2	36.3	49.0	68.3	93.3
Total	2,790	2,913	3,039	3,182	3,312	3,535	3,829	4,205

Biofuel and fossil fuel blends ■ Biofuels ■ Coal ■ Electricity ■ Gas ■ LT Heat ■ Oil Products ■ Renewables Total

Figure 3.30: FEC by fuel type for natural gas price scenarios, ktoe



	EU Gas Price 2024	2027	2030	2033	2036	2040	2045	2050
Renewables	0	0	0	0	0	0	0	0
Oil Products	0	-1	0	0.3	0.3	0	0	0
LT Heat	-0.003	-0.003	-0.003	-0.003	-0.003	-0.002	0	0
Gas	2	1	0	0.5	0	0	1	22
Electricity	0.03	8	1	-1	-0.3	0.01	1	-27
Coal	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	17
Biofuel and fossil fuel blends	0	0	0	0	0	0	0	0

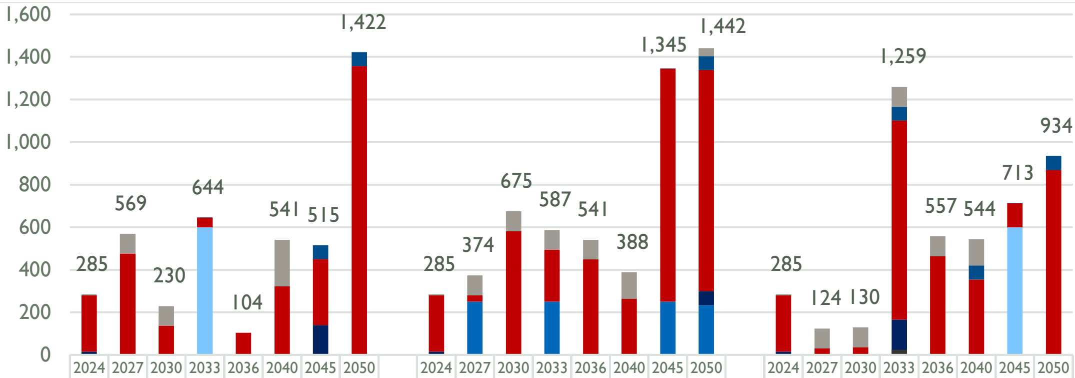
	Unchanged Gas Price 2024	2027	2030	2033	2036	2040	2045	2050
Renewables	0	-0.4	-0.05	-0.7	-0.02	-0.02	-0.01	0
Oil Products	0	-1	0	0.3	0.3	0	-0.5	0
LT Heat	0	0	0	0.01	0.01	0	0	0
Gas	6	15	10	29	4	16	-41	-9
Electricity	0	5	3	-12	-4	-7	39	4
Coal	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	17
Biofuel and fossil fuel blends	0	0	0	0	0	0	0	0

Figure 3.31: Comparison of FEC by fuel type for natural gas price scenarios and Baseline Scenario, ktoe

The Unchanged Gas Price scenario adds a 25-MW geothermal power plant in 2033, reschedules the Loriberd and Shnokh HPPs from 2045 to 2023, delays the commissioning of a new 600-MW NPP to 2045 (from 2033 in the Baseline Scenario), builds 210 MW of additional solar PV at the end of the planning period, fully utilizes modeled wind potential (500 MW), and constructs two hydro pumped storage power plants in 2033 and 2040.

Figures 3.32 and 3.33 provide the new capacity implementation schedules for these scenarios over the planning horizon. Generation by plant is presented in Table 3.12. Figures 3.34 and 3.35 compare projected generation capacity by plant and generation technology to the Baseline Scenario over the planning horizon.

TABLE 3.11: CAPACITY BY PLANT/PLANT TYPE FOR NATURAL GAS PRICE SCENARIOS, MW																								
SCENARIO	BASELINE								EU GAS PRICE								UNCHANGED GAS PRICE							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
CCGT	-	-	-	-	-	-	-	-	-	250	250	500	500	500	750	750	-	-	-	-	-	-	-	-
Gas turbine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	234	-	-	-	-	-	-	-	-
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Geothermal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	25	25	25	25
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	66	-	-	-	66	66	66	66	66
Shnokh HPP	-	-	-	-	-	-	75	75	-	-	-	-	-	-	-	-	-	-	-	75	75	75	75	75
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-
NPP (new)	-	-	-	600	600	600	600	600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	600	600
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,026	1,130	1,452	1,727	2,630	369	400	982	1,226	1,674	1,939	3,000	3,751	369	400	437	1,372	1,836	2,190	2,270	2,841
Hydro pumped storage plant	-	-	-	-	-	-	65	130	-	-	-	-	-	-	-	65	-	-	-	65	65	130	130	195
Lithium-ion storage	-	-	-	0.02	0.02	0.02	0.02	0.06	-	-	-	-	0.01	0.03	0.1	0.1	-	-	-	-	0.004	0.004	0.05	0.1
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	409	409	371	4	97	190	283	376	500	500	500	4	97	190	283	376	500	500	462
Total	**3,233**	**3,362**	**3,592**	**3,769**	**3,873**	**4,414**	**4,616**	**5,289**	**3,233**	**3,167**	**3,842**	**3,962**	**4,504**	**4,892**	**5,924**	**6,782**	**3,233**	**2,917**	**3,047**	**3,839**	**4,396**	**4,940**	**5,340**	**5,681**



Baseline

	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	-	219	-	-
Lithium-ion storage	-	-	-	0.02	-	0.00	-	0.04
Hydro pumped storage plant	-	-	-	-	-	-	65	65
Solar	266	476	137	44	104	322	309	1,35
Nuclear	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-
Geothermal	-	-	-	-	-	-	-	-
Gas-fired	-	-	-	-	-	-	-	-
Total	285	569	230	644	104	541	515	1,42

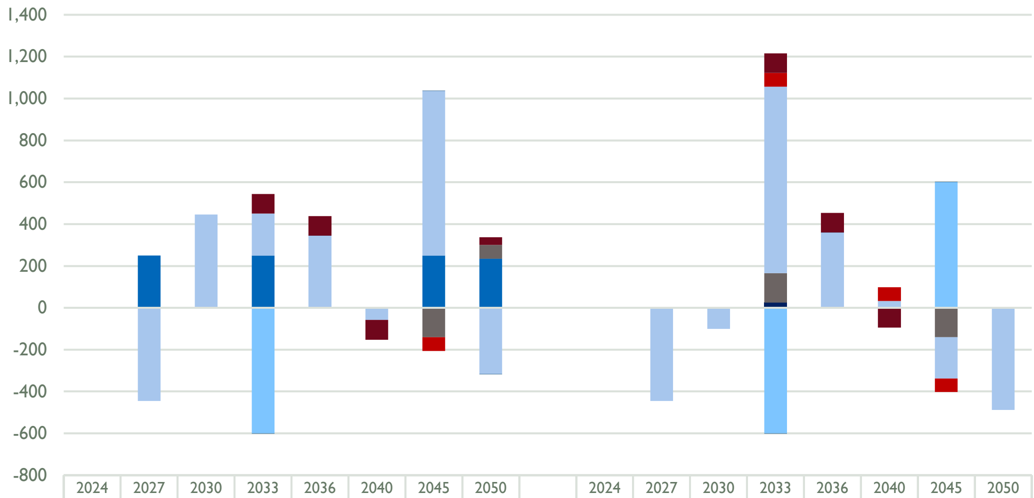
EU Gas Price

	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	93	93	124	-	38
Lithium-ion storage	-	-	-	-	0.01	0.02	0.06	0.01
Hydro pumped storage plant	-	-	-	-	-	-	-	65
Solar	266	31	582	244	448	264	1,09	1,03
Nuclear	-	-	-	-	-	-	-	-
Hydro	15	-	-	-	-	-	-	66
Geothermal	-	-	-	-	-	-	-	-
Gas-fired	-	250	-	250	-	-	250	234
Total	285	374	675	587	541	388	1,34	1,44

Unchanged Gas Price

	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	93	93	124	-	-
Lithium-ion storage	-	-	-	-	0.00	-	0.04	0.04
Hydro pumped storage plant	-	-	-	65	-	65	-	65
Solar	266	31	37	935	464	355	113	869
Nuclear	-	-	-	-	-	-	600	-
Hydro	15	-	-	141	-	-	-	-
Geothermal	-	-	-	25	-	-	-	-
Gas-fired	-	-	-	-	-	-	-	-
Total	285	124	130	1,25	557	544	713	934

Figure 3.32: New capacity implementation schedule in natural gas price scenarios, MW



EU Gas Price

	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	93	93	-95	0	38
Lithium-ion storage	0	0	0	-0.02	0.01	0.02	0.06	-0.03
Hydro pumped storage plant	0	0	0	0	0	0	-65	0
Solar	0	-445	445	200	344	-58	786	-317
Nuclear	0	0	0	-600	0	0	0	0
Hydro	0	0	0	0	0	0	-141	66
Geothermal	0	0	0	0	0	0	0	0
Gas-fired	0	250	0	250	0	0	250	234

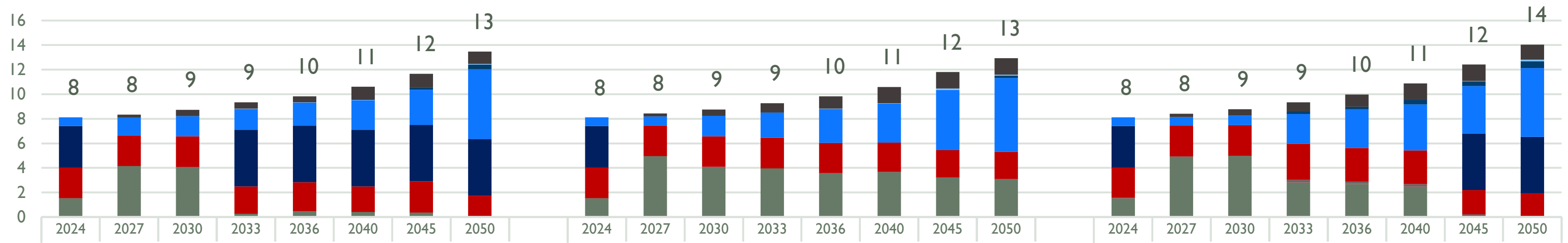
Unchanged Gas Price

	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	93	93	-95	0	0
Lithium-ion storage	0	0	0	-0.02	0.004	-0.002	0.04	0
Hydro pumped storage plant	0	0	0	65	0	65	-65	0
Solar	0	-445	-100	891	360	33	-196	-487
Nuclear	0	0	0	-600	0	0	600	0
Hydro	0	0	0	141	0	0	-141	0
Geothermal	0	0	0	25	0	0	0	0
Gas-fired	0	0	0	0	0	0	0	0

Figure 3.33: Comparison of new power plant construction between natural gas price scenarios and Baseline Scenario, MW

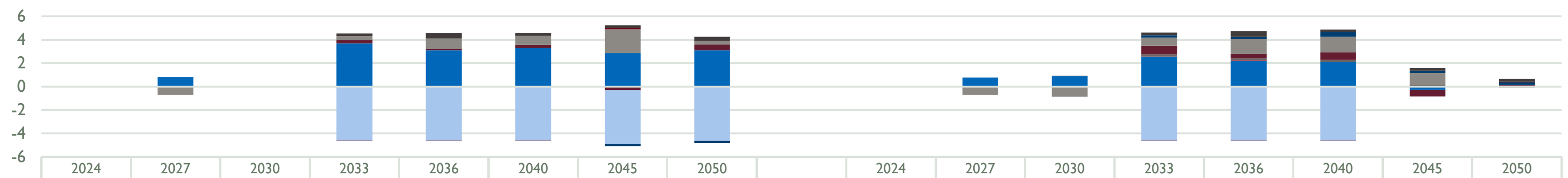
TABLE 3.12: GENERATION BY PLANT/PLANT TYPE FOR NATURAL GAS PRICE SCENARIOS, GWH

SCENARIO	BASELINE								EU GAS PRICE								UNCHANGED GAS PRICE							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
CCGT	-	-	-	-	-	-	-	-	-	1,862	1,862	3,533	3,235	3,210	3,081	2,966	-	-	-	-	-	-	-	-
Gas turbine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	129	-	-	-	-	-	-	-	-
Yerevan CCGT	71	1,672	1,672	22	59	60	-	-	71	1,171	361	52	67	86	-	-	74	1,672	1,672	1,033	950	909	-	-
Yerevan CCGT-2	1,471	1,891	1,891	248	417	343	364	-	1,472	1,891	1,822	376	287	381	145	-	1,474	1,891	1,891	1,785	1,739	1,569	84	-
Hrazdan Unit 5	-	591	510	-	-	-	-	-	-	40	44	-	-	-	-	-	-	1,371	1,423	-	-	-	-	-
Local cogeneration plant	7	7	7	7	7	8	8	26	7	7	7	7	7	8	8	8	7	7	7	17	17	18	8	28
Geothermal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	194	187	194	137	77
Vorotan HPP Cascade	984	984	984	979	984	984	984	598	984	984	984	984	984	984	984	848	984	984	984	984	984	984	614	693
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346	414	414	414	414	414	414	414	414	414	414	414	414	414	414	414	346
Loriberd HPP	-	-	-	-	-	-	203	203	-	-	-	-	-	-	-	203	-	-	-	203	203	203	203	203
Shnokh HPP	-	-	-	-	-	-	291	291	-	-	-	-	-	-	-	-	-	-	-	291	291	291	291	291
Small HPP (existing)	932	935	935	654	790	528	492	122	932	935	935	935	894	815	673	590	932	935	935	886	673	683	292	117
Small HPP (new)	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	4,601	4,601	4,601	4,601	4,601	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,601	4,601
Solar (existing)	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	1,645	1,811	2,328	2,770	5,689	592	641	1,574	1,965	2,684	3,108	4,811	6,014	592	641	700	2,344	3,088	3,656	3,783	5,601
Hydro pumped storage plant	-	-	-	-	-	-	188	376	-	-	-	-	-	-	-	188	-	-	-	188	188	376	376	564
Lithium-ion storage	-	-	-	15	8	20	20	68	-	-	-	-	4	14	109	70	-	-	-	-	3	-	33	126
Wind (existing)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	1,091	1,091	990	11	259	507	755	1,003	1,334	1,334	1,334	11	259	507	755	1,003	1,334	1,334	1,233
Total	**8,095**	**8,347**	**8,734**	**9,332**	**9,839**	**10,617**	**11,667**	**13,472**	**8,096**	**8,443**	**8,749**	**9,261**	**9,820**	**10,593**	**11,798**	**12,925**	**8,101**	**8,413**	**8,773**	**9,335**	**9,979**	**10,871**	**12,411**	**14,042**



	Baseline 2024	2027	2030	2033	2036	2040	2045	2050	EU Gas Price 2024	2027	2030	2033	2036	2040	2045	2050	Unchanged Gas Price 2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0	0.01	0.3	0.5	0.8	1.0	1.3	1.3	1.3	0.01	0.3	0.5	0.8	1.0	1.3	1.3	1.2
Lithium-ion storage	-	-	-	0.02	0.01	0.02	0.02	0.07	-	-	-	-	0.004	0.01	0.1	0.1	-	-	-	-	0.003	-	0.03	0.1
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4	-	-	-	-	-	-	-	0.2	-	-	-	0.2	0.2	0.4	0.4	0.6
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7	0.7	0.7	1.7	2.0	2.8	3.2	4.9	6.0	0.7	0.7	0.8	2.4	3.2	3.7	3.9	5.6
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6	3.4	-	-	-	-	-	-	-	3.4	-	-	-	-	-	4.6	4.6
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7	2.5	2.5	2.5	2.5	2.5	2.4	2.2	2.2	2.5	2.5	2.5	2.9	2.7	2.7	2.0	1.8
Geothermal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.2	0.2	0.1	0.1
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.03
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-	1.5	5.0	4.1	4.0	3.6	3.7	3.2	3.1	1.5	4.9	5.0	2.8	2.7	2.5	0.1	-
Total	8	8	9	9	10	11	12	13	8	8	9	9	10	11	12	13	8	8	9	9	10	11	12	14

Figure 3.34: Electricity generation by power plant/type for natural gas price scenarios and Baseline Scenario, TWh



	EU Gas Price 2024	2027	2030	2033	2036	2040	2045	2050	Unchanged Gas Price 2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0.2	0.5	0.2	0.2	0.3	0	0	0	0.2	0.5	0.2	0.2	0.2
Lithium-ion storage	0	0	0	-0.02	-0.004	-0.006	0.1	0.002	0	0	0	-0.02	-0.01	-0.02	0.01	0.1
Hydro pumped storage plant	0	0	0	0	0	0	-0.2	-0.2	0	0	0	0.2	0.2	0.4	0.2	0.2
Solar	0	-0.7	0	0.3	1	1	2	0	0	-1	-1	1	1	1	1	-0.1
Nuclear	0	0	0	-5	-5	-5	-5	-5	0	0	0	-5	-5	-5	0	0
Hydro	0	0	0	0.3	0.1	0.3	-0.3	0.5	0	0	0	1	0	1	-1	0.1
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.1	0.1
Gas-fired CHPs	0	0	0	0	0	0	0	-0.02	0	0	0	0.01	0.01	0.01	0.00	0.002
Gas-fired	0	1	0.01	4	3	3	3	3	0.005	1	1	3	2	2	-0.3	0

Figure 3.35: Comparison of electricity generation by power plant/type for natural gas price scenarios and Baseline Scenario, TWh

INVESTMENTS IN NEW POWER SYSTEM CAPACITY vary significantly between scenarios as a result of differences in the generation technology mix. Table 3.13 and Figure 3.36 compare investments for new capacity between the natural gas price and Baseline Scenarios. For the Unchanged Gas Price scenario, investment is 1.6 percent higher than in the Baseline Scenario, mainly due to the revised power plant implementation schedule (such as delaying the construction of the 600-MW NPP from 2033 to 2045), the switch from one type of power plant to another, and the 2033 construction of a 25-MW geothermal plant. Before 2033, more electricity is generated by gas-fired power plants, including when the gas price is lower than in the Baseline Scenario.

TABLE 3.13: TOTAL POWER SECTOR INVESTMENTS IN NEW CAPACITY UNDER NATURAL GAS PRICE SCENARIOS

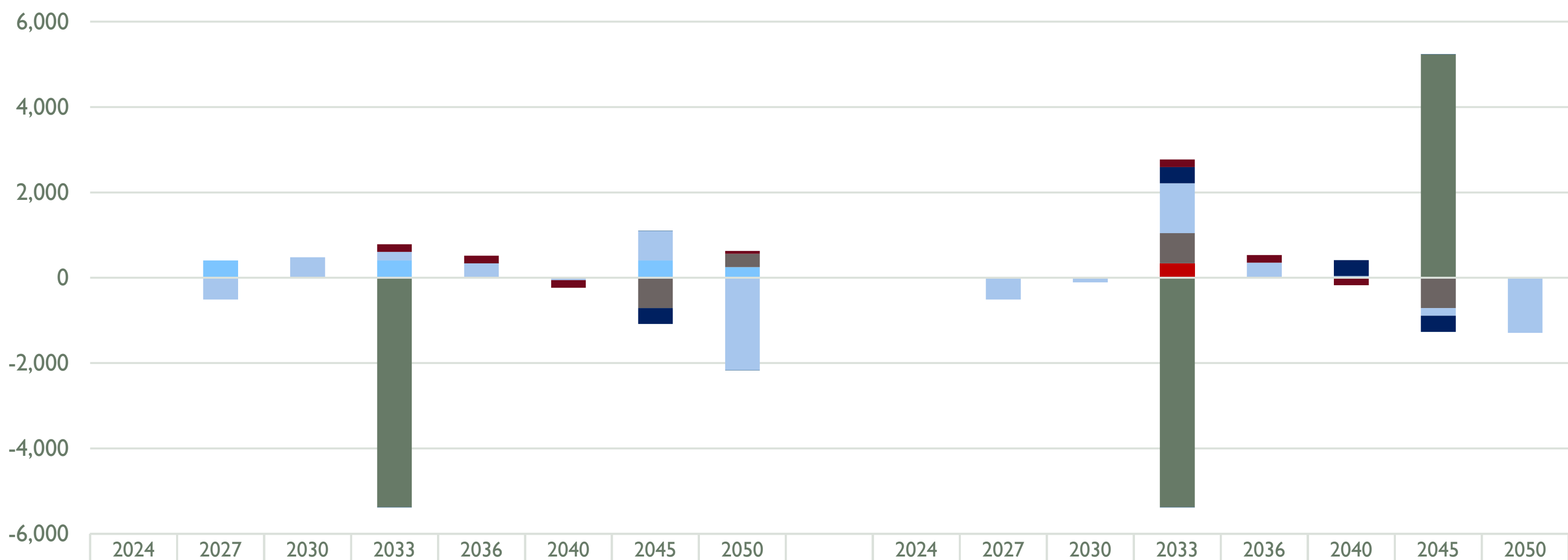
SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	12,854	-
EU Gas Price	7,391	-42.5
Unchanged Gas Price	13,065	+1.6

GHG EMISSIONS differences are presented in Figure 3.37. The main polluting energy carrier for both scenarios remains natural gas, with around 83 percent of total GHG emissions in almost all milestone years.

At the end of the planning period in the EU Gas Price scenario, the transport and residential sectors contribute to total GHG emissions, with 30 and 24 percent respectively. The next highest polluting sector is commercial (13 percent), followed by industry and the power sector (12 percent each) and agriculture (1 percent). Fugitive emissions on the supply side amount to 8 percent.

Similarly, in the Unchanged Gas Price scenario, the transport and residential sectors remain the highest polluting in 2050, with 36 and 27 percent shares respectively. They are followed by the commercial (15 percent) and industrial (14 percent) sectors. Emissions from the power sector are almost zero because no gas-fired power plants are allowed at that time. The share of the agricultural sector is less than 1 percent and fugitive emissions from the supply side account for 8 percent.

ENERGY INDEPENDENCE for the natural gas price scenarios is presented in Figure 3.38. Armenia's independence level strictly follows the TPES trend and decreases in parallel to rising imports of natural gas.



	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
	EU Gas Price								Unchanged Gas Price							
Wind	0	0	0	177	176	-178	0	69	0	0	0	177	176	-178	0	0
Lithium-ion storage	0	0	0	-0.01	0.005	0.01	0.03	-0.01	0	0	0	-0.01	0.002	-0.001	0.02	0
Hydro pumped storage plant	0	0	0	0	0	0	-377	0	0	0	0	377	0	377	-377	0
Solar	0	-511	476	204	337	-54	692	-2,160	0	-511	-107	1,167	354	38	-183	-1,291
Nuclear	0	0	0	-5,375	0	0	0	0	0	0	0	-5,375	0	0	5,231	0
Hydro	0	0	0	0	0	0	-709	314	0	0	0	709	0	0	-709	0
Geothermal	0	0	0	0	0	0	0	0	0	0	0	337	0	0	0	0
Gas-fired	0	403	0	403	0	0	403	247	0	0	0	0	0	0	0	0

Figure 3.36: Comparison of investments in new power system capacity under natural gas price scenarios and Baseline Scenario, millions of USD

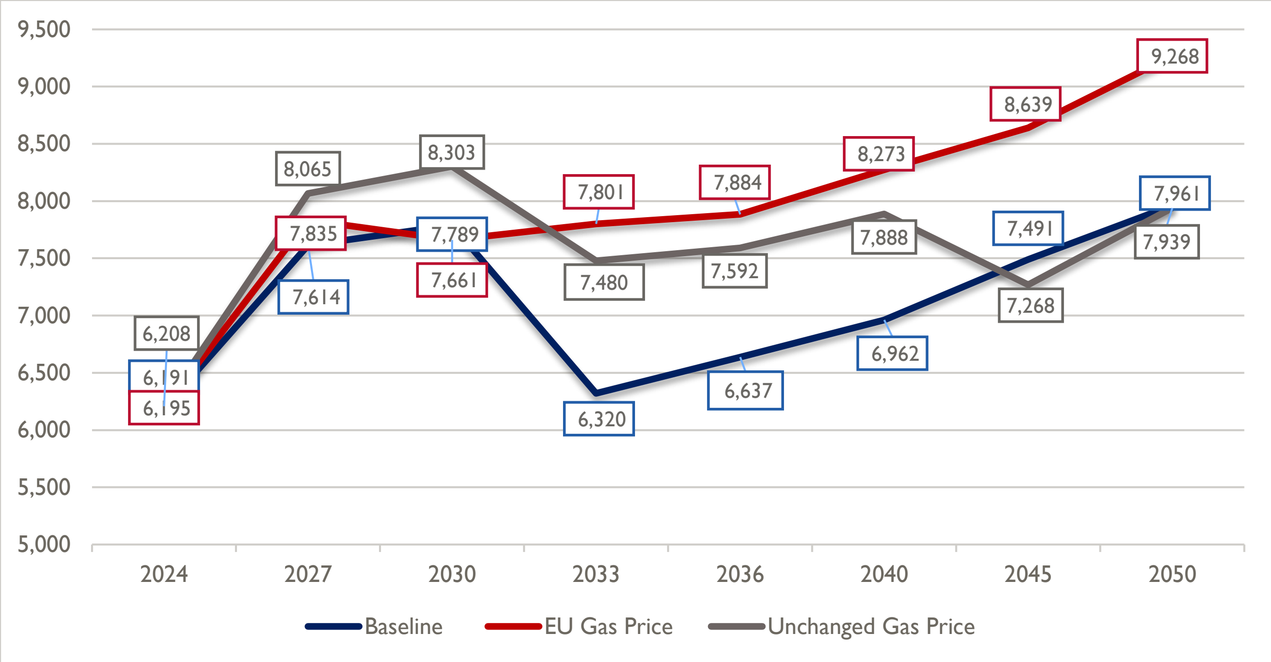


Figure 3.37: GHG emissions (CO_{2eq}) for natural gas price scenarios, kt

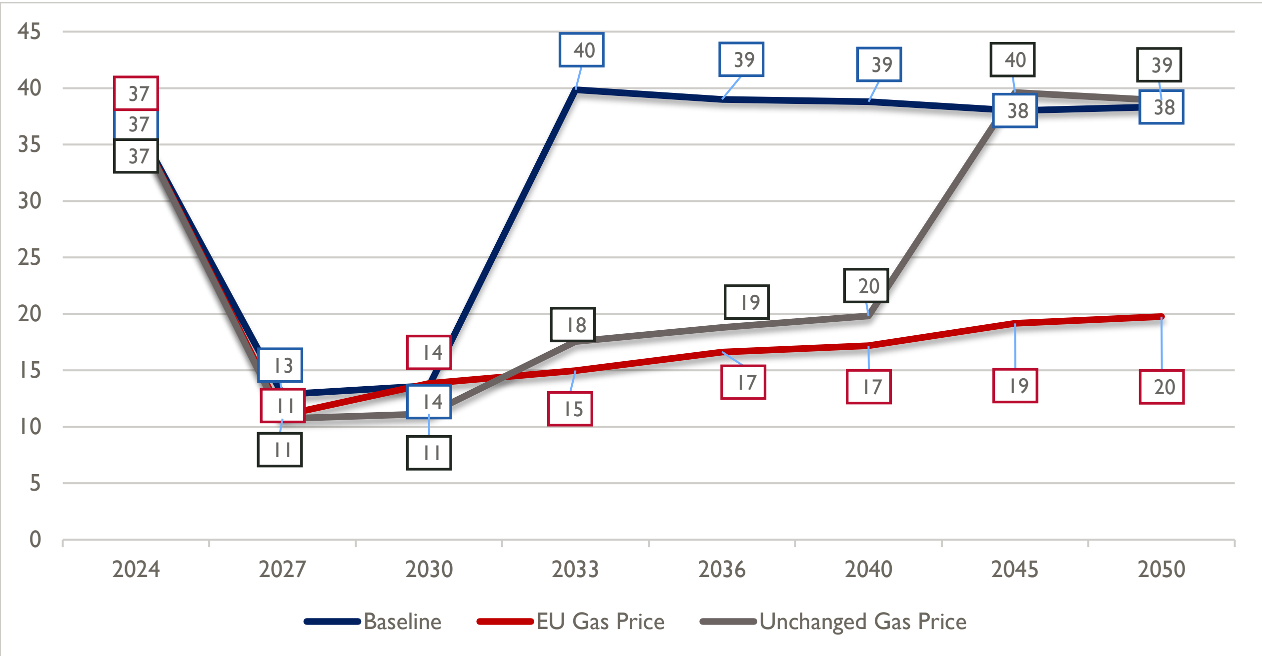


Figure 3.38: Energy independence levels for natural gas price scenarios, %

EXTREME GAS PRICE

The extreme gas price scenario considers the changes to the EU natural gas price in 2022. It posits that until 2033, the gas price in Armenia will follow the natural gas price in the EU ($1,000/1,000 m³), with no gas supply afterward. If this were to occur, it would require new policy measures that strongly differ from Armenia's current policies to support several major changes:

- A switch from natural gas to electricity, blends of biofuel with fossil fuel, and oil products
- Increased NPP and RES generation capacity to fill the gap in generation from gas-fired power plants

- Increased transmission and distribution grid capacity to transfer increased electricity generation, etc.

Because this is extremely unlikely, the results are presented in more generally and do not include the level of detail that the other scenarios have.

This scenario brings substantial changes to Armenia's power sector. The switch from gas-fired power generation to other generation technologies will start in 2033, when the gas price peaks. Gas-fired power generation will decline significantly, and the demand will be covered mostly by NPPs and RES. The implementation of the Loriberd and Shnokh HPPs will move up to 2033, and storage technology capacity will also increase to support a high share of variable renewable generation in the system. All this will require a significant increase in investment in new capacities.

The efficiency of NPPs is lower than that of TPPs, which will increase TPES. Natural gas will be replaced by electricity, blends of biofuel with fossil fuel, and oil products. Growth in electricity demand will cause Armenia to build new capacity, consider implementing new technology, increase power flows in both transmission and distribution networks, and explore new technical solutions to maintain the reliability and security of its power supply. Adaptation will require new measures to prepare the environment for new types of fuels, generation, and demand-side technologies.

Natural gas is the most polluting energy carrier in all scenarios considered, so GHG emissions will drastically decrease in all sectors after the natural gas supply ends in 2033. There will be no emissions in the power system by the end of the planning horizon.

In the meantime, ending Armenia's reliance on imported energy carriers will bring its energy independence to around 90 percent by the end of the planning horizon.

NUCLEAR DEVELOPMENT SCENARIOS

Five scenarios consider extending the life of ANPP and different options for SMR module implementation (Table 3.14). One scenario extends ANPP's lifetime to 2032 (ANPP 2032); another to 2037 (ANPP 2037). Two additional scenarios extend ANPP to 2037 and add more nuclear generation: one adds a SMR-300 module in 2037 (ANPP 2037 and One SMR) and the other adds the first SMR-300 module in 2037 and the second in 2045 (ANPP 2037 and Two SMR). One final scenario analyzes energy sector development if ANPP's lifetime is extended by 2026 and an SMR-300 is implemented from 2036 (ANPP 2026 and One SMR-300). Neither scenario considers adding new fossil generation.

TABLE 3.14: NUCLEAR DEVELOPMENT SCENARIOS, MW

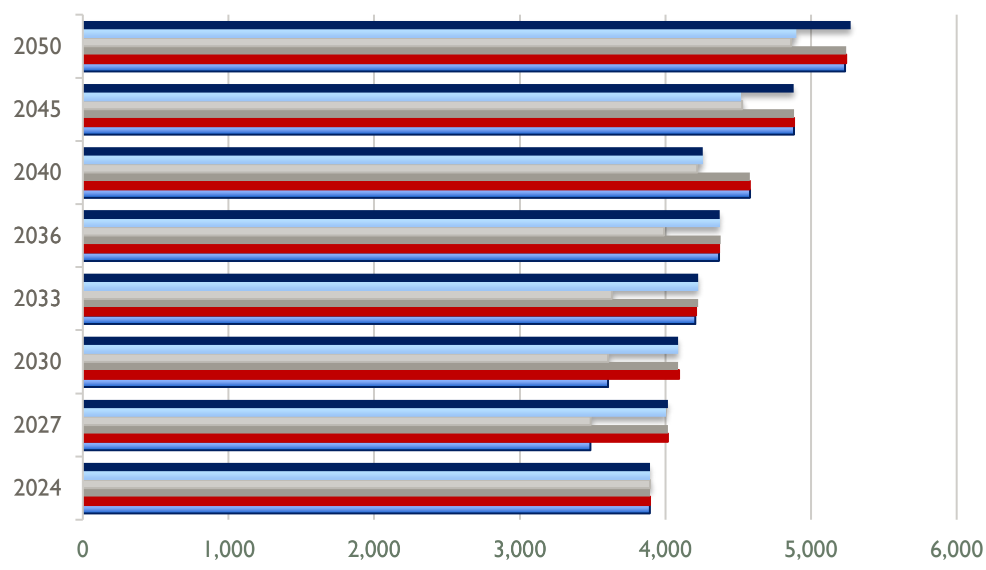
SCENARIO	2024	2027	2030	2033	2036	2040	2045	2050
Baseline	440	-	-	-	-	-	-	-
ANPP 2032	440	440	440	-	-	-	-	-
ANPP 2037	440	440	440	440	440	-	-	-
ANPP 2026 and One SMR-300	440	-	-	-	300	300	300	300
ANPP 2037 and One SMR	440	440	440	440	440	300	300	300
ANPP 2037 and Two SMR	440	440	440	440	440	300	600	600

TOTAL SYSTEM COST will vary within 2.3 to 0.4 percent of the cost under the Baseline Scenario (Table 3.15), mostly due to the cost of implementing new nuclear units.

TABLE 3.15: TOTAL SYSTEM COST FOR NUCLEAR DEVELOPMENT SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	67,763	-
ANPP 2032	66,969	-1.2
ANPP 2037	66,220	-2.3
ANPP 2026 and One SMR-300	68,049	0.4
ANPP 2037 and One SMR	66,370	-2.1
ANPP 2037 and Two SMR	66,445	-1.9

TPES projections are presented in Figure 3.39; TPES projections by fuel are presented in Figure 3.40. Extended ANPP operation results in a redistribution of electricity generation between nuclear and gas-fired power plants until 2030, so TPES is higher in the ANPP 2032 and ANPP 2037 scenarios than in the Baseline Scenario. In scenarios with forced new NPP implementation, the difference from the Baseline Scenario mostly depends on installed capacity and the time of new SMR-300 units' implementation. Figure 3.41 illustrates TPES composition in the nuclear development scenarios compared to the Baseline Scenario.



	2024	2027	2030	2033	2036	2040	2045	2050
ANPP 2037 and two SMR	3,893	4,017	4,086	4,224	4,372	4,257	4,880	5,271
ANPP 2037 and one SMR	3,893	4,003	4,086	4,224	4,372	4,256	4,517	4,899
ANPP 2026 and One SMR-300	3,893	3,487	3,607	3,632	3,990	4,219	4,526	4,864
ANPP 2037	3,893	4,017	4,086	4,224	4,379	4,580	4,882	5,242
ANPP 2032	3,893	4,017	4,093	4,210	4,367	4,580	4,882	5,242
Baseline	3,893	3,485	3,605	4,206	4,367	4,580	4,882	5,233

Figure 3.39: TPES for nuclear development scenarios, ktoe

FEC projections for all nuclear development scenarios are practically identical to the Baseline Scenario.

ELECTRICITY GENERATION TECHNOLOGIES. Tables 3.16 and 3.17 present the least-cost configuration of Armenia's power sector for the nuclear development scenarios. The main differences in generation capacity configuration are in nuclear, RES, and storage technologies. In all scenarios, electricity generation from ANPP and the new SMR-300 modules results in a redistribution of new solar PV capacities and differences in the implementation schedule for wind farms compared with the Baseline Scenario.

Figures 3.42, 3.43, 3.44, and 3.45 show new capacity implementation schedules for these scenarios over the planning horizon.

Tables 3.18 and 3.19 present generation by power plant for the nuclear development scenarios. Figures 3.46–3.49 show projected generation capacity by power plant and generation technology for the nuclear development scenarios and their differences from the Baseline Scenario over the planning horizon.

Electricity generation in the ANPP 2032 and ANPP 2037 scenarios directly corresponds to the selected generation capacities. The main differences in the generation mix compared with the Baseline Scenario are the result of extended ANPP operation, with almost 3.37 TWh of electricity production in 2027 and 2030 replacing gas-fired power plant production. In the ANPP 2037 scenario, additional wind and solar capacities as well as gas-fired generation are implemented in 2033–2036.

In the ANPP 2026 and One SMR-300 scenario, there is no nuclear generation in the power system in 2033–2035. During this period, the demand is mostly covered by additional generation from gas-fired plants and solar PV, whereas forced implementation of new nuclear plants in the scenarios ANPP 2037 and One SMR-300 and ANPP 2037 and Two SMR-300 result in reduced RES generation.

INVESTMENTS IN NEW POWER SYSTEM CAPACITY. Changes in the generation technology mix affect total power sector investment in new generation. Table 3.20 and Figures 3.50 and 3.51 compare investments in new capacity between the nuclear development and Baseline Scenarios. There are practically no differences between the ANPP life extension scenarios over the entire planning horizon, only a reallocation of NPP investments from 2033 to 2040. More investments are required in the other three scenarios due to the considerable differences in the new SMR-300 module implementation schedule and the amount of installed capacity compared with the Baseline Scenario.

GHG EMISSIONS per nuclear development scenario are presented in Figure 3.52. They are almost equal in all scenarios, except for ANPP 2026 and One SMR-300, where emissions are similar to the Baseline Scenario in 2027 and 2030 and differ from other nuclear scenarios in 2033. This is because in this scenario, only a 300-MW SMR is foreseen in 2036. GHG emissions for all scenarios are the same in 2024, reflecting an identical generation mix.

ENERGY INDEPENDENCE. Figure 3.53 represents the level of energy independence, which will not exceed 40 percent under any scenario in any milestone year. The independence level for the ANPP 2026 and One SMR-300 scenario is the lowest due to increased gas-fired generation replacing nuclear and solar generation.

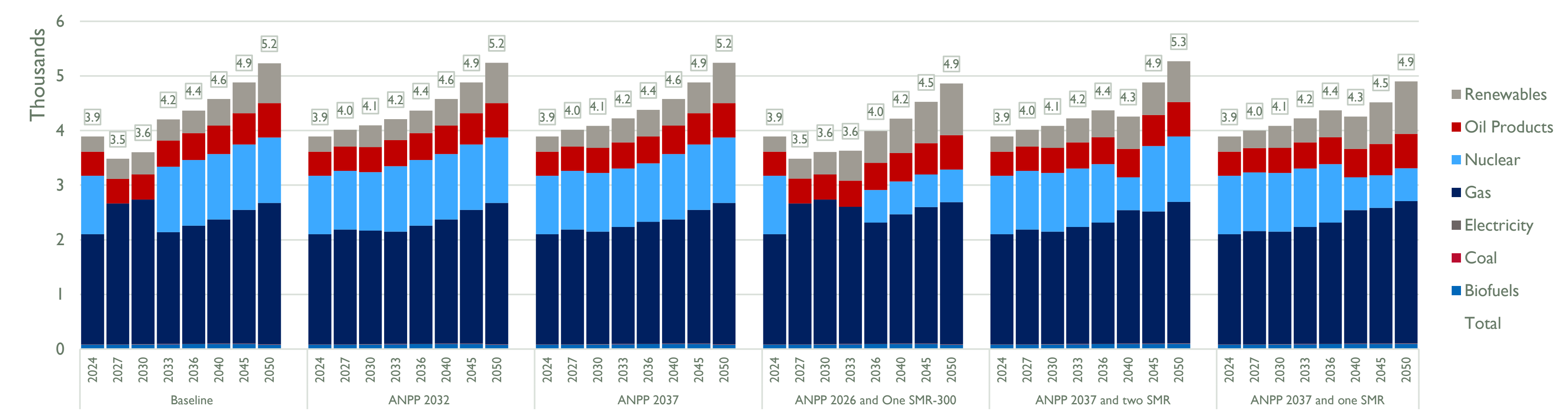
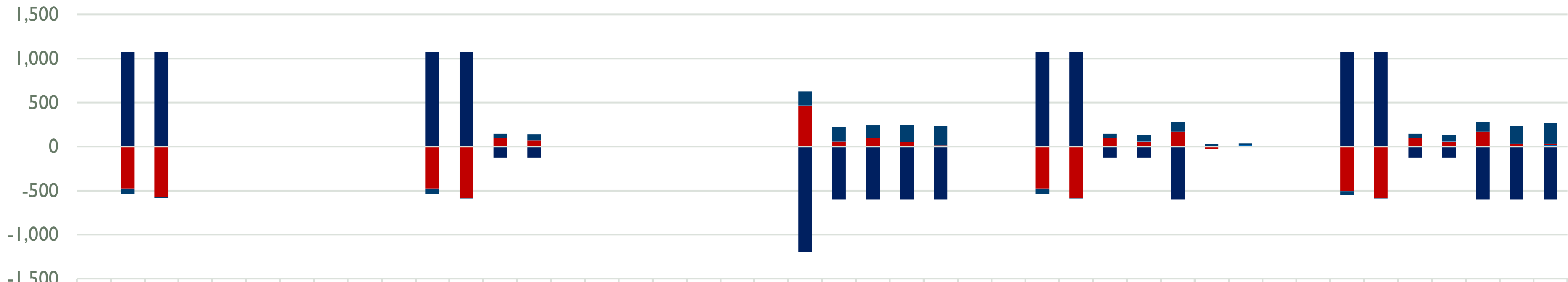


Figure 3.40: TPES by fuel for Nuclear development scenarios, ktoe



ANPP 2032	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	0	-62	-15	-5	-0.02	-0.2	0.01	10
Oil Products	0	-1	0	0	0	0	0	0
Nuclear	0	1,071	1,071	0	0	0	0	0
Gas	-0.02	-477	-568	9	-0.04	0.37	0.01	-1
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	0

ANPP 2037	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	0	-62	-7	53	69	-0.2	0.01	10
Oil Products	0	-1	0	0.3	0.3	0	0	0
Nuclear	0	1,071	1,071	-128	-128	0	0	0
Gas	-0.02	-477	-584	92	70	0.4	0.01	-1
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	0

ANPP 2026 and One SMR-300	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	0	0	0	160	167	145	192	216
Oil Products	0	0	0	0.3	0.3	0	0	0
Nuclear	0	0	0	-1,19	-599	-599	-599	-599
Gas	-0.00	1	1	465	55	94	51	14
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	0

ANPP 2037 and two SMR	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	0	-62	-7	53	77	105	28	19
Oil Products	0	-1	0	0.3	0.3	0	0	0
Nuclear	0	1,071	1,071	-128	-128	-599	0	0
Gas	-0.02	-477	-584	92	55	171	-31	2
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	17

ANPP 2037 and one SMR	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	0	-46	-7	53	77	105	198	232
Oil Products	0	-1	0	0.3	0.3	0	0	0
Nuclear	0	1,071	1,071	-128	-128	-599	-599	-599
Gas	-0.02	-506	-584	92	54	171	36	17
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	17

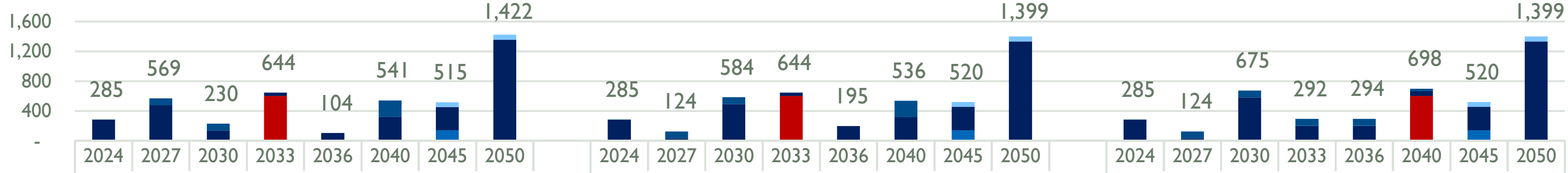
Figure 3.41: Comparison of TPES for nuclear development and Baseline Scenarios, ktoe

TABLE 3.16: CAPACITY BY PLANT/PLANT TYPE FOR BASELINE AND TWO NUCLEAR DEVELOPMENT SCENARIOS, MW

SCENARIO	BASELINE								ANPP 2032								ANPP 2037							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	-	-	-	66	66	-	-	-	-	-	-	66	66	-	-	-	-	-	-	66	66
Shnokh HPP	-	-	-	-	-	-	75	75	-	-	-	-	-	-	75	75	-	-	-	-	-	-	75	75
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	440	440	-	-	-	-	-	440	440	440	440	440	-	-	-
NPP (new)	-	-	-	600	600	600	600	600	-	-	-	600	600	600	600	600	-	-	-	-	-	600	600	600
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,026	1,130	1,452	1,727	2,630	369	400	890	935	1,130	1,446	1,726	2,771	369	400	982	1,181	1,381	1,446	1,726	2,771
Hydro pumped storage plant	-	-	-	-	-	-	65	130	-	-	-	-	-	-	65	130	-	-	-	-	-	-	65	130
Lithium-ion storage	-	-	-	0.02	0.02	0.02	0.02	0.06	-	-	-	0.02	0.02	0.02	0.02	0.07	-	-	-	0.01	0.02	0.02	0.02	0.07
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	409	409	371	4	97	190	190	190	410	410	372	4	97	190	283	376	410	410	372
Total	**3,233**	**3,362**	**3,592**	**3,769**	**3,873**	**4,414**	**4,616**	**5,289**	**3,233**	**3,357**	**3,941**	**3,678**	**3,873**	**4,409**	**4,616**	**5,431**	**3,233**	**3,357**	**4,032**	**3,857**	**4,151**	**4,409**	**4,616**	**5,431**

TABLE 3.17: CAPACITY BY PLANT/PLANT TYPE FOR THREE NUCLEAR DEVELOPMENT SCENARIOS, MW

SCENARIO	ANPP 2026 AND ONE SMR-300								ANPP 2037 AND TWO SMR								ANPP 2037 AND ONE SMR							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Geothermal	-	-	-	25	25	25	25	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	66	66	66	66	66	-	-	-	-	-	-	-	66	-	-	-	-	-	-	66	66
Shnokh HPP	-	-	-	75	75	75	75	75	-	-	-	-	-	-	-	75	-	-	-	-	-	-	75	75
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	440	440	440	440	-	-	-	440	440	440	440	440	-	-	-
NPP (new)	-	-	-	-	300	300	300	300	-	-	-	-	-	300	600	600	-	-	-	-	-	300	300	300
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,371	1,705	1,800	2,519	3,290	369	400	982	1,181	1,550	1,939	2,219	2,944	369	516	982	1,181	1,549	1,939	2,629	3,572
Hydro pumped storage plant	-	-	-	65	65	65	130	195	-	-	-	-	-	65	130	195	-	-	-	-	-	65	130	195
Lithium-ion storage	-	-	-	-	-	-	0.1	0.1	-	-	-	0.01	0.02	0.02	0.1	0.1	-	-	-	0.01	0.02	0.02	0.1	0.2
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	283	319	476	500	462	4	97	190	283	376	500	500	462	4	97	190	283	376	500	500	462
Total	**3,233**	**3,362**	**3,592**	**3,839**	**4,508**	**4,760**	**5,289**	**5,830**	**3,233**	**3,357**	**4,032**	**3,857**	**4,320**	**4,757**	**5,123**	**5,759**	**3,233**	**3,473**	**4,032**	**3,857**	**4,319**	**4,757**	**5,374**	**6,087**

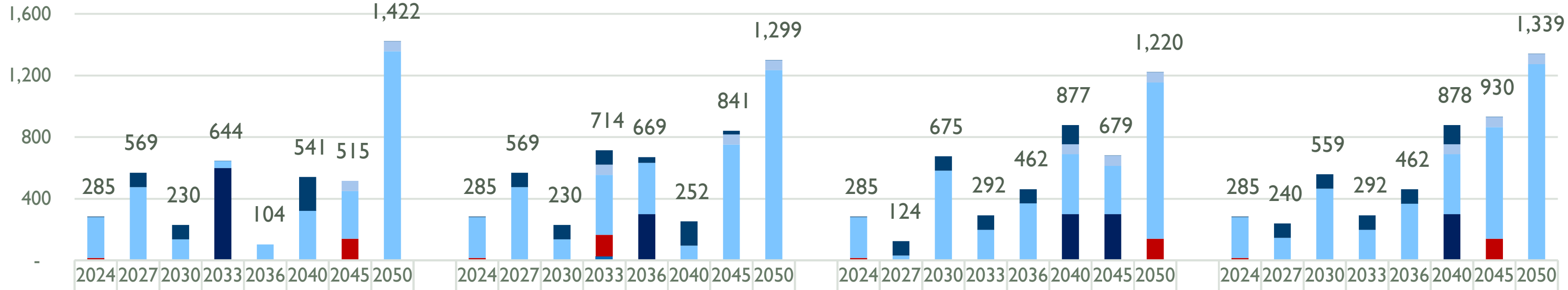


Baseline	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	-	219	-	-
Lithium-ion storage	-	-	-	0.02	-	0.002	-	0.04
Hydro pumped storage plant	-	-	-	-	-	-	65	65
Solar	266	476	137	44	104	322	309	1,357
Nuclear	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-
Total	285	569	230	644	104	541	515	1,422

ANPP 2032	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	-	220	-	-
Lithium-ion storage	-	-	-	0.02	-	0.002	-	0.04
Hydro pumped storage plant	-	-	-	-	-	-	65	65
Solar	266	31	491	44	195	316	314	1,333
Nuclear	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-
Total	285	124	584	644	195	536	520	1,399

ANPP 2037	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	93	93	34	-	-
Lithium-ion storage	-	-	-	0.01	0.02	-	-	0.04
Hydro pumped storage plant	-	-	-	-	-	-	65	65
Solar	266	31	582	199	201	64	314	1,333
Nuclear	-	-	-	-	-	600	-	-
Hydro	15	-	-	-	-	-	141	-
Total	285	124	675	292	294	698	520	1,399

Figure 3.42: New capacity implementation schedule in ANPP life extension scenarios, MW



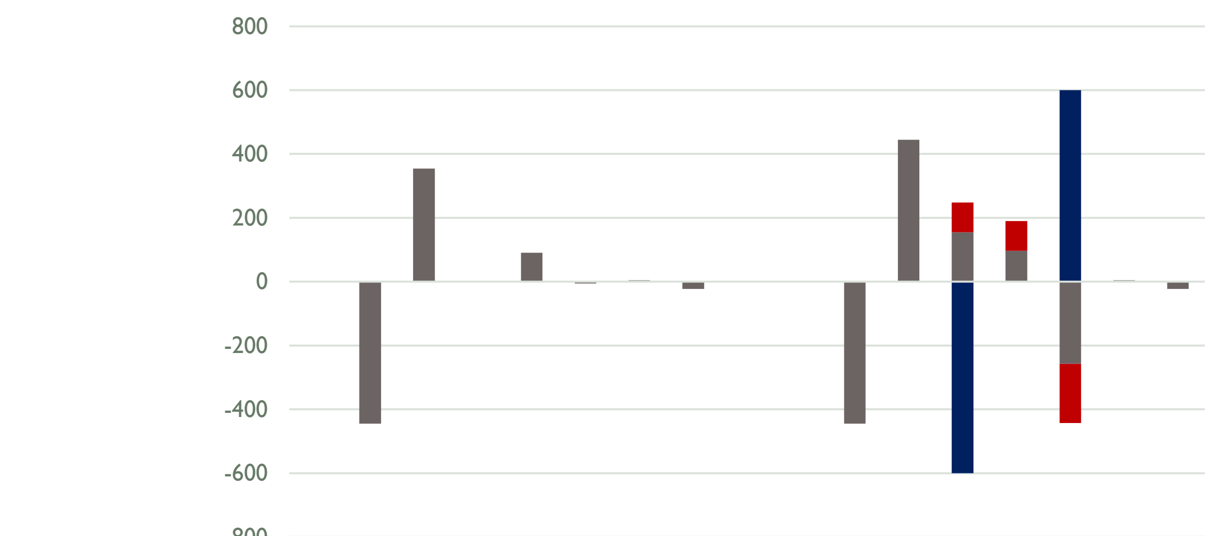
Baseline	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	-	219	-	-
Lithium-ion storage	-	-	-	0.0	-	0.0	-	0.0
Hydro pumped storage plant	-	-	-	-	-	-	65	65
Solar	266	476	137	44	104	322	309	1,3
Nuclear	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-
Geothermal	-	-	-	-	-	-	-	-
Total	285	569	230	644	104	541	515	1,4

ANPP 2026 and One SMR-300	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	93	36	158	24	-
Lithium-ion storage	-	-	-	-	-	-	0.1	0.0
Hydro pumped storage plant	-	-	-	65	-	-	65	65
Solar	266	476	137	390	334	95	752	1,2
Nuclear	-	-	-	-	300	-	-	-
Hydro	15	-	-	141	-	-	-	-
Geothermal	-	-	-	25	-	-	-	-
Total	285	569	230	714	669	252	841	1,2

ANPP 2037 and two SMR	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	93	93	124	-	-
Lithium-ion storage	-	-	-	0.0	0.0	-	0.0	0.0
Hydro pumped storage plant	-	-	-	-	-	65	65	65
Solar	266	31	582	199	369	388	314	1,0
Nuclear	-	-	-	-	-	300	300	-
Hydro	15	-	-	-	-	-	-	141
Geothermal	-	-	-	-	-	-	-	-
Total	285	124	675	292	462	877	679	1,2

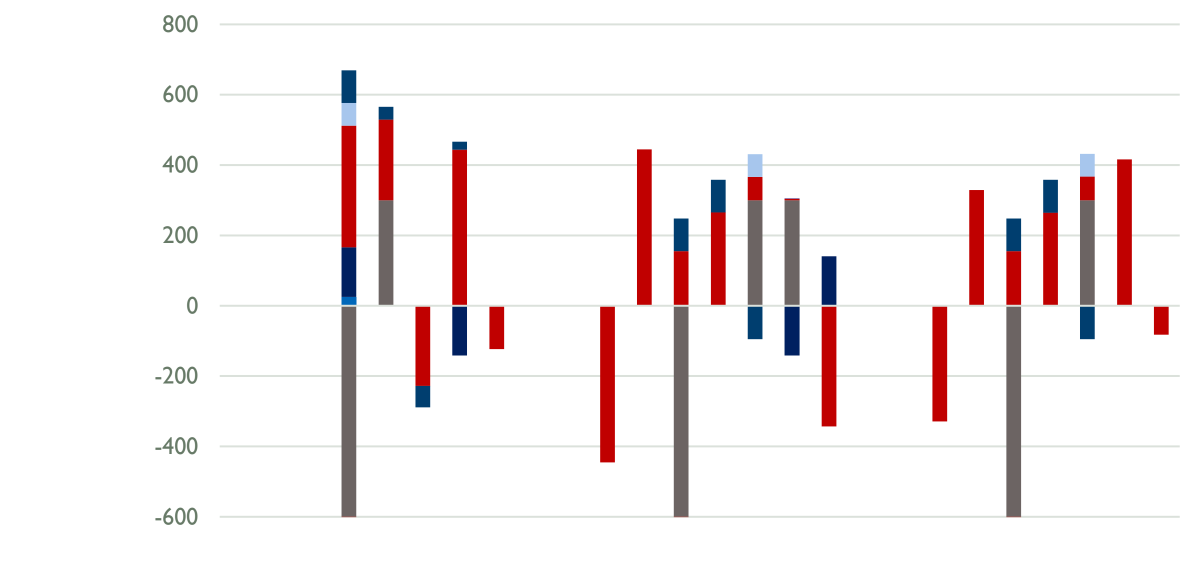
ANPP 2037 and one SMR	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	93	93	124	-	-
Lithium-ion storage	-	-	-	0.0	0.0	-	0.1	0.1
Hydro pumped storage plant	-	-	-	-	-	65	65	65
Solar	266	147	466	199	369	389	724	1,2
Nuclear	-	-	-	-	-	300	-	-
Hydro	15	-	-	-	-	-	141	-
Geothermal	-	-	-	-	-	-	-	-
Total	285	240	559	292	462	878	930	1,3

Figure 3.43: New capacity implementation schedule in ANPP life extension and new NPP scenarios, MW



	ANPP 2032								ANPP 2037							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0	0	1	0	0	0	0	0	93	93	-185	0	0
Lithium-ion storage	0	0	0	0	0	0	0	0.002	0	0	0	-0.01	0.02	-0.002	0	0.001
Hydro pumped storage plant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar	0	-445	354	0	91	-6	5	-23	0	-445	445	155	97	-258	5	-23
Nuclear	0	0	0	0	0	0	0	0	0	0	0	-600	0	600	0	0
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3.44: Comparison of new power plant construction for ANPP life extension scenarios and Baseline Scenario, MW



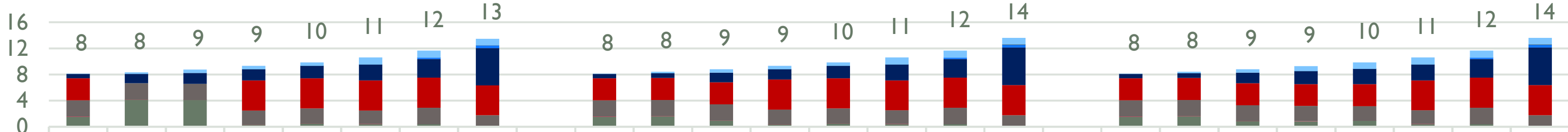
	ANPP 2026 and One SMR-300								ANPP 2037 and two SMR								ANPP 2037 and one SMR							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	93	36	-61	24	0	0	0	0	93	93	-95	0	0	0	0	0	93	93	-95	0	0
Lithium-ion storage	0	0	0	-0.02	0	-0.00	0.1	0	0	0	0	-0.01	0.02	-0.00	0.03	-0.01	0	0	0	-0.01	0.02	-0.00	0.1	0.02
Hydro pumped storage plant	0	0	0	65	0	0	0	0	0	0	0	0	0	65	0	0	0	0	0	0	0	65	0	0
Solar	0	0	0	346	230	-227	443	-123	0	-445	445	155	266	66	5	-343	0	-329	329	155	265	67	415	-83
Nuclear	0	0	0	-600	300	0	0	0	0	0	0	-600	0	300	300	0	0	0	0	-600	0	300	0	0
Hydro	0	0	0	141	0	0	-141	0	0	0	0	0	0	0	-141	141	0	0	0	0	0	0	0	0
Geothermal	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3.45: Comparison of new power plant construction for ANPP life extension scenarios, new NPP scenarios, and Baseline Scenario, MW

TABLE 3.18: GENERATION BY PLANT/PLANT TYPE FOR BASELINE AND TWO NUCLEAR DEVELOPMENT SCENARIOS, GWH																								
SCENARIO	BASELINE								ANPP 2032								ANPP 2037							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	71	1,672	1,672	22	59	60	-	-	71	87	82	22	59	60	-	-	71	87	82	22	59	60	-	-
Yerevan CCGT-2	1,471	1,891	1,891	248	417	343	364	-	1,471	1,506	864	300	417	346	364	-	1,471	1,506	766	739	799	346	364	-
Hrazdan Unit 5	-	591	510	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Local cogeneration plant	7	7	7	7	7	8	8	26	7	7	7	7	7	8	8	26	7	7	7	7	7	8	8	26
Vorotan HPP Cascade	984	984	984	979	984	984	984	598	984	984	984	984	984	984	984	589	984	984	984	984	984	984	984	589
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346	414	414	414	414	414	414	414	346	414	414	414	414	414	414	414	346
Loriberd HPP	-	-	-	-	-	-	203	203	-	-	-	-	-	-	203	203	-	-	-	-	-	-	203	203
Shnokh HPP	-	-	-	-	-	-	291	291	-	-	-	-	-	-	291	291	-	-	-	-	-	-	291	291
Small HPP (existing)	932	935	935	654	790	528	492	122	932	932	905	743	790	533	492	154	932	932	857	774	692	533	492	154
Small HPP (new)	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-	3,374	3,374	3,374	-	-	-	-	-	3,374	3,374	3,374	3,374	3,374	-	-	-
NPP (new)	-	-	-	4,601	4,601	4,601	4,601	4,601	-	-	-	4,601	4,601	4,601	4,601	4,601	-	-	-	-	-	4,601	4,601	4,601
Solar (existing)	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	1,645	1,811	2,328	2,770	5,689	592	641	1,428	1,499	1,811	2,318	2,768	5,781	592	641	1,574	1,893	2,215	2,318	2,768	5,781
Hydro pumped storage plant	-	-	-	-	-	-	188	376	-	-	-	-	-	-	188	376	-	-	-	-	-	-	188	376
Lithium-ion storage	-	-	-	15	8	20	20	68	-	-	-	15	8	20	20	86	-	-	-	4	11	20	20	86
Wind (existing)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	1,091	1,091	990	11	259	507	507	507	1,093	1,093	158	11	259	507	755	1,003	1,093	1,093	992
Total	**8,095**	**8,347**	**8,734**	**9,332**	**9,839**	**10,617**	**11,667**	**13,472**	**8,095**	**8,443**	**8,804**	**9,332**	**9,839**	**10,617**	**11,666**	**13,608**	**8,095**	**8,443**	**8,804**	**9,277**	**9,847**	**10,617**	**11,666**	**13,608**

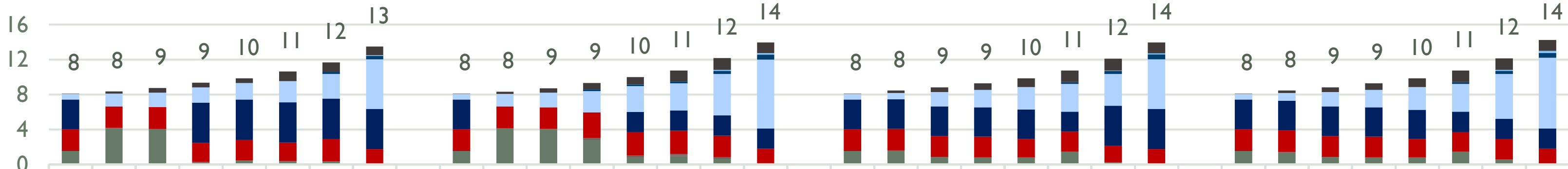
TABLE 3.19: GENERATION BY PLANT/PLANT TYPE FOR THREE NUCLEAR DEVELOPMENT SCENARIOS, GWH

SCENARIO	ANPP 2026 AND ONE SMR-300								ANPP 2037 AND TWO SMR								ANPP 2037 AND ONE SMR							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	71	1,672	1,672	1,032	89	115	-	-	71	87	82	92	107	204	-	-	71	76	82	92	107	202	-	-
Yerevan CCGT-2	1,471	1,891	1,891	1,784	723	864	631	-	1,471	1,506	766	739	702	1,243	252	-	1,471	1,337	766	739	701	1,244	576	-
Hrazdan Unit 5	-	575	487	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Local cogeneration plant	7	7	7	17	7	8	26	26	7	7	7	7	7	8	8	26	7	7	7	7	7	8	8	26
Geothermal	-	-	-	194	187	187	157	106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vorotan HPP Cascade	984	984	984	984	984	984	848	588	984	984	984	984	984	984	785	632	984	984	984	984	984	984	787	693
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	246	414	414	414	414	414	414	414	313	414	414	414	414	414	414	338	240
Loriberd HPP	-	-	-	203	203	203	203	203	-	-	-	-	-	-	-	203	-	-	-	-	-	-	203	203
Shnokh HPP	-	-	-	291	291	291	291	291	-	-	-	-	-	-	-	291	-	-	-	-	-	-	291	291
Small HPP (existing)	932	935	935	886	647	648	562	180	932	932	857	774	519	723	482	122	932	925	857	774	518	721	566	202
Small HPP (new)	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-	3,374	3,374	3,374	3,374	3,374	-	-	-	3,374	3,374	3,374	3,374	3,374	-	-	-
NPP (new)	-	-	-	-	2,300	2,300	2,300	2,300	-	-	-	-	-	2,300	4,601	4,601	-	-	-	-	-	2,300	2,300	2,300
Solar (existing)	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	2,341	2,876	3,028	4,674	7,905	592	641	1,574	1,893	2,486	3,108	3,558	5,669	592	827	1,574	1,893	2,484	3,108	5,030	8,075
Hydro pumped storage plant	-	-	-	188	188	188	376	564	-	-	-	-	-	188	376	564	-	-	-	-	-	188	376	564
Lithium-ion storage	-	-	-	-	-	-	102	159	-	-	-	4	11	-	37	126	-	-	-	4	11	-	100	232
Wind (existing)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	755	850	1,271	1,334	1,233	11	259	507	755	1,003	1,334	1,334	1,233	11	259	507	755	1,003	1,334	1,334	1,233
Total	**8,095**	**8,332**	**8,711**	**9,330**	**10,002**	**10,741**	**12,159**	**13,963**	**8,095**	**8,443**	**8,804**	**9,277**	**9,847**	**10,746**	**12,087**	**13,943**	**8,095**	**8,443**	**8,804**	**9,277**	**9,844**	**10,743**	**12,150**	**14,222**



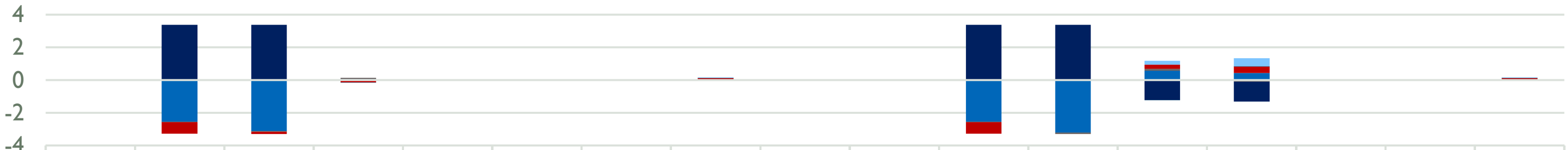
	Baseline								ANPP 2032								ANPP 2037							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0	0.01	0.3	0.5	0.8	1.0	1.1	1.1	1.0
Lithium-ion storage	-	-	-	0.02	0.01	0.02	0.02	0.07	-	-	-	0.02	0.01	0.02	0.02	0.1	-	-	-	0.004	0.01	0.02	0.02	0.1
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4	-	-	-	-	-	-	0.2	0.4	-	-	-	-	-	-	0.2	0.4
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7	0.7	0.7	1.5	1.6	1.9	2.4	2.8	5.8	0.7	0.7	1.7	2.0	2.3	2.4	2.8	5.8
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6	3.4	3.4	3.4	4.6	4.6	4.6	4.6	4.6	3.4	3.4	3.4	3.4	3.4	4.6	4.6	4.6
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7	2.5	2.5	2.5	2.3	2.3	2.1	2.5	1.7	2.5	2.5	2.4	2.3	2.2	2.1	2.5	1.7
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-	1.5	1.6	0.9	0.3	0.5	0.4	0.4	-	1.5	1.6	0.8	0.8	0.9	0.4	0.4	-
Total	8	8	9	9	10	11	12	13	8	8	9	9	10	11	12	14	8	8	9	9	10	11	12	14

Figure 3.46: Electricity generation by power plant/type for ANPP life extension scenarios, TWh



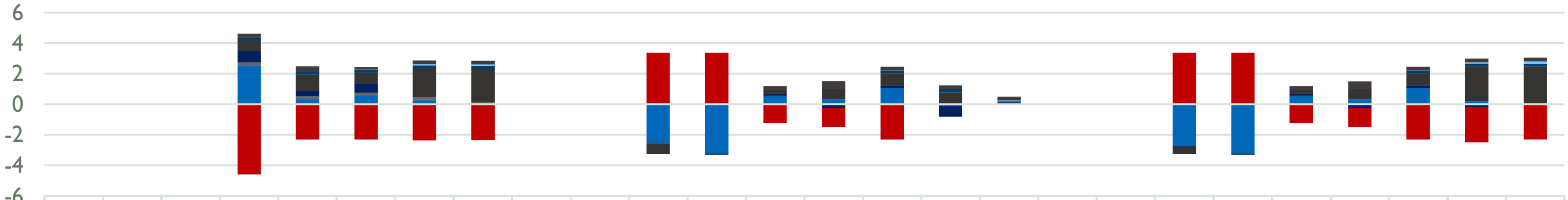
	Baseline								ANPP 2026 and One SMR-300								ANPP 2037 and two SMR								ANPP 2037 and one SMR							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.0	0.3	0.5	0.5	0.5	1.1	1.1	1.0	0.0	0.3	0.5	0.8	0.9	1.3	1.3	1.2	0.0	0.3	0.5	0.8	1.0	1.3	1.3	1.2	0.0	0.3	0.5	0.8	1.0	1.3	1.3	1.2
Lithium-ion storage	-	-	-	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-	-	0.1	0.2	-	-	-	0.0	0.0	-	0.0	0.1	-	-	-	0.0	0.0	-	0.1	0.2
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4	-	-	-	0.2	0.2	0.2	0.4	0.6	-	-	-	-	-	0.2	0.4	0.6	-	-	-	-	-	0.2	0.4	0.6
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7	0.7	1.4	1.7	2.4	3.0	3.1	4.8	7.9	0.7	0.7	1.7	2.0	2.6	3.2	3.6	5.7	0.7	0.9	1.7	2.0	2.6	3.2	5.1	8.1
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6	3.4	-	-	-	2.3	2.3	2.3	2.3	3.4	3.4	3.4	3.4	3.4	2.3	4.6	4.6	3.4	3.4	3.4	3.4	3.4	2.3	2.3	2.3
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7	2.5	2.5	2.5	2.9	2.7	2.7	2.5	1.7	2.5	2.5	2.4	2.3	2.1	2.3	1.8	1.7	2.5	2.5	2.4	2.3	2.1	2.3	2.3	1.8
Geothermal	-	-	-	-	-	-	-	-	-	-	-	0.2	0.2	0.2	0.2	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gas-fired CHPs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-	1.5	4.1	4.1	2.8	0.8	1.0	0.6	-	1.5	1.6	0.8	0.8	0.8	1.4	0.3	-	1.5	1.4	0.8	0.8	0.8	1.4	0.6	-
Total	8	8	9	9	10	11	12	13	8	8	9	9	10	11	12	14	8	8	9	9	10	11	12	14	8	8	9	9	10	11	12	14

Figure 3.47: Electricity generation by power plant/type for ANPP life extension and new NPP scenarios, TWh



	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
	ANPP 2032								ANPP 2037							
Wind	0	0	0	0	0	0.002	0.002	0.002	0	0	0	0.2	0.5	0.002	0.002	0.002
Lithium-ion storage	0	0	0	0	0	0	0	0.02	0	0	0	-0.01	0.003	0	0	0.02
Hydro pumped storage plant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar	0	-1	-0.1	-0.1	0	-0.01	-0.002	0.1	0	-1	0	0.2	0.4	-0.01	-0.002	0.1
Nuclear	0	3	3	0	0	0	0	0	0	3	3	-1	-1	0	0	0
Hydro	0	-0.003	-0.03	0.1	0	0.005	0	0.02	0	-0.003	-0.1	0.1	-0.1	0.005	0	0.02
Gas-fired CHPs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas-fired	0	-3	-3	0.05	0	0.003	0	0	0	-3	-3	1	0.4	0.003	0	0

Figure 3.48: Comparison of electricity generation by power plant/type for ANPP life extension scenarios and Baseline Scenario, TWh



ANPP 2026 and One SMR-300	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0.2	0.3	0.2	0.2	0.2
Lithium-ion storage	0	0	0	-0.02	-0.01	-0.02	0.1	0.1
Hydro pumped storage plant	0	0	0	0.2	0.2	0.2	0.2	0.2
Solar	0	0	0	1	1	1	2	2
Nuclear	0	0	0	-5	-2	-2	-2	-2
Hydro	0	0	0	1	0.4	1	-0.1	-0.1
Geothermal	0	0	0	0.2	0.2	0.2	0.2	0.1
Gas-fired CHPs	0	0	0	0.01	0	0	0.02	0
Gas-fired	0	-0.02	-0.02	3	0.3	1	0.3	0

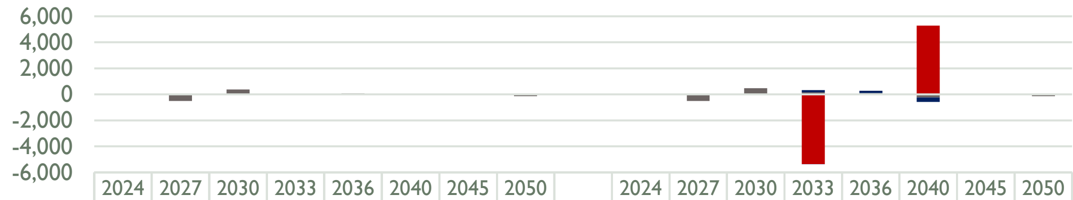
ANPP 2037 and two SMR	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0.2	0.5	0.2	0.2	0.2
Lithium-ion storage	0	0	0	-0.01	0.003	-0.02	0.02	0.1
Hydro pumped storage plant	0	0	0	0	0	0.2	0.2	0.2
Solar	0	-1	0	0.2	1	1	1	-0.02
Nuclear	0	3	3	-1	-1	-2	0	0
Hydro	0	-0.00	-0.1	0.1	-0.3	0.2	-1	0.001
Geothermal	0	0	0	0	0	0	0	0
Gas-fired CHPs	0	0	0	0	0	0	0	0
Gas-fired	0	-3	-3	1	0.3	1	-0.1	0

ANPP 2037 and one SMR	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0.2	0.5	0.2	0.2	0.2
Lithium-ion storage	0	0	0	-0.01	0.003	-0.02	0.1	0.2
Hydro pumped storage plant	0	0	0	0	0	0.2	0.2	0.2
Solar	0	-1	0	0.2	1	1	2	2
Nuclear	0	3	3	-1	-1	-2	-2	-2
Hydro	0	-0.01	-0.1	0.1	-0.3	0.2	-0.2	0.1
Geothermal	0	0	0	0	0	0	0	0
Gas-fired CHPs	0	0	0	0	0	0	0	0
Gas-fired	0	-3	-3	1	0.3	1	0.2	0

Figure 3.49 Comparison of electricity generation by power plant/type for ANPP life extension scenarios, new NPP scenarios, and Baseline Scenario, TWh

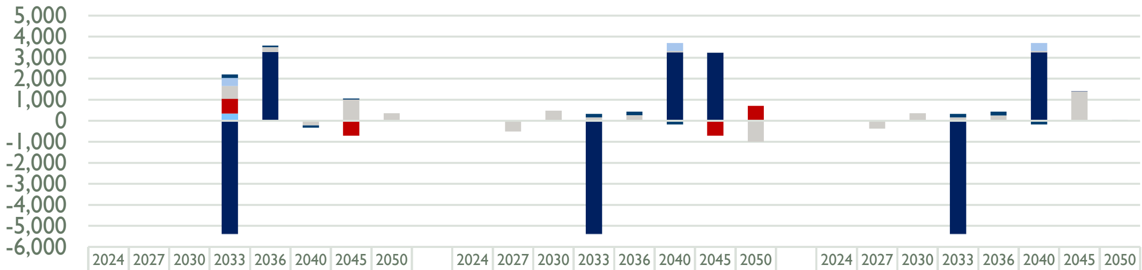
TABLE 3.20: TOTAL POWER SECTOR INVESTMENTS FOR NEW CAPACITY FOR NUCLEAR DEVELOPMENT SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	12,854	-
ANPP 2032	12,662	-1.5
ANPP 2037	12,599	-2.0
ANPP 2026 and One SMR-300	13,636	6.1
ANPP 2037 and One SMR	13,166	2.4
ANPP 2037 and Two SMR	13,947	8.5



	ANPP 2032								ANPP 2037							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0	0	1	0	0	0	0	0	177	176	-348	0	0
Lithium-ion storage	0	0	0	0	0	0	0	0.001	0	0	0	-0.01	0.01	-0.001	0	0.001
Hydro pumped storage plant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar	0	-511	379	0	89	-5	4	-149	0	-511	476	158	95	-242	4	-149
Nuclear	0	0	0	0	0	0	0	0	0	0	0	-5,375	0	5,285	0	0
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3.50: Comparison of investments in new power system capacity for ANPP life extension scenarios and Baseline Scenario, millions of USD

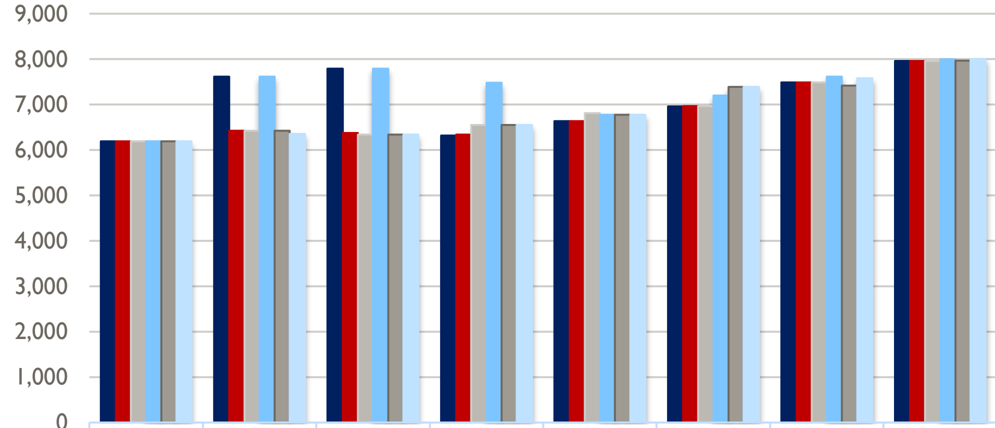


	ANPP 2026 and One SMR-300							
	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	177	68	-115	44	0
Lithium-ion storage	0	0	0	-0.01	0	-0.00	0.05	0
Hydro pumped storage plant	0	0	0	377	0	0	0	0
Solar	0	0	0	609	225	-214	1,019	355
Nuclear	0	0	0	-5,37	3,277	0	0	0
Hydro	0	0	0	709	0	0	-709	0
Geothermal	0	0	0	337	0	0	0	0

	ANPP 2037 and two SMR							
	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	177	176	-178	0	0
Lithium-ion storage	0	0	0	-0.01	0.01	-0.00	0.01	-0.00
Hydro pumped storage plant	0	0	0	0	0	377	0	0
Solar	0	-511	476	158	260	62	4	-1,00
Nuclear	0	0	0	-5,37	0	3,253	3,220	0
Hydro	0	0	0	0	0	0	-709	709
Geothermal	0	0	0	0	0	0	0	0

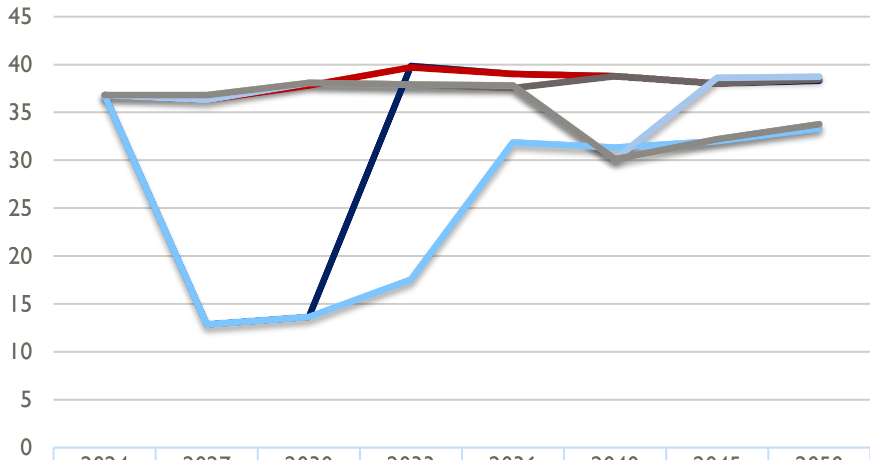
	ANPP 2037 and one SMR							
	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	177	176	-178	0	0
Lithium-ion storage	0	0	0	-0.01	0.01	-0.00	0.03	0.011
Hydro pumped storage plant	0	0	0	0	0	377	0	0
Solar	0	-378	352	158	259	63	1,401	28
Nuclear	0	0	0	-5,37	0	3,253	0	0
Hydro	0	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0	0

Figure 3.51: Comparison of investments in new power system capacity for ANPP life extension scenarios, new NPP scenarios, and Baseline Scenario, millions of USD



	2024	2027	2030	2033	2036	2040	2045	2050
Baseline	6,191	7,614	7,789	6,320	6,637	6,962	7,491	7,961
ANPP 2032	6,191	6,422	6,375	6,343	6,637	6,963	7,491	7,959
ANPP 2037	6,191	6,422	6,336	6,551	6,813	6,963	7,491	7,959
ANPP 2026 and One SMR-300	6,191	7,617	7,792	7,478	6,774	7,195	7,617	7,996
ANPP 2037 and two SMR	6,191	6,422	6,336	6,551	6,774	7,387	7,414	7,967
ANPP 2037 and one SMR	6,191	6,350	6,336	6,551	6,774	7,387	7,580	8,004

Figure 3.52: GHG emissions (CO2eq) for nuclear development scenarios, kt



	2024	2027	2030	2033	2036	2040	2045	2050
Baseline	37	13	14	40	39	39	38	38
ANPP 2032	37	36	38	40	39	39	38	38
ANPP 2037	37	36	38	38	38	39	38	38
ANPP 2026 and One SMR-300	37	13	14	18	32	31	32	33
ANPP 2037 and two SMR	37	36	38	38	38	30	39	39
ANPP 2037 and one SMR	37	37	38	38	38	30	32	34

Figure 3.53: Energy independence levels for nuclear development scenarios, %

ENERGY EFFICIENCY SCENARIOS

The energy efficiency scenarios consider improvements in end-use technologies and an increase in the share of EVs.

IMPROVEMENT IN END-USE TECHNOLOGY SCENARIOS

To examine the influence of different levels of energy efficiency implemented in the system, four end-use technology improvement scenarios were considered. EE-No Limit places no limits on measures such as replacing demand-side technologies with advanced, better, or improved ones by 2050 to achieve the least-cost solution. The other three scenarios introduce different levels of forced implementation of energy efficiency measures: 20 percent (EE-20), 50 percent (EE-50), and 90 percent (EE-90).

TOTAL SYSTEM COST in all scenarios is lower than in the Baseline Scenario (Table 3.21), and it decreases as energy efficiency penetration increases in end-use technologies. Although efficient technologies have higher costs, reduced energy consumption means that total system cost decreases.

TABLE 3.21: TOTAL SYSTEM COST FOR ENERGY EFFICIENCY SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	67,763	-
EE-No Limit	49,559	-26.9
EE-20	66,644	-1.7
EE-50	63,670	-6.0
EE-90	61,087	-9.9

TPES projections are presented in Figure 3.54, which shows that TPES falls with the increase in the energy efficiency of demand-side technologies. In the EE-No Limit, EE-50, and EE-90 scenarios, this is a result of moving the construction of a new 600-MW NPP to 2040. TPES in the EE-20 scenario is very close to that in the Baseline Scenario, with practically the same composition over the planning period. The results of TPES by fuel type are presented in Figures 3.55 and 3.56. Figures 3.57 and 3.58 illustrate the differences in TPES composition compared to the Baseline Scenario.

FEC projections are presented in Figure 3.59; in all scenarios, it is lower than in the Baseline Scenario (Figures 3.60 and 3.61).

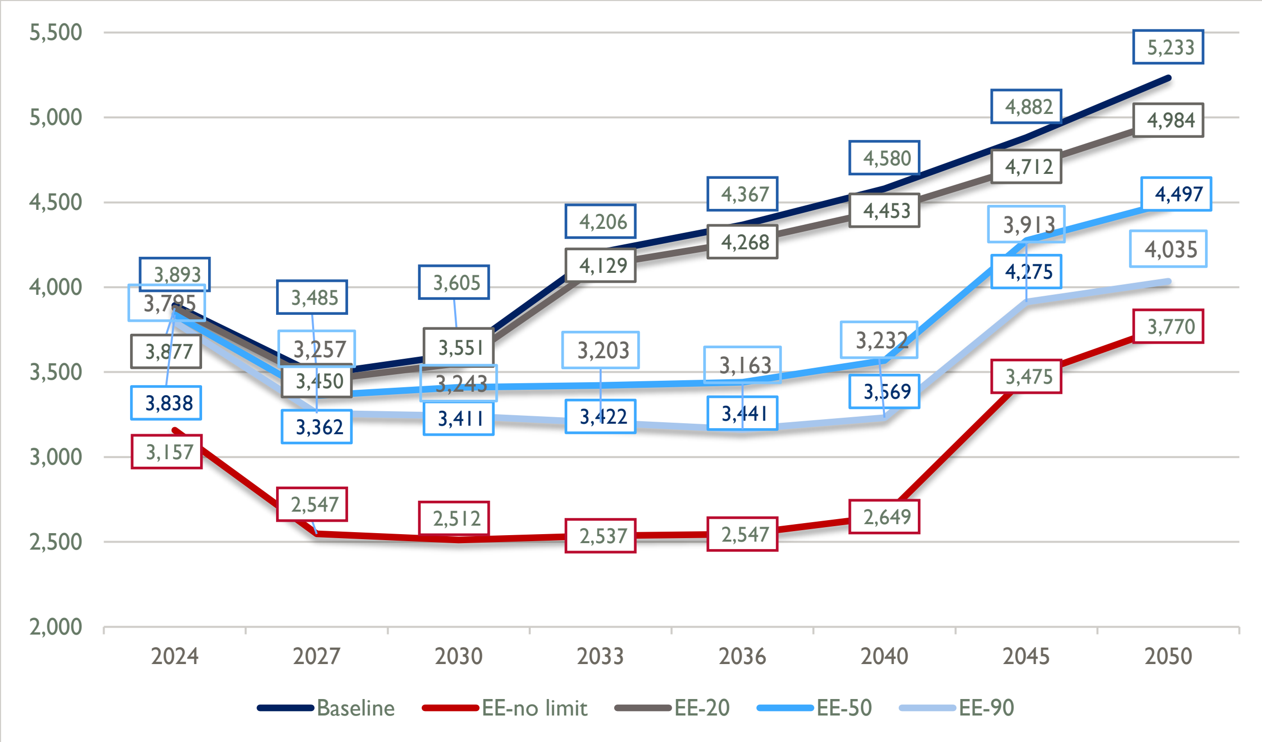


Figure 3.54: TPES for energy efficiency scenarios, ktoe

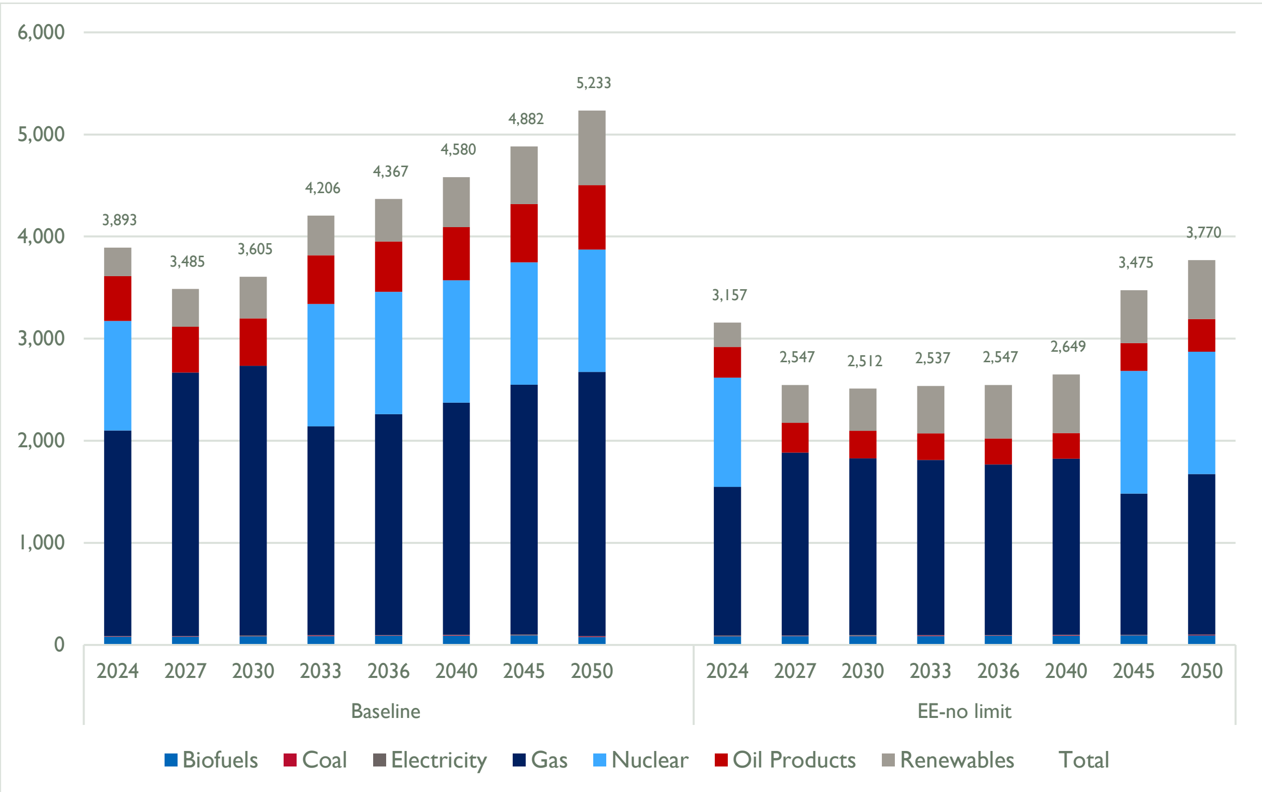


Figure 3.55: TPES by fuel type for EE-No Limit scenario, ktoe

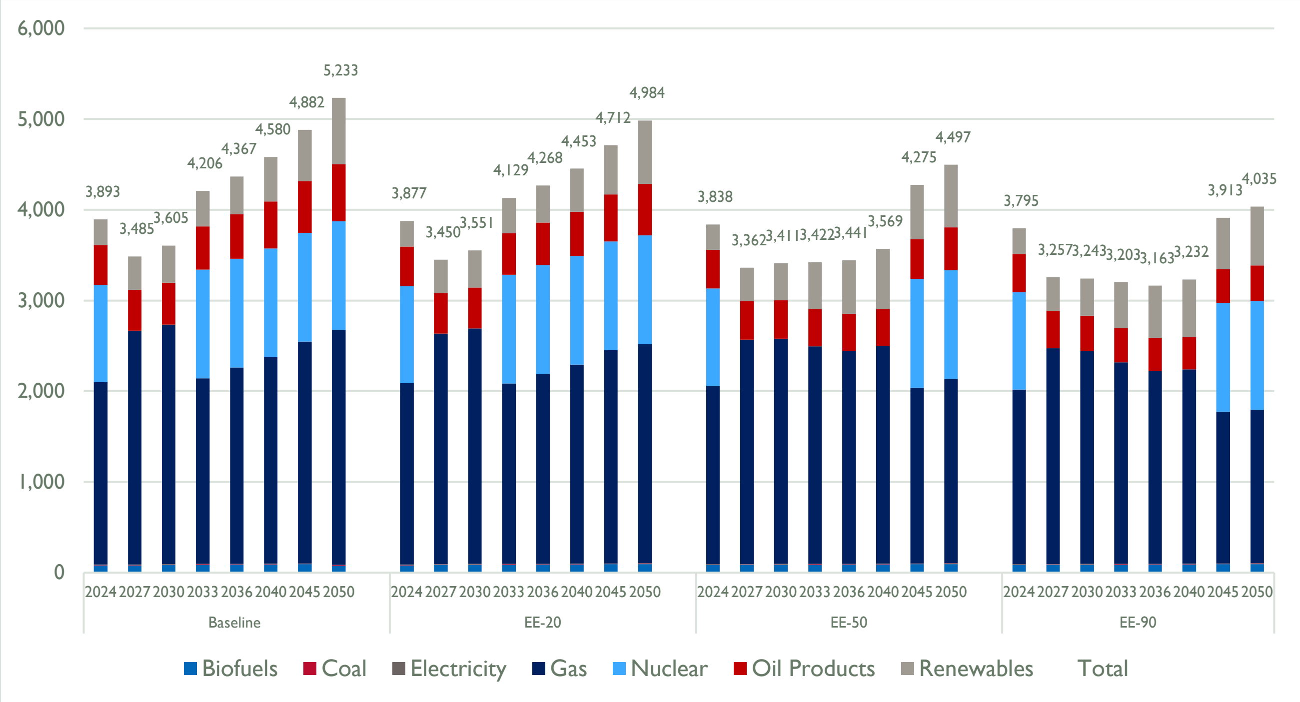
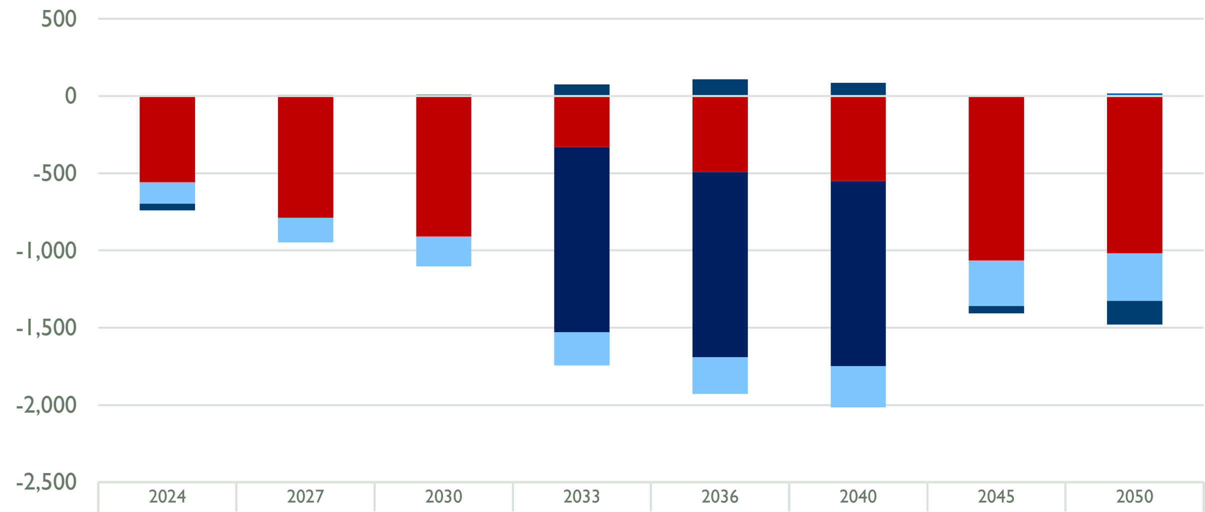
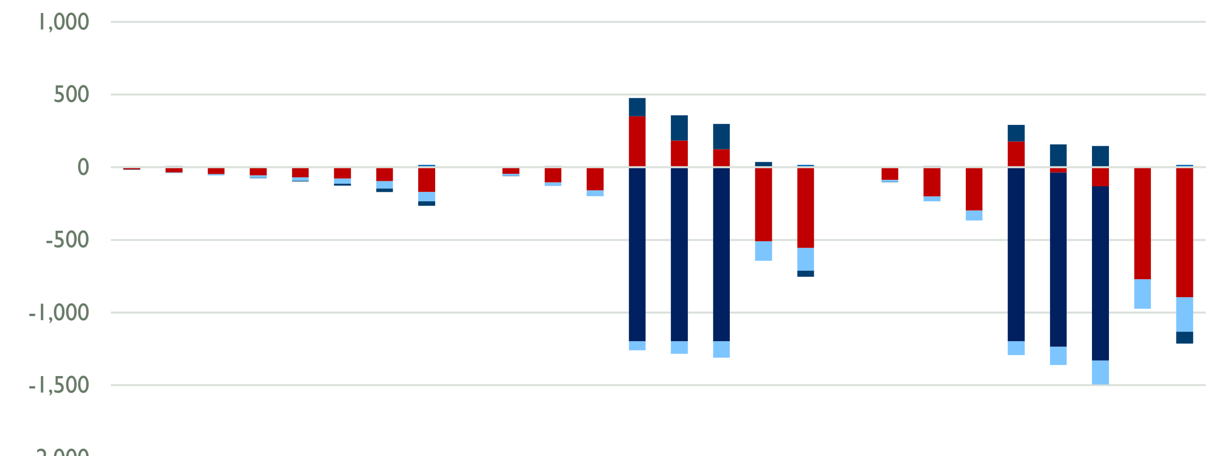


Figure 3.56: TPES by fuel type for EE-20, EE-50, and EE-90 scenarios, ktoe



	2024	2027	2030	2033	2036	2040	2045	2050
	EE-no limit							
Renewables	-42.8	2.3	6	75	108	85	-48	-153
Oil Products	-140	-160	-192	-215	-239	-269	-295	-308
Nuclear	0	0	0	-1,199	-1,199	-1,199	0	0
Gas	-557	-787	-910	-331	-491	-549	-1,063	-1,018
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	-1	0
Biofuels	4.5	6	3	0	0	0	0	17

Figure 3.57: Comparison of TPES by fuel type between EE-No Limit scenario and Baseline Scenario, ktoe



EE-20	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	-0.2	0.2	0.3	-2	-6	-13	-23	-31
Oil Products	-2	-4	-10	-18	-24	-35	-52	-63
Nuclear	0	0	0	0	0	0	0	0
Gas	-14	-37	-47	-57	-69	-78	-96	-171
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Biofuels	0	6	3	0	0	0	0	17

EE-50	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	-1	0.3	1	126	173	173	36	-41
Oil Products	-12	-25	-39	-62	-84	-111	-133	-157
Nuclear	0	0	0	-1,19	-1,19	-1,19	0	0
Gas	-46	-105	-160	351	184	125	-510	-555
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Biofuels	5	6	3	0	0	0	0	17

EE-90	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	-0.5	2	3	113	157	146	4	-82
Oil Products	-14	-35	-69	-95	-125	-164	-201	-238
Nuclear	0	0	0	-1,19	-1,19	-1,19	0	0
Gas	-87	-201	-299	178	-38	-132	-772	-895
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Biofuels	5	6	3	0	0	0	0	17

Figure 3.58: Comparison of TPES by fuel type between EE-20, EE-50, and EE-90 scenarios and Baseline Scenario, ktoe

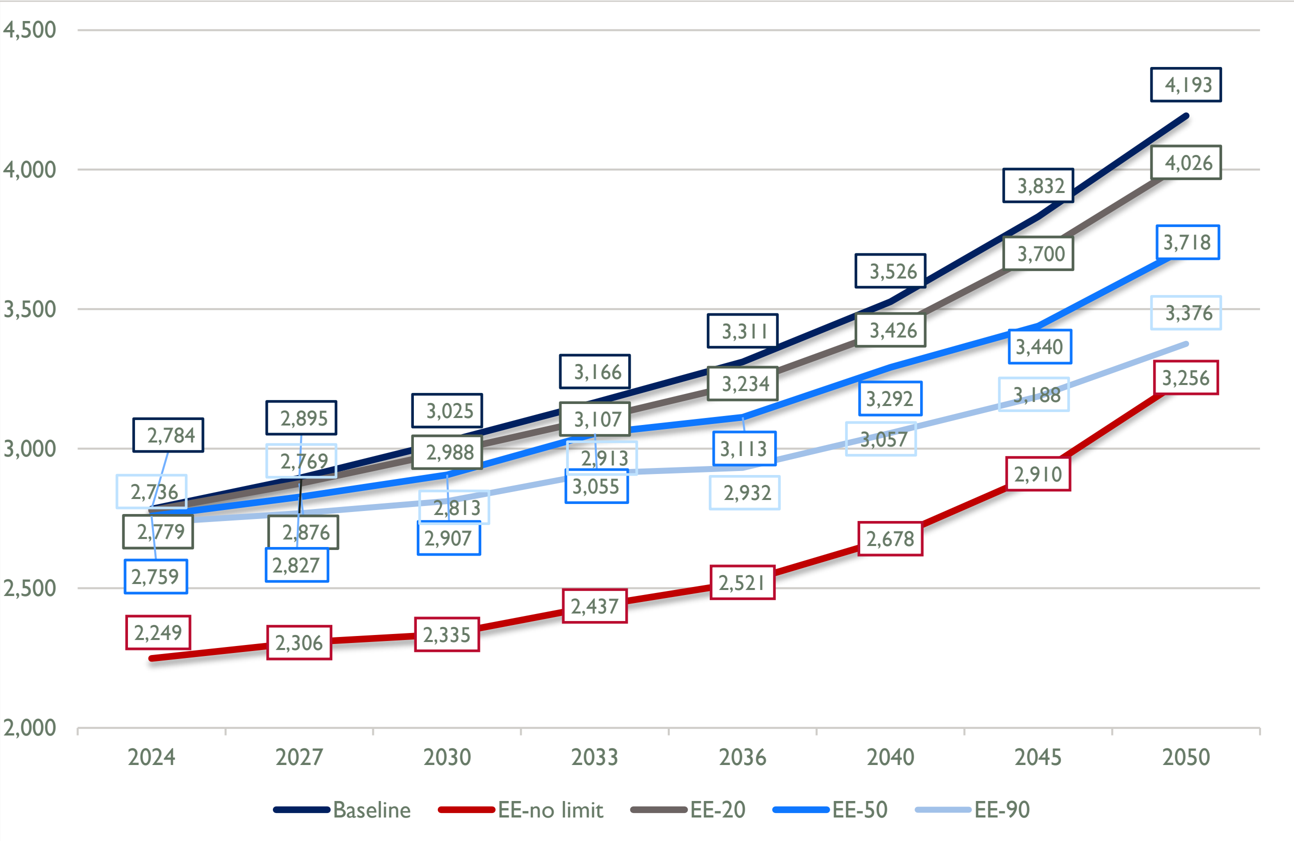


Figure 3.59: FEC for energy efficiency scenarios, ktoe

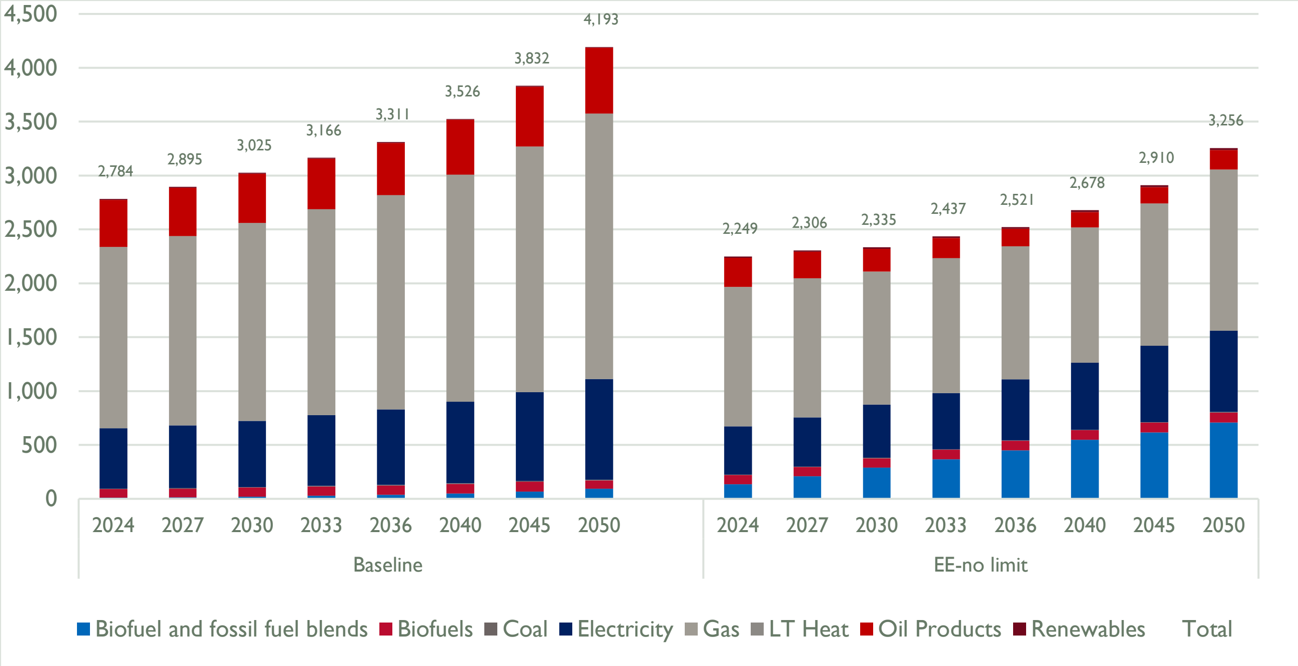


Figure 3.60: FEC by fuel type for EE-No Limit scenario, ktoe

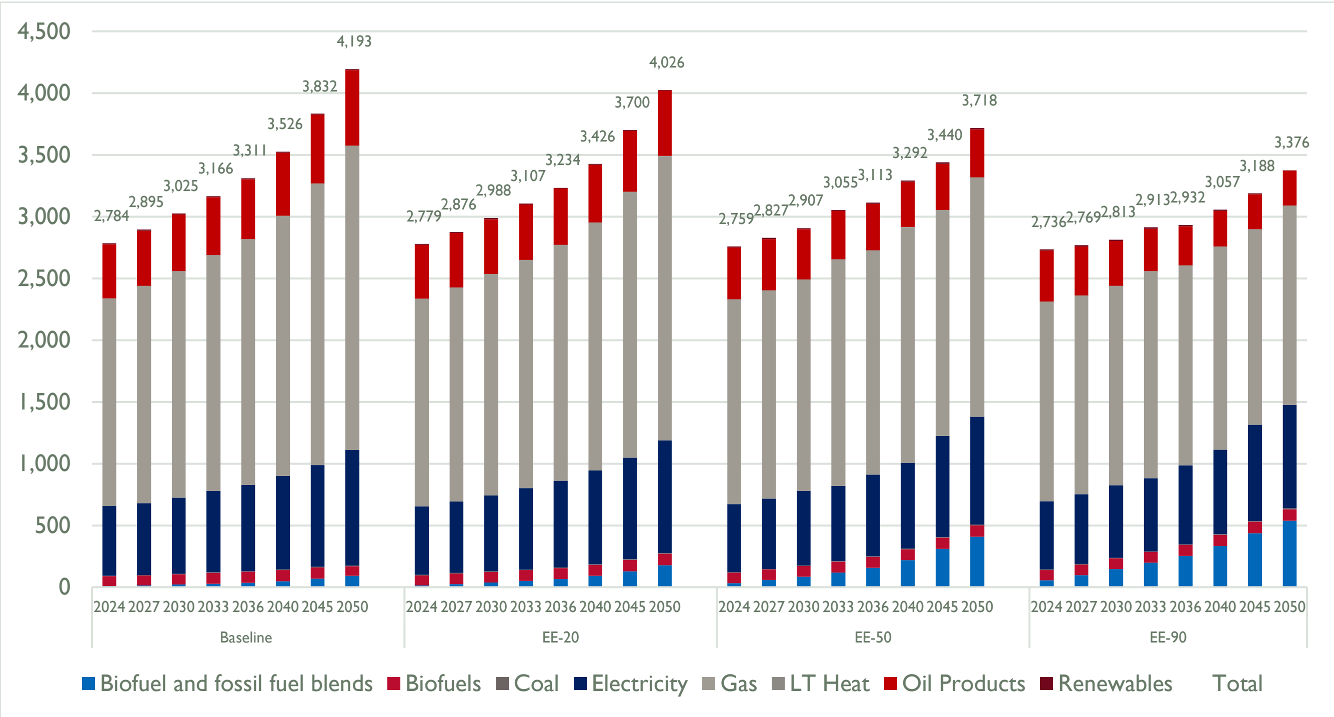
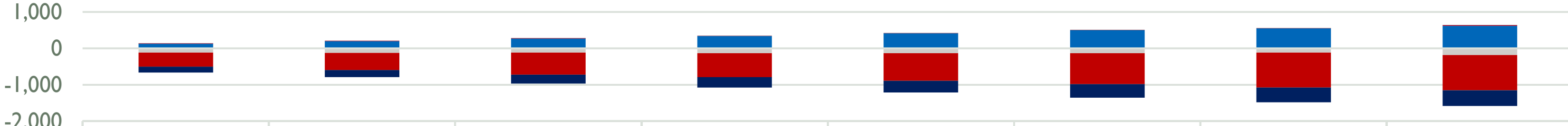


Figure 3.61: FEC by fuel type for EE-20, EE-50, and EE-90 scenarios, ktoe

Figures 3.62 and 3.63 illustrate the differences in composition of FEC compared to the Baseline Scenario.



EE-no limit	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	2	2	6	7	7	9	10	12
Oil Products	-165	-198	-246	-283	-321	-368	-404	-431
LT Heat	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Gas	-390	-468	-601	-657	-756	-849	-960	-968
Electricity	-113	-125	-121	-135	-132	-137	-114	-182
Coal	-0.3	0	0	0	0	0	-1	0
Biofuels	5	6	3	0	0	0	0	17
Biofuel and fossil fuel blends	127	195	269	340	413	498	547	615

Figure 3.62: Comparison of FEC by fuel type for EE-No Limit scenario and Baseline Scenario, ktoe

EE-20	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	-0.04	0.2	0.3	0.1	-0.3	-1	-1	-2
Oil Products	-3	-6	-14	-22	-30	-44	-64	-80
LT Heat	-0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02
Gas	-2	-25	-43	-61	-78	-98	-127	-161
Electricity	-6	-4	-1	1	1	0	-1	-25
Coal	0	0	0	0	0	0	0	0
Biofuels	0	6	3	0	0	0	0	17
Biofuel and fossil fuel blends	6	10	16	23	30	42	61	85

EE-50	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	-0.2	0.3	1	2	2	3	4	3
Oil Products	-17	-33	-52	-80	-109	-144	-181	-220
LT Heat	-0.01	-0.02	-0.02	-0.02	-0.04	-0.1	-0.1	-0.1
Gas	-26	-71	-122	-75	-174	-199	-452	-527
Electricity	-10	-11	-13	-48	-39	-63	-4	-63
Coal	0	0	0	0	0	0	0	0
Biofuels	5	6	3	0	0	0	0	17
Biofuel and fossil fuel blends	23	42	64	91	121	169	241	315

EE-90	2024	2027	2030	2033	2036	2040	2045	2050
Renewables	1	2	3	3	3	2	-1	-5
Oil Products	-23	-51	-94	-129	-169	-221	-275	-327
LT Heat	-0.02	-0.03	-0.05	-0.1	-0.1	-0.1	-0.1	-0.2
Gas	-66	-147	-223	-231	-370	-461	-694	-850
Electricity	-10	-18	-27	-66	-61	-74	-44	-97
Coal	0	0	0	0	0	0	0	0
Biofuels	5	6	3	0	0	0	0	17
Biofuel and fossil fuel blends	45	83	126	169	217	284	369	445

Figure 3.63: Comparison of FEC by fuel type between EE-20, EE-50, and EE-90 scenarios and Baseline Scenario, ktoe

ELECTRICITY GENERATION TECHNOLOGIES. The least-cost configuration of the power sector under these scenarios is presented in Tables 3.22 and 3.23. Significant changes in generation capacity configuration relate to the NPP and RES implementation schedules, as well as less RES capacity depending on demand.

Figures 3.64, 3.65, 3.66, and 3.67 provide the new capacity implementation schedules over the planning horizon.

Generation by power plant is presented in Tables 3.24 and 3.25. Figures 3.68, 3.69, 3.70, and 3.71 show projected generation capacity by power plant and generation technology for each energy efficiency scenario and how they differ from the Baseline Scenario over the planning horizon.

The EE-20 scenario practically repeats the Baseline Scenario with slightly reduced generation, stipulated by lower consumption from more efficient demand technologies. The only difference is the postponement of Loriberd HPP construction from 2045 to 2050 and an insignificant reduction of solar and wind capacities.

By contrast, the EE-50 and EE-90 scenarios differ highly from the Baseline Scenario because of the postponement of the new 600-MW NPP from 2033 to 2045, faster development of solar in 2033–2045, the reduction of total solar power by 160–170 MW at the end of the planning horizon, and the implementation of about 90 MW of additional wind capacity. In the EE-50 scenario, the Loriberd HPP is implemented much earlier (in 2033) than in the Baseline Scenario (2045), but it is not added until 2050 in the EE-90 scenario. Both scenarios implement the Shnokh HPP in 2033, compared with 2045 in the Baseline Scenario. Furthermore, both scenarios only need one hydro pumped storage plant with 65 MW capacity from 2033, in contrast to the Baseline Scenario (130 MW in 2050).

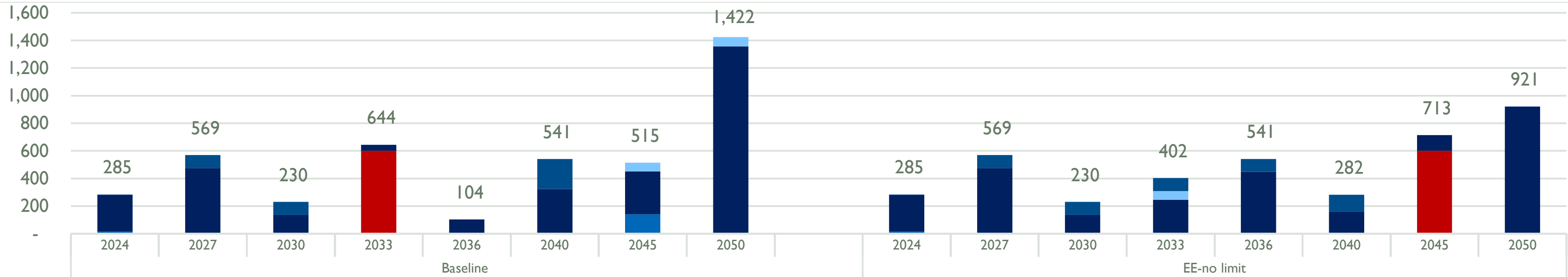
In the EE-No Limit scenario, neither the Loriberd nor the Shnokh HPP is needed, and the new 600-MW NPP is rescheduled to 2045 from 2033 in the Baseline Scenario. In this scenario, only one hydro pumped storage plant with 65 MW capacity is required from 2033. Solar power is slightly reduced, unlike wind, which is implemented at its maximum permissible level (500 MW).

TABLE 3.22: CAPACITY BY PLANT/PLANT TYPE FOR EE-NO LIMIT SCENARIO, MW

SCENARIO	BASELINE								EE-NO LIMIT							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8P	8	8	8	8	8	8
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	-
Shnokh HPP	-	-	-	-	-	-	75	75	-	-	-	-	-	-	-	-
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-
NPP (new)	-	-	-	600	600	600	600	600	-	-	-	-	-	-	600	600
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,026	1,130	1,452	1,727	2,630	369	845	982	1,226	1,674	1,832	1,912	2,379
Hydro pumped storage plant	-	-	-	-	-	-	65	130	-	-	-	65	65	65	65	65
Lithium-ion storage	-	-	-	0.02	0.02	0.02	0.02	0.06	0.002	0.002	0.002	0.002	0.002	0.01	0.06	0.1
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	409	409	371	4	97	190	283	376	500	500	462
Total	**3,233**	**3,362**	**3,592**	**3,769**	**3,873**	**4,414**	**4,616**	**5,289**	**3,233**	**3,362**	**3,592**	**3,527**	**4,069**	**4,351**	**4,751**	**4,923**

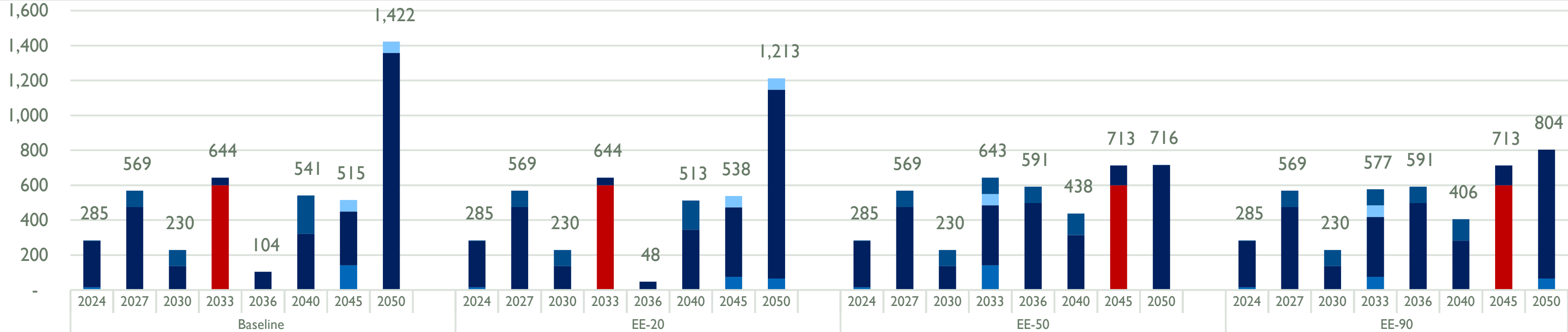
TABLE 3.23: CAPACITY BY PLANT/PLANT TYPE FOR EE-20, EE-50, EE-90 SCENARIOS, MW

SCENARIO	EE-20								EE-50								EE-90							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	-	-	-	-	66	-	-	-	66	66	66	66	66	-	-	-	-	-	-	-	66
Shnokh HPP	-	-	-	-	-	-	75	75	-	-	-	75	75	75	75	75	-	-	-	75	75	75	75	75
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-
NPP (new)	-	-	-	600	600	600	600	600	-	-	-	-	-	-	600	600	-	-	-	-	-	-	600	600
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,026	1,074	1,420	1,785	2,413	369	845	982	1,326	1,824	2,139	2,218	2,471	369	845	982	1,326	1,824	2,106	2,185	2,460
Hydro pumped storage plant	-	-	-	-	-	-	65	130	-	-	-	65	65	65	65	65	-	-	-	65	65	65	65	65
Lithium-ion storage	-	-	-	0.02	0.02	0.02	0.02	0.06	-	-	-	-	0.01	0.1	0.1	0.1	-	-	-	-	-	0.05	0.1	0.1
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	356	356	319	4	97	190	283	376	500	500	462	4	97	190	283	376	500	500	462
Total	**3,233**	**3,362**	**3,592**	**3,769**	**3,818**	**4,330**	**4,556**	**5,020**	**3,233**	**3,362**	**3,592**	**3,768**	**4,360**	**4,798**	**5,198**	**5,156**	**3,233**	**3,362**	**3,592**	**3,702**	**4,294**	**4,699**	**5,099**	**5,145**



	Baseline 2024	2027	2030	2033	2036	2040	2045	2050	EE-no limit 2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	-	219	-	-	4	93	93	93	93	124	-	-
Lithium-ion storage	-	-	-	0.02	-	0.002	-	0.04	0.002	-	-	-	-	0.005	0.06	0.03
Hydro pumped storage plant	-	-	-	-	-	-	65	65	-	-	-	65	-	-	-	-
Solar	266	476	137	44	104	322	309	1,357	266	476	137	244	448	158	113	921
Nuclear	-	-	-	600	-	-	-	-	-	-	-	-	-	-	600	-
Hydro	15	-	-	-	-	-	141	-	15	-	-	-	-	-	-	-
Total	285	569	230	644	104	541	515	1,422	285	569	230	402	541	282	713	921

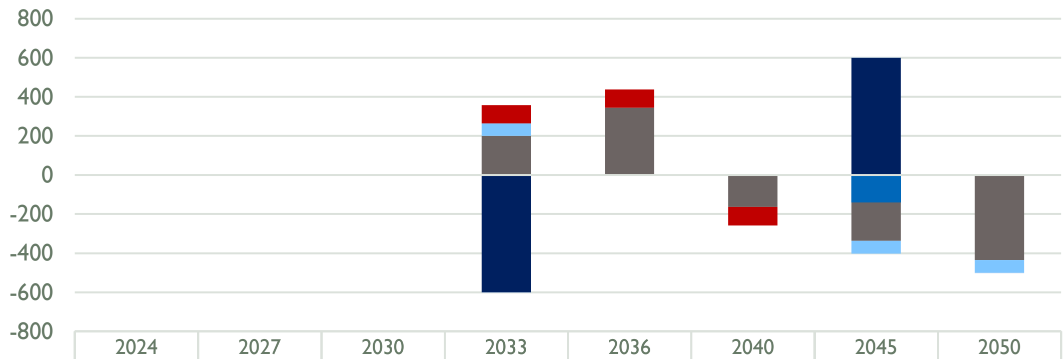
Figure 3.64: New capacity implementation schedule in EE-No Limit scenario, MW



	Baseline 2024	2027	2030	2033	2036	2040	2045	2050	EE-20 2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	-	219	-	-	4	93	93.0	-	-	166	-	-
Lithium-ion storage	-	-	-	0.02	-	0.002	-	0.04	-	-	-	0.02	-	0.000	-	0.03
Hydro pumped storage plant	-	-	-	-	-	-	65	65	-	-	-	-	-	-	65	65
Solar	266	476	137	44	104	322	309	1,357	266	476	137	44	48	346	398	1,082
Nuclear	-	-	-	600	-	-	-	-	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-	15	-	-	-	-	-	75	66
Total	285	569	230	644	104	541	515	1,422	285	569	230	644	48	513	538	1,213

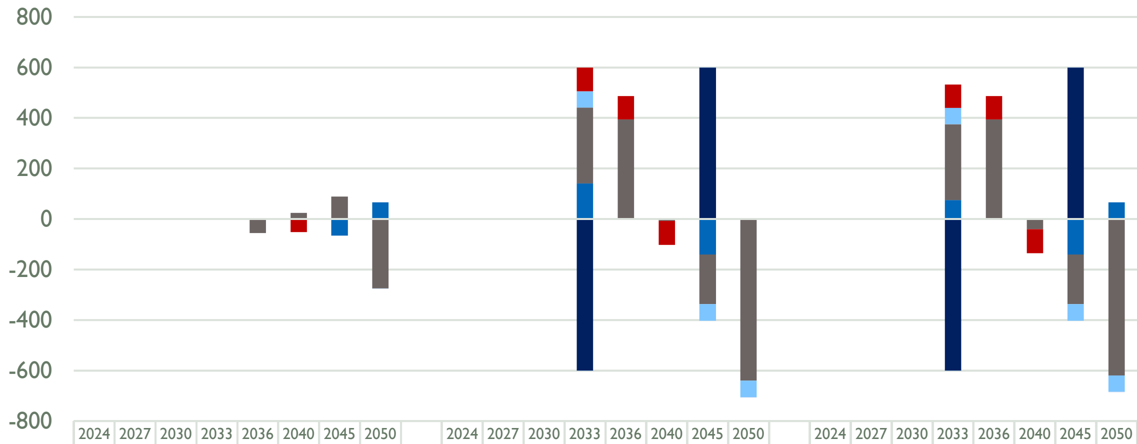
	EE-50 2024	2027	2030	2033	2036	2040	2045	2050	EE-90 2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	93	93	124	-	-	4	93	93	93	93	124	-	-
Lithium-ion storage	-	-	-	-	0.01	0.06	0.01	0.003	-	-	-	-	-	0.05	0.04	-
Hydro pumped storage plant	-	-	-	65	-	-	-	-	-	-	-	65	-	-	-	-
Solar	266	476	137	344	498	314	113	716	266	476	137	344	498	282	113	738
Nuclear	-	-	-	-	-	-	600	-	-	-	-	-	-	-	600	-
Hydro	15	-	-	141	-	-	-	-	15	-	-	75	-	-	-	66
Total	285	569	230	643	591	438	713	716	285	569	230	577	591	406	713	804

Figure 3.65: New capacity implementation schedule in EE-20, EE-50, EE-90 scenarios, MW



	2024	2027	2030	2033	2036	2040	2045	2050
	EE-no limit							
Wind	0	0	0	93	93	-95	0	0
Lithium-ion storage	0.002	0	0	-0.02	0	0.003	0.06	-0.01
Hydro pumped storage plant	0	0	0	65	0	0	-65	-65
Solar	0	0	0	200	344	-164	-196	-435
Nuclear	0	0	0	-600	0	0	600	0
Hydro	0	0	0	0	0	0	-141	0

Figure 3.66: Comparison of new power plant construction for EE-No Limit scenario and Baseline Scenario, MW



	2024	2027	2030	2033	2036	2040	2045	2050
	EE-20							
Wind	0	0	0	0	0	-52	0	0
Lithium-ion storage	0	0	0	0	0	-0.00	0	-0.01
Hydro pumped storage plant	0	0	0	0	0	0	0	0
Solar	0	0	0	0	-56	24	89	-275
Nuclear	0	0	0	0	0	0	0	0
Hydro	0	0	0	0	0	0	-66	66

	2024	2027	2030	2033	2036	2040	2045	2050
	EE-50							
Wind	0	0	0	93	93	-95	0	0
Lithium-ion storage	0	0	0	-0.02	0.01	0.06	0.01	-0.04
Hydro pumped storage plant	0	0	0	65	0	0	-65	-65
Solar	0	0	0	300	394	-8	-196	-640
Nuclear	0	0	0	-600	0	0	600	0
Hydro	0	0	0	141	0	0	-141	0

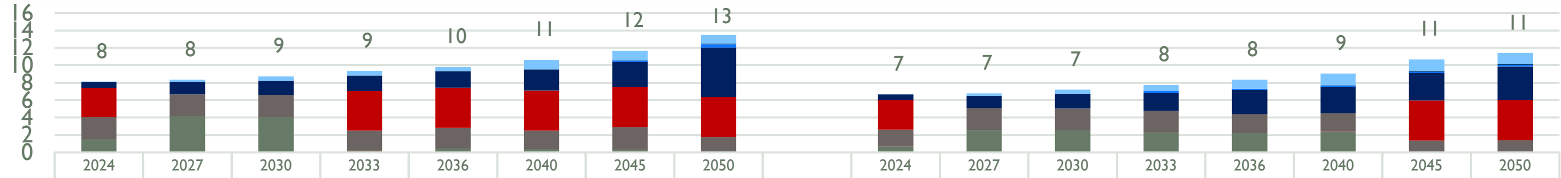
	2024	2027	2030	2033	2036	2040	2045	2050
	EE-90							
Wind	0	0	0	93	93	-95	0	0
Lithium-ion storage	0	0	0	-0.02	0	0.05	0.04	-0.04
Hydro pumped storage plant	0	0	0	65	0	0	-65	-65
Solar	0	0	0	300	394	-40	-196	-619
Nuclear	0	0	0	-600	0	0	600	0
Hydro	0	0	0	75	0	0	-141	66

Figure 3.67: Comparison of new power plant construction for EE-20, EE-50, and EE-90 scenarios and Baseline Scenario, MW

TABLE 3.24: GENERATION BY PLANT/PLANT TYPE FOR EE-NO LIMIT SCENARIO, GWH																
SCENARIO	BASELINE								EE-NO LIMIT							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	71	1,672	1,672	22	59	60	-	-	-	889	916	1,003	956	1,020	-	-
Yerevan CCGT-2	1,471	1,891	1,891	248	417	343	364	-	642	1,521	1,435	1,321	1,284	1,324	19	-
Hrazdan Unit 5	-	591	510	-	-	-	-	-	-	162	196	-	-	-	-	-
Local cogeneration plant	7	7	7	7	7	8	8	26	-	-	-	23	-	30	-	12
Vorotan HPP Cascade	984	984	984	977	984	984	984	598	834	984	984	984	984	984	568	568
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346	407	414	414	414	414	414	284	284
Loriberd HPP	-	-	-	-	-	-	203	203	-	-	-	-	-	-	-	-
Shnokh HPP	-	-	-	-	-	-	291	291	-	-	-	-	-	-	-	-
Small HPP (existing)	932	935	935	654	790	528	492	122	570	935	935	881	589	566	314	369
Small HPP (new)	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	4,601	4,601	4,601	4,601	4,601	-	-	-	-	-	-	4,601	4,601
Solar (existing)	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	1,645	1,811	2,328	2,770	5,689	592	1,354	1,574	1,965	2,684	2,938	3,065	3,869
Hydro pumped storage plant	-	-	-	-	-	-	188	376	-	-	-	188	188	188	188	188
Lithium-ion storage	-	-	-	15	8	20	20	68	1	-	-	-	-	9	62	129
Wind (existing)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	1,091	1,091	990	11	259	507	755	1,003	1,334	1,334	1,233
Total	**8,095**	**8,347**	**8,734**	**9,332**	**9,839**	**10,617**	**11,667**	**13,472**	**6,672**	**6,759**	**7,200**	**7,774**	**8,342**	**9,047**	**10,676**	**11,414**

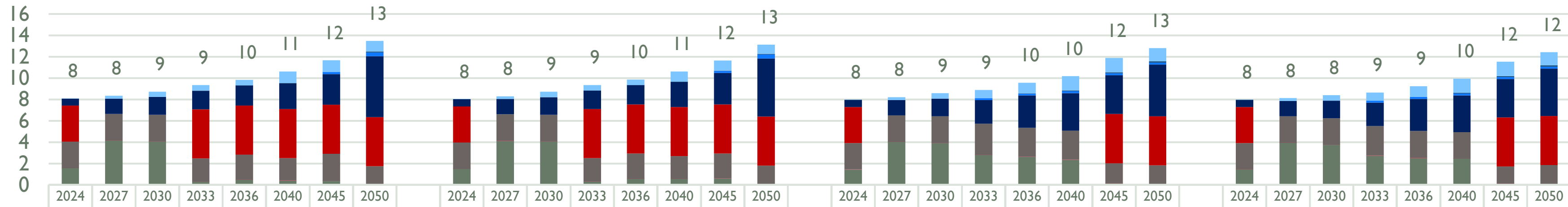
TABLE 3.25: GENERATION BY PLANT/PLANT TYPE FOR EE-20, EE-50, EE-90 SCENARIOS, GWH

SCENARIO	EE-20								EE-50								EE-90							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	64	1,672	1,672	22	54	67	-	-	59	1,672	1,569	1,018	983	893	-	-	56	1,607	1,440	1,004	1,015	1,008	-	-
Yerevan CCGT-2	1,404	1,891	1,891	291	502	488	593	-	1,372	1,891	1,891	1,771	1,631	1,452	140	-	1,381	1,891	1,891	1,725	1,495	1,430	94	-
Hrazdan Unit 5	-	541	499	-	-	-	-	-	-	453	452	-	-	-	-	-	-	430	407	-	-	-	-	-
Local cogeneration plant	7	7	7	7	7	7	7	17	6	6	6	16	16	16	5	15	6	6	5	15	15	14	2	12
Vorotan HPP Cascade	984	984	984	970	984	984	984	612	984	984	984	984	984	984	580	645	984	984	984	984	984	984	568	568
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346	414	414	414	414	414	414	298	274	414	414	414	414	414	414	284	273
Loriberd HPP	-	-	-	-	-	-	-	203	-	-	-	203	203	203	203	203	-	-	-	-	-	-	-	203
Shnokh HPP	-	-	-	-	-	-	291	291	-	-	-	291	291	291	291	291	-	-	-	291	291	291	291	291
Small HPP (existing)	929	935	935	636	818	571	492	159	923	935	935	870	673	673	349	228	916	935	935	907	679	626	325	338
Small HPP (new)	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	4,601	4,601	4,601	4,601	4,601	-	-	-	-	-	-	4,601	4,601	-	-	-	-	-	-	4,601	4,601
Solar (existing)	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	1,645	1,722	2,277	2,863	5,447	592	1,354	1,574	2,126	2,925	3,429	3,556	4,858	592	1,354	1,574	2,126	2,925	3,377	3,504	4,435
Hydro pumped storage plant	-	-	-	-	-	-	188	376	-	-	-	188	188	188	188	188	-	-	-	188	188	188	188	188
Lithium-ion storage	-	-	-	15	10	21	16	56	-	-	-	-	9	62	93	101	-	-	-	-	-	34	90	122
Wind (existing)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	951	951	850	11	259	507	755	1,003	1,334	1,334	1,233	11	259	507	755	1,003	1,334	1,334	1,233
Total	**8,019**	**8,297**	**8,722**	**9,348**	**9,859**	**10,622**	**11,641**	**13,120**	**7,974**	**8,208**	**8,573**	**8,877**	**9,560**	**10,177**	**11,878**	**12,799**	**7,972**	**8,120**	**8,398**	**8,649**	**9,249**	**9,940**	**11,522**	**12,426**



	Baseline 2024	Baseline 2027	Baseline 2030	Baseline 2033	Baseline 2036	Baseline 2040	Baseline 2045	Baseline 2050	EE-no limit 2024	EE-no limit 2027	EE-no limit 2030	EE-no limit 2033	EE-no limit 2036	EE-no limit 2040	EE-no limit 2045	EE-no limit 2050
Wind	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0	0.01	0.3	0.5	0.8	1.0	1.3	1.3	1.2
Lithium-ion storage	-	-	-	0.02	0.01	0.02	0.02	0.07	0.001	-	-	-	-	0.01	0.1	0.1
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4	-	-	-	0.2	0.2	0.2	0.2	0.2
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7	0.7	1.4	1.7	2.0	2.8	3.0	3.1	3.9
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6	3.4	-	-	-	-	-	4.6	4.6
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7	2.0	2.5	2.5	2.4	2.1	2.1	1.3	1.4
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	-	-	-	0.02	-	0.03	-	0.01
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-	0.6	2.6	2.5	2.3	2.2	2.3	0.02	-
Total	8	8	9	9	10	11	12	13	7	7	7	8	8	9	11	11

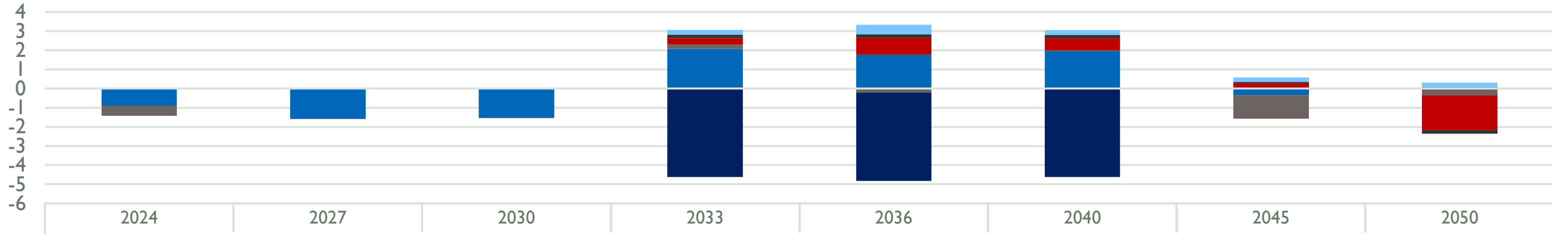
Figure 3.68: Electricity generation by power plant/type for EE-No Limit scenario and Baseline Scenario, TWh



	Baseline 2024	Baseline 2027	Baseline 2030	Baseline 2033	Baseline 2036	Baseline 2040	Baseline 2045	Baseline 2050	EE-20 2024	EE-20 2027	EE-20 2030	EE-20 2033	EE-20 2036	EE-20 2040	EE-20 2045	EE-20 2050
Wind	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0	0.01	0.3	0.5	0.5	0.5	1.0	1.0	0.9
Lithium-ion storage	-	-	-	0.02	0.01	0.02	0.02	0.07	-	-	-	0.02	0.01	0.02	0.02	0.1
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4	-	-	-	-	-	-	0.2	0.4
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7	0.7	1.4	1.7	1.7	1.8	2.4	2.9	5.4
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6	3.4	-	-	4.6	4.6	4.6	4.6	4.6
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7	2.5	2.5	2.5	2.2	2.4	2.1	2.3	1.8
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-	1.5	4.1	4.1	0.3	0.6	0.6	0.6	-
Total	8	8	9	9	10	11	12	13	8	8	9	9	10	11	12	13

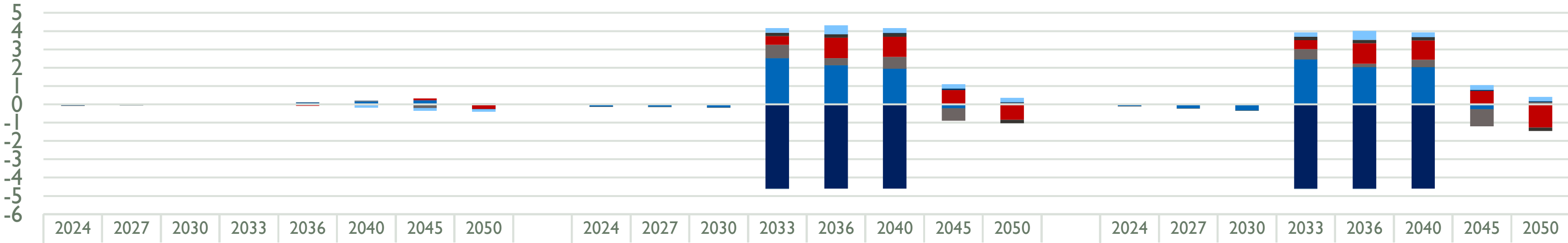
	EE-50 2024	EE-50 2027	EE-50 2030	EE-50 2033	EE-50 2036	EE-50 2040	EE-50 2045	EE-50 2050	EE-90 2024	EE-90 2027	EE-90 2030	EE-90 2033	EE-90 2036	EE-90 2040	EE-90 2045	EE-90 2050
Wind	0.01	0.3	0.5	0.8	1.0	1.3	1.3	1.2	0.01	0.3	0.5	0.8	1.0	1.3	1.3	1.2
Lithium-ion storage	-	-	-	-	0.01	0.1	0.1	0.1	-	-	-	-	-	0.03	0.1	0.1
Hydro pumped storage plant	-	-	-	0.2	0.2	0.2	0.2	0.2	-	-	-	0.2	0.2	0.2	0.2	0.2
Solar	0.7	1.4	1.7	2.2	3.0	3.5	3.6	4.9	0.7	1.4	1.7	2.2	3.0	3.5	3.6	4.4
Nuclear	3.4	-	-	-	-	-	4.6	4.6	3.4	-	-	-	-	-	4.6	4.6
Hydro	2.5	2.5	2.5	2.9	2.7	2.7	1.9	1.8	2.5	2.5	2.5	2.8	2.5	2.5	1.6	1.8
Gas-fired CHPs	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.01
Gas-fired	1.4	4.0	3.9	2.8	2.6	2.3	0.1	-	1.4	3.9	3.7	2.7	2.5	2.4	0.1	-
Total	8	8	9	9	10	10	12	13	8	8	8	9	9	10	12	12

Figure 3.69: Electricity generation by power plant/type for EE-20, EE-50, and EE-90 scenarios and Baseline Scenario, TWh



	2024	2027	2030	2033	2036	2040	2045	2050
	EE-no limit							
Wind	0	0	0	0.2	0.5	0.2	0.2	0.2
Lithium-ion storage	0.001	0	0	-0.02	-0.01	-0.01	0.04	0.06
Hydro pumped storage plant	0	0	0	0.2	0.2	0.2	0	-0.2
Solar	0	0	0	0.3	1	1	0.3	-2
Nuclear	0	0	0	-5	-5	-5	0.0	0.0
Hydro	-0.5	0	0	0.2	-0.2	0.04	-1	-0.3
Gas-fired CHPs	-0.01	-0.01	-0.01	0.02	-0.01	0.02	-0.01	-0.01
Gas-fired	-1	-2	-2	2	2	2	0	0

Figure 3.70: Comparison of electricity generation by power plant/type for EE-No Limit scenario and Baseline Scenario, TWh



	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
	EE-20								EE-50								EE-90							
Wind	0	0	0	0	0	-0.1	-0.1	-0.1	0	0	0	0.2	0.5	0.2	0.2	0.2	0	0	0	0.2	0.5	0.2	0.2	0.2
Lithium-ion storage	0	0	0	0	0.002	0.001	-0.004	-0.012	0	0	0	-0.02	0.001	0.04	0.1	0.03	0	0	0	-0.02	-0.01	0.01	0.1	0.05
Hydro pumped storage plant	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.0	-0.2	0	0	0	0.2	0.2	0.2	0	-0.2
Solar	0	0	0	0	-0.1	-0.1	0.1	-0.2	0	0	0	0.5	1	1	1	-1	0	0	0	0.5	1	1	1	-1
Nuclear	0	0	0	0	0	0	0	0	0	0	0	-5	-5	-5	0	0	0	0	0	-5	-5	-5	0	0
Hydro	-0.002	0	0	-0.03	0.03	0.04	-0.2	0.1	-0.01	0	0	0.7	0.4	0.6	-0.7	0.1	-0.02	0	0	0.5	0.2	0.4	-1	0.1
Gas-fired CHPs	0	0	0	0	0	0	-0.001	-0.01	0	0	0	0.01	0.01	0.01	-0.003	-0.01	-0.001	-0.001	-0.002	0.01	0.01	0.01	-0.01	-0.01
Gas-fired	-0.1	-0.1	-0.01	0.04	0.1	0.2	0.2	0.0	-0.1	-0.1	-0.2	3	2	2	-0.2	0	-0.1	-0.2	-0.3	2	2	2	-0.3	0

Figure 3.71: Comparison of electricity generation by power plant/type for EE-20, EE-50, and EE-90 scenarios and Baseline Scenario, TWh

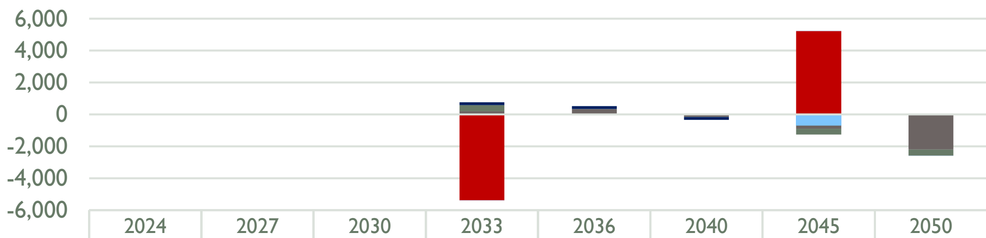
INVESTMENTS IN NEW POWER SYSTEM CAPACITY. Changes in demand technology efficiencies and generation technology implementation schedules result in significantly different needs for total power sector investment in new generation. Table 3.26 and Figures 3.72 and 3.73 compare investments in new power system capacity between the energy efficiency and Baseline Scenarios. The main driver of differences is the existence of a new 600-MW NPP in the EE-No Limit, EE-50, and EE-90 scenarios.

TABLE 3.26: TOTAL POWER SECTOR INVESTMENTS IN NEW CAPACITY FOR ENERGY EFFICIENCY SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	12,854	-
EE-No Limit	9,801	-23.7
EE-20	12,453	-3.1
EE-50	11,596	-9.8
EE-90	11,129	-13.4

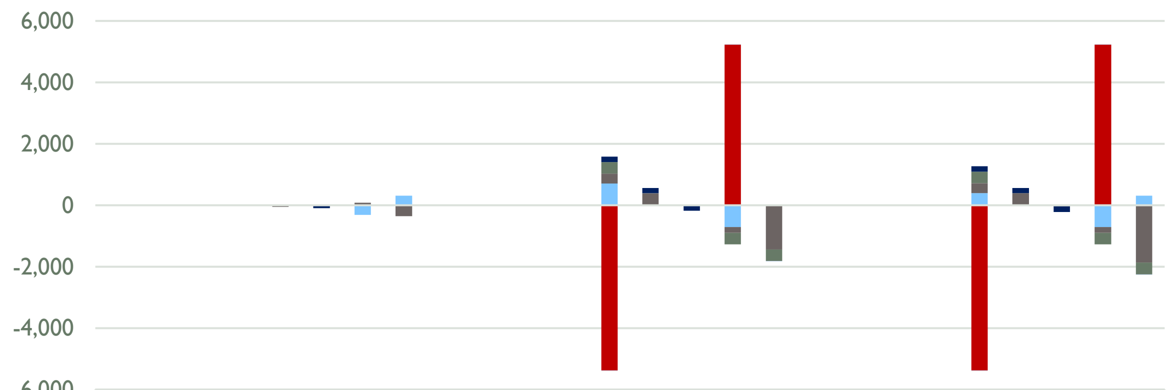
GHG EMISSIONS by scenario are presented in Figure 3.74. In the EE-No Limit, EE-50, and EE-90 scenarios, after the decommissioning of ANPP in 2027, GHG emissions increase due to demand for gas-fired power generation. Starting in 2030, emissions continuously fall as the demand for fossil fuel use (natural gas and oil products) decreases. In 2045, emissions drop even more when the new 600-MW NPP is introduced into the power system. Their growth after that is mainly the result of increased demand covered by gas-fired power plants. The EE-20 scenario follows the Baseline Scenario, with slightly less emission pollution due to a small increase in demand technology efficiencies, as a result of which demand drops (insignificantly).

ENERGY INDEPENDENCE is presented in Figure 3.75; as the use of fossil fuels makes Armenia less energy-independent, this graph is approximately the mirror image of the GHG emissions graph.



	2024	2027	2030	2033	2036	2040	2045	2050
	EE-no limit							
Wind	0	0	0	177	176	-178	0	0
Lithium-ion storage	0.002	0	0	-0.01	0	0.001	0.03	-0.01
Hydro pumped storage	0	0	0	377	0	0	-377	-377
Solar	0	0	0	204	337	-154	-183	-2,200
Nuclear	0	0	0	-5,375	0	0	5,231	0
Hydro	0	0	0	0	0	0	-709	0

Figure 3.72: Comparison of investments in new power system capacity for EE-No Limit scenario and Baseline Scenario, millions of USD



	EE-20								EE-50								EE-90							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0	0	-99	0	0	0	0	0	177	176	-178	0	0	0	0	0	177	176	-178	0	0
Lithium-ion storage	0	0	0	0	0	-0.0	0	-0.0	0	0	0	-0.0	0.01	0.03	0.01	-0.0	0	0	0	-0.0	0	0.02	0.02	-0.0
Hydro pumped storage	0	0	0	0	0	0	0	0	0	0	0	377	0	0	-377	-377	0	0	0	377	0	0	-377	-377
Solar	0	0	0	0	-54	23	80	-351	0	0	0	319	391	-3	-183	-1,4	0	0	0	319	391	-36	-183	-1,8
Nuclear	0	0	0	0	0	0	0	0	0	0	0	-5,3	0	0	5,23	0	0	0	0	-5,3	0	0	5,23	0
Hydro	0	0	0	0	0	0	-314	314	0	0	0	709	0	0	-709	0	0	0	0	395	0	0	-709	314

Figure 3.73: Comparison of investments in new power system capacity for EE-20, EE-50, and EE-90 scenarios and Baseline Scenario, millions of USD

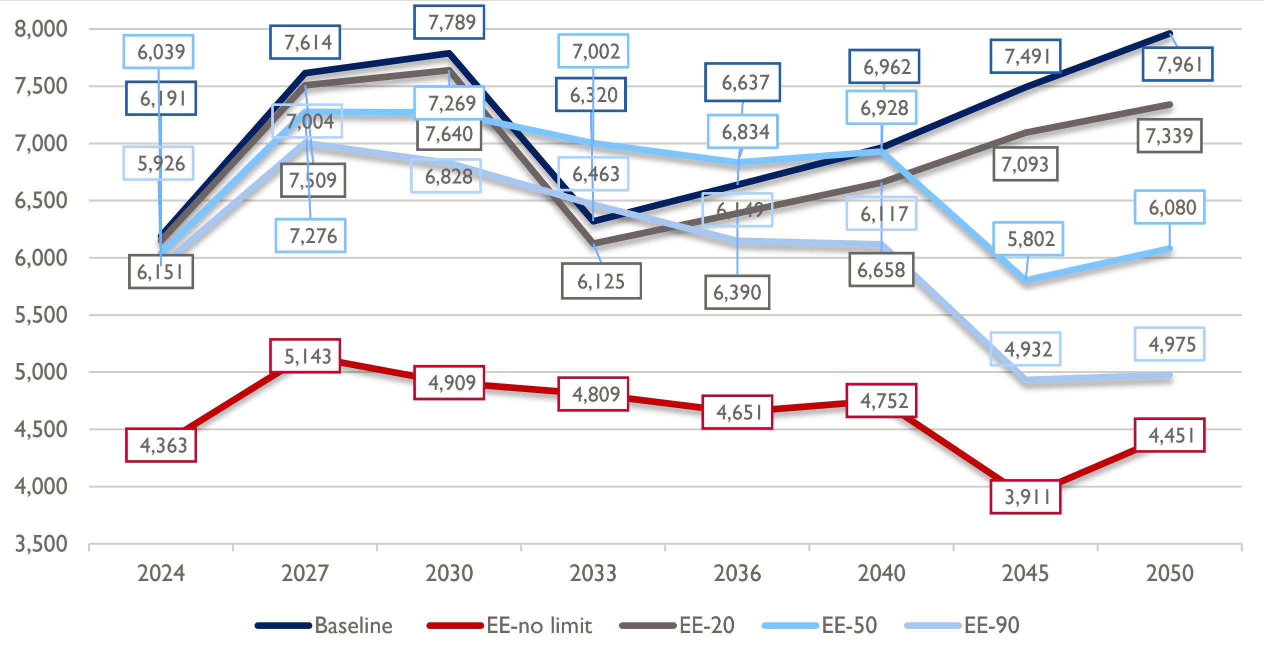


Figure 3.74: GHG emissions (CO_{2eq}) for energy efficiency scenarios, kt

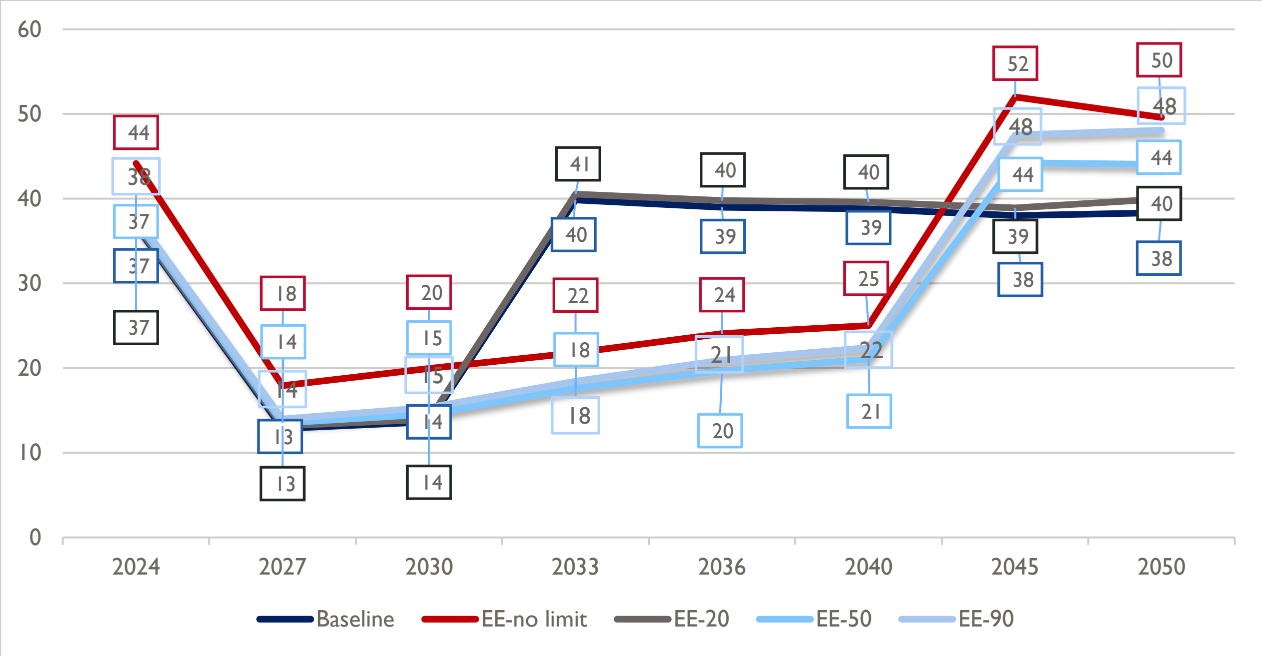


Figure 3.75: Energy independence levels for energy efficiency scenarios, %

TRANSPORT ELECTRIFICATION SCENARIOS

According to the IEA's *Net Zero by 2050: A Roadmap for the Global Energy Sector*, one of the main pathways to achieving the goal of net-zero emissions by 2050 is the wide implementation of electric transport, especially EVs. To evaluate the results of implementing such an ambitious target, two scenarios assess the impact of increasing EVs to 50 percent of total cars (EV-50) and reaching total electrification (EV-100) of cars by 2050. This scenarios consider only electrification of light-duty cars and doesn't consider other transport.

TOTAL SYSTEM COST will amount to $66 billion for the EV-50 scenario and $66.9 billion for EV-100. Comparison with the Baseline Scenario in Table 3.27 shows that both scenarios cost slightly less than the Baseline Scenario, 2.6 and 1.3 percent respectively.

TABLE 3.27: TOTAL SYSTEM COST FOR TRANSPORT ELECTRIFICATION SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	67,763	-
EV-50	65,993	-2.6
EV-100	66,867	-1.3

TPES projections for the transport electrification scenarios are presented in Figure 3.76.

In both the EV-50 and EV-100 scenarios, electricity demand increases and requires new generation capacity. After ANPP decommissioning in 2027, additional electricity is produced by gas-fired power plants that have higher efficiency than NPPs, so fewer primary energy carriers are needed. In the EV-100 scenario, TPES jumps in 2033 and then steadily increases from then on; the fact that this initial increase is greater than that in the Baseline Scenario is the result of the new 1,080-MW NPP to cover additional demand from EV. In EE-50 scenario, TPES shows a slight decrease from 2033 in comparison with the Baseline Scenario, which is mostly the result of reduced use of natural gas and oil products in the transport sector. The results of TPES by fuel type are presented in Figure 3.77.

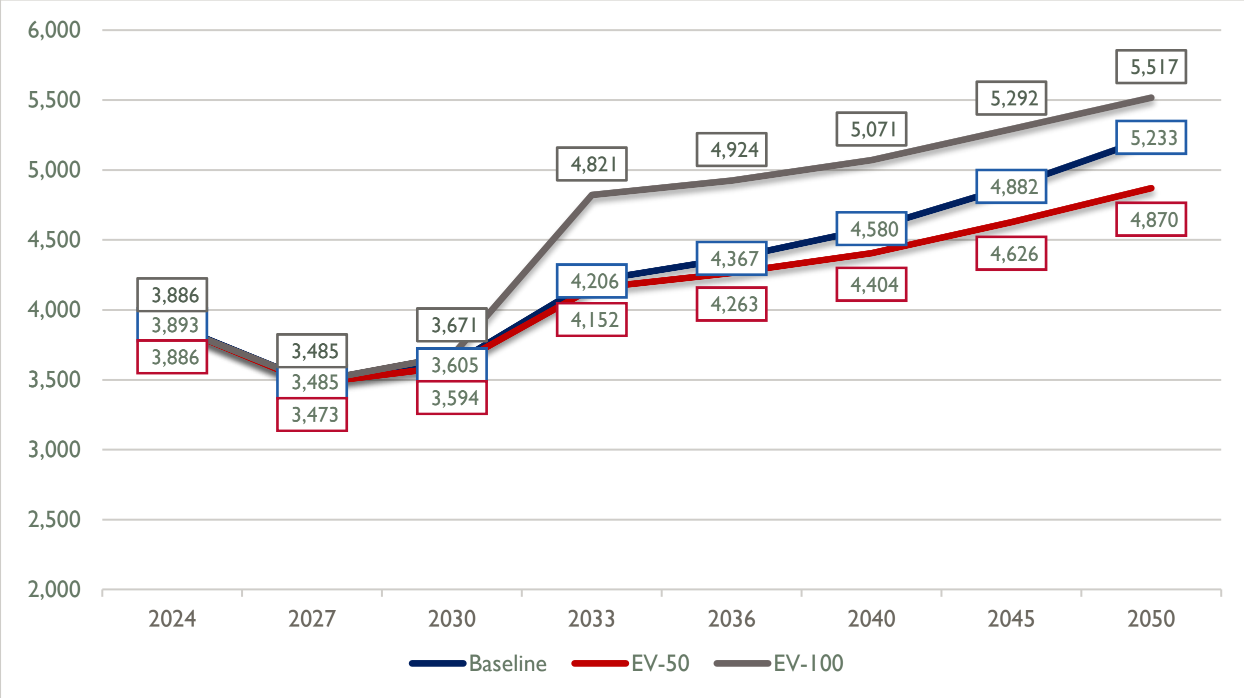


Figure 3.76: TPES for transport electrification scenarios, ktoe

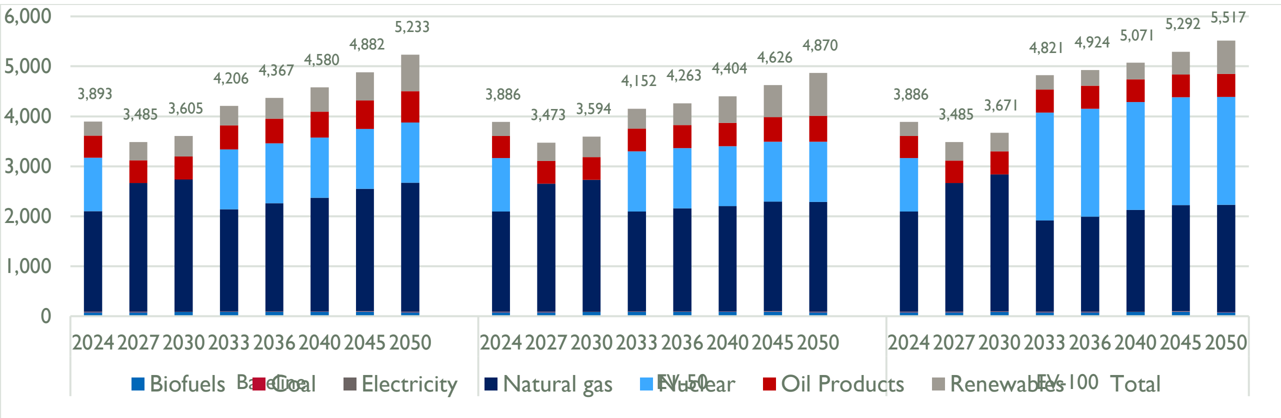
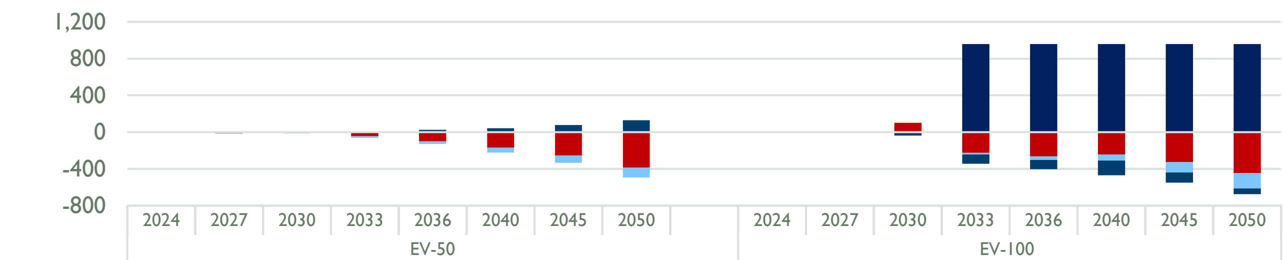


Figure 3.77: TPES by fuel type for transport electrification scenarios, ktoe

Figure 3.78 illustrates the changes in composition of TPES in the transport electrification scenarios compared to the Baseline Scenario.



	EV-50 2024	EV-50 2027	EV-50 2030	EV-50 2033	EV-50 2036	EV-50 2040	EV-50 2045	EV-50 2050	EV-100 2024	EV-100 2027	EV-100 2030	EV-100 2033	EV-100 2036	EV-100 2040	EV-100 2045	EV-100 2050
Renewables	0.0	0.0	0.0	7	25	44	78	131	0	0.0	-35	-102	-101	-158	-112	-64
Oil Products	0	0	-4	-17	-31	-50	-79	-109	0	4	-2	-15	-36	-66	-111	-167
Nuclear	0	0	0	0	0	0	0	0	0	0	0	959	959	959	959	959
Gas	-7	-12	-7	-43	-99	-170	-255	-385	-7	-4	99	-220	-255	-236	-327	-443
Electricity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	0	0	0	3	-7	-10	-8	0	-1

Figure 3.78: Comparison of TPES by fuel type for transport electrification scenarios and Baseline Scenario, ktoe

FEC projections for the EV-50 and EV-100 scenarios are presented in Figure 3.79. In both scenarios, FEC is lower than that in the Baseline during the entire planning period, and the EV-100 FEC decreases faster than EV-50 FEC. Furthermore, in both scenarios, electricity consumption increases (due to widespread EV usage) by less than the savings in natural gas and oil products. 105 ktoe and 241 ktoe of new demand in EV-50 and EV-100 respectively are dwarfed by 368 ktoe and 424 ktoe of natural gas savings as well as 146 ktoe and 155 ktoe of savings in oil products respectively. Comparing these results with the Baseline Scenario in Figure 3.80 and Figure 3.81 illustrates the changes in composition of FEC among the transport electrification scenarios and Baseline Scenario. The share of electricity in the total energy mix grows from 20 percent in 2024 to 26 percent in 2050 for the EV-50 scenario, and to 31 percent in the EV-100 scenario, replacing the consumption of natural gas and oil products.

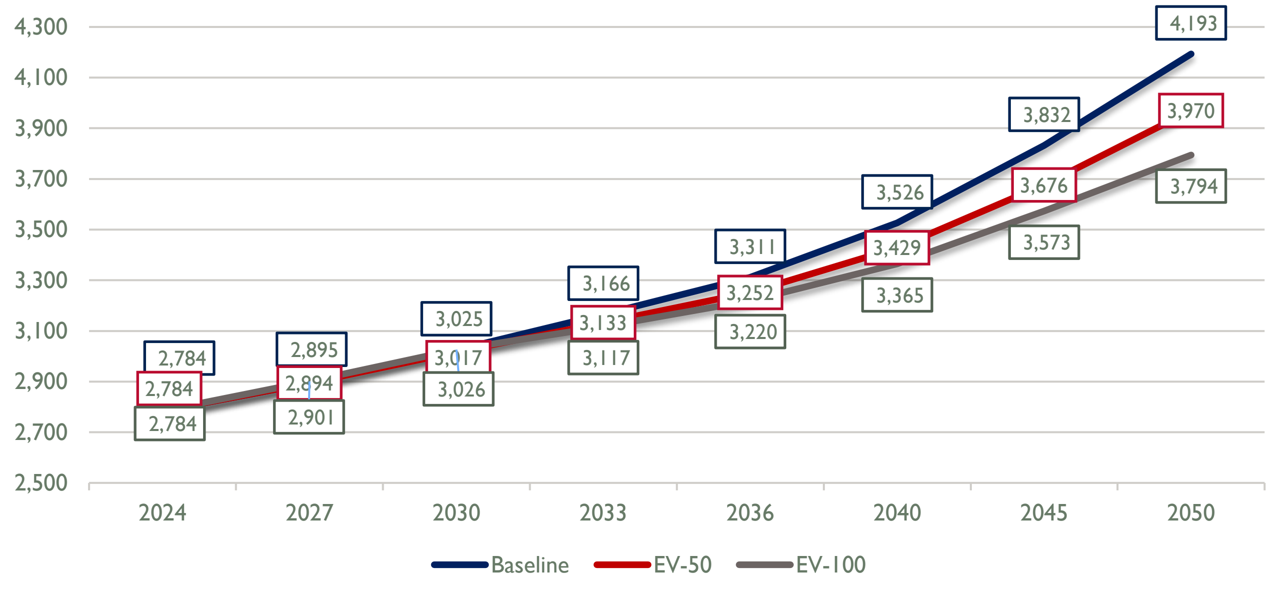


Figure 3.79: FEC for transport electrification scenarios, ktoe

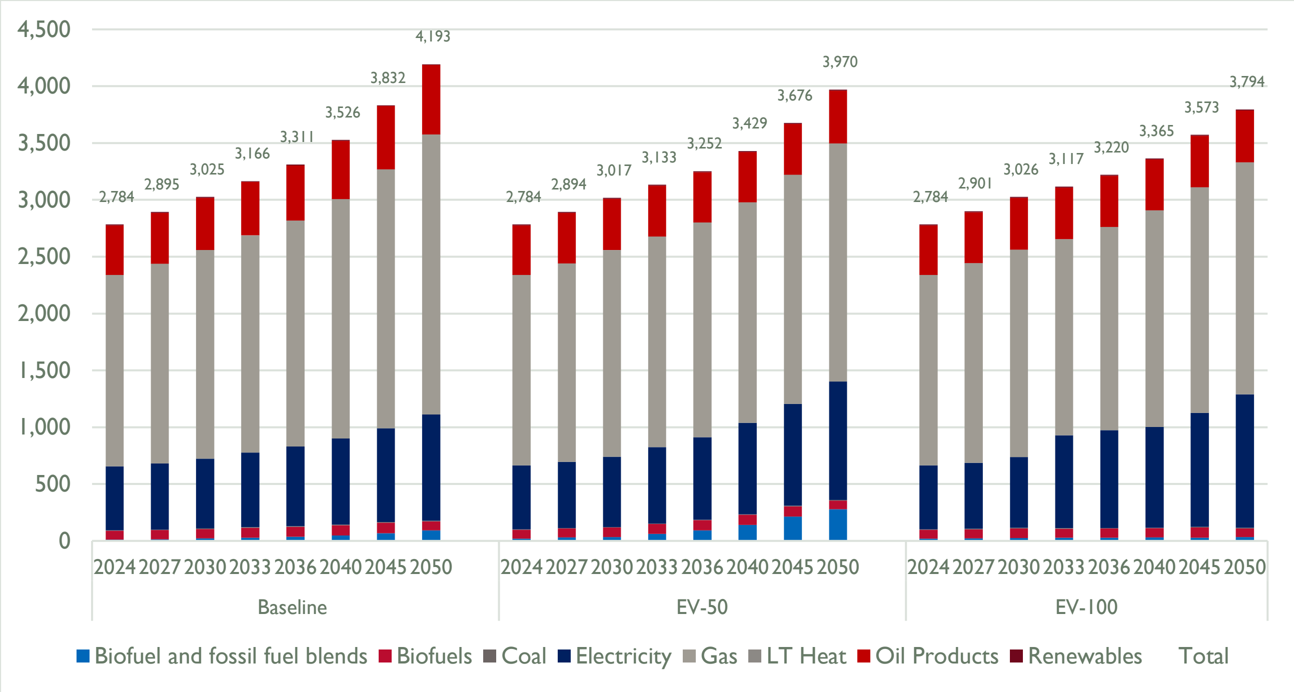
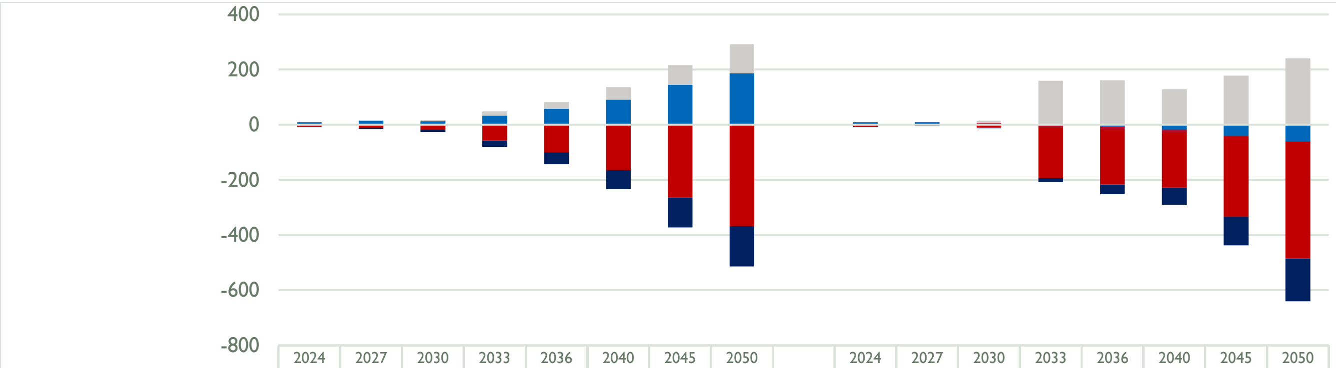


Figure 3.80: FEC by fuel type for transport electrification scenarios, ktoe



	EV-50 2024	EV-50 2027	EV-50 2030	EV-50 2033	EV-50 2036	EV-50 2040	EV-50 2045	EV-50 2050	EV-100 2024	EV-100 2027	EV-100 2030	EV-100 2033	EV-100 2036	EV-100 2040	EV-100 2045	EV-100 2050
Renewables	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil Products	-1	-3	-7	-24	-42	-69	-108	-146	-1	3	-2	-15	-35	-62	-103	-155
LT Heat	0	0	0	0	0	0	0	0	-0.003	-0.003	-0.003	-0.003	-0.003	-0.002	0	0
Gas	-7	-13	-19	-57	-101	-165	-264	-368	-7	-3	-11	-185	-201	-200	-293	-424
Electricity	0	0	5	15	26	45	72	105	0	0	8	160	161	129	178	241
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	0	0	0	3	-7	-10	-8	0	-1
Biofuel and fossil fuel blends	8	15	13	33	57	91	145	186	8	7	3	-2	-7	-19	-41	-61

Figure 3.81: Comparison of FEC by fuel type for transport electrification and Baseline Scenarios

ELECTRICITY GENERATION TECHNOLOGIES. Table 3.28 presents the least-cost configuration of power sector for the transport electrification scenarios, with significant changes in generation capacity configuration for nuclear, RES, and storage technologies.

In the EV-50 scenario, increased electricity demand is covered by solar PV and the Shnokh and Loriberd HPPs are implemented in 2045. The new NPP implementation schedule and capacity are the same as in the Baseline Scenario.

In the EV-100 scenario, increased electricity demand is covered by the implementation of a new 1,080-MW NPP in 2033, which replaces some of the wind and solar generation compared with the Baseline Scenario. Solar PV capacity increases starting in 2045, reaching approximately the Baseline

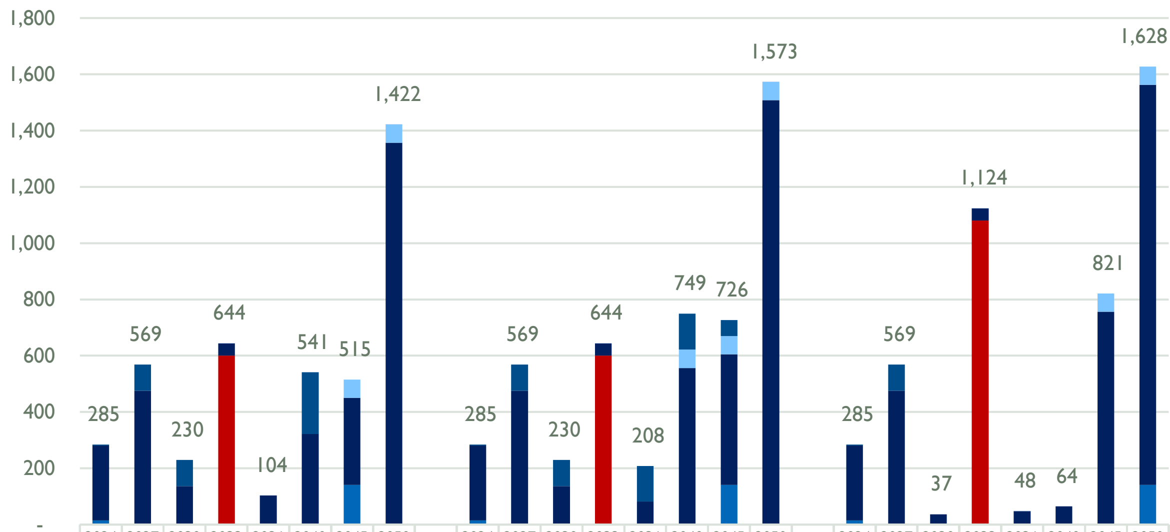
Scenario level due to the end of TPPs' lifetime. Storage capacity increases along with it. The implementation of the Shnokh and Loriberd HPPs in this scenario is foreseen in 2050.

Figures 3.82 and 3.83 provide the new capacity implementation schedules for these scenarios over the planning horizon, and generation by power plant is presented in Table 3.29.

Figures 3.84 and 3.85 show projected generation capacity by power plant and generation technology as well as the difference between these scenarios and the Baseline Scenario over the planning horizon.

TABLE 3.28: CAPACITY BY PLANT/PLANT TYPE FOR TRANSPORT ELECTRIFICATION SCENARIOS, MW

SCENARIO	BASELINE								EV-50								EV-100							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	-	-	-	66	66	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	66
Shnokh HPP	-	-	-	-	-	-	75	75	-	-	-	-	-	-	75	75	-	-	-	-	-	-	-	75
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-
NPP (new)	-	-	-	600	600	600	600	600	-	-	-	600	600	600	600	600	-	-	-	1,080	1,080	1,080	1,080	1080
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,026	1,130	1,452	1,727	2,630	369	845	982	1,026	1,108	1,665	2,095	3,149	369	845	882	926	974	1,039	1,761	2,729
Hydro pumped storage plant	-	-	-	-	-	-	65	130	-	-	-	-	-	65	130	195	-	-	-	-	-	-	65	130
Lithium-ion storage	-	-	-	0.02	0.02	0.02	0.02	0.06	-	-	-	0.02	0.02	0.02	0.1	0.1	-	-	-	0.03	0.03	0.03	0.03	0.03
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	409	409	371	4	97	190	190	316	443	500	462	4	97	97	97	97	97	97	59
Total	**3,233**	**3,362**	**3,592**	**3,769**	**3,873**	**4,414**	**4,616**	**5,289**	**3,233**	**3,362**	**3,592**	**3,769**	**3,977**	**4,727**	**5,140**	**5,964**	**3,233**	**3,362**	**3,399**	**4,056**	**4,105**	**4,169**	**4,677**	**5,556**

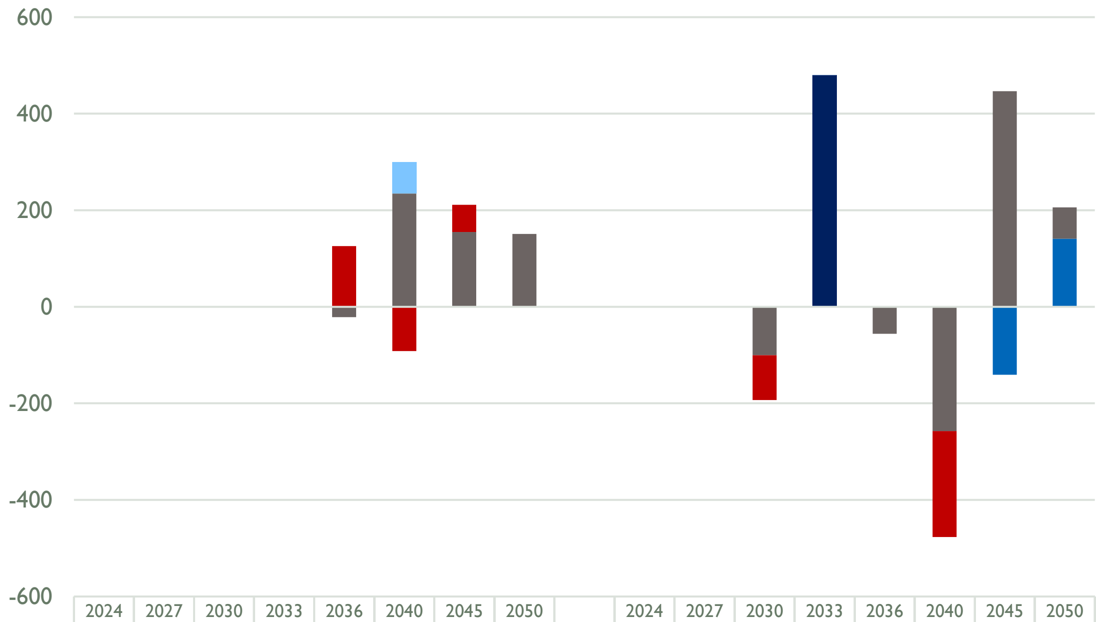


	Baseline 2024	Baseline 2027	Baseline 2030	Baseline 2033	Baseline 2036	Baseline 2040	Baseline 2045	Baseline 2050
Wind	4	93	93	-	-	219	-	-
Lithium-ion storage	-	-	-	0.02	-	0.002	-	0.04
Hydro pumped storage plant	-	-	-	-	-	-	65	65
Solar	266	476	137	44	104	322	309	1,357
Nuclear	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-
Total	285	569	230	644	104	541	515	1,422

	EV-50 2024	EV-50 2027	EV-50 2030	EV-50 2033	EV-50 2036	EV-50 2040	EV-50 2045	EV-50 2050
Wind	4	93	93	-	125.8	128	57	-
Lithium-ion storage	-	-	-	0.02	-	-	0.04	0.02
Hydro pumped storage plant	-	-	-	-	-	65	65	65
Solar	266	476	137	44	82	557	464	1,508
Nuclear	-	-	-	600	-	-	-	-
Hydro	15	-	-	-	-	-	141	-
Total	285	569	230	644	208	749	726	1,573

	EV-100 2024	EV-100 2027	EV-100 2030	EV-100 2033	EV-100 2036	EV-100 2040	EV-100 2045	EV-100 2050
Wind	4	93	-	-	-	-	-	-
Lithium-ion storage	-	-	-	0.03	0.005	-	-	-
Hydro pumped storage plant	-	-	-	-	-	-	65	65
Solar	266	476	37	44	48	64	756	1,422
Nuclear	-	-	-	1,080	-	-	-	-
Hydro	15	-	-	-	-	-	-	141
Total	285	569	37	1,124	48	64	821	1,628

Figure 3.82: New capacity implementation schedule in transport electrification scenarios, MW



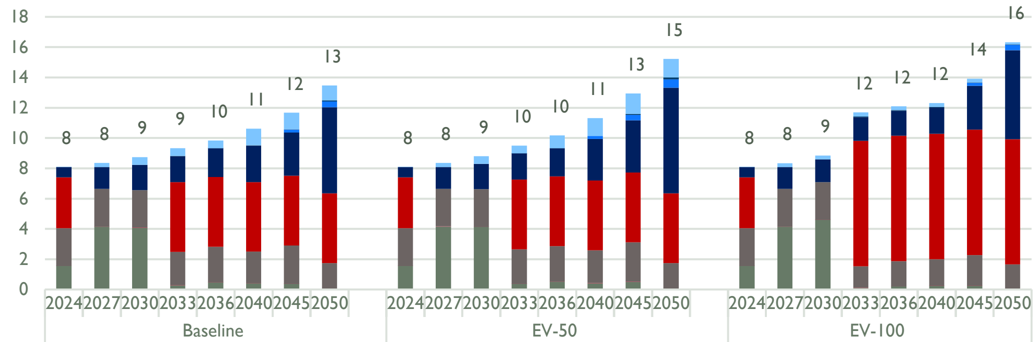
	EV-50 2024	EV-50 2027	EV-50 2030	EV-50 2033	EV-50 2036	EV-50 2040	EV-50 2045	EV-50 2050
Wind	0	0	0	0	126	-91	57	0
Lithium-ion storage	0	0	0	0	0	-0.002	0	-0.02
Hydro pumped storage plant	0	0	0	0	0	65	0	0
Solar	0	0	0	0	-22	235	155	151
Nuclear	0	0	0	0	0	0	0	0
Hydro	0	0	0	0	0	0	0	0

	Transport-100 2024	Transport-100 2027	Transport-100 2030	Transport-100 2033	Transport-100 2036	Transport-100 2040	Transport-100 2045	Transport-100 2050
Wind	0	0	-93	0	0	-219	0	0
Lithium-ion storage	0	0	0	0.01	0.005	-0.002	0	-0.04
Hydro pumped storage plant	0	0	0	0	0	0	0	0
Solar	0	0	-100	0	-56	-258	447	65
Nuclear	0	0	0	480	0	0	0	0
Hydro	0	0	0	0	0	0	-141	141

Figure 3.83: Comparison of new power plant construction for transport electrification scenarios and Baseline Scenario, MW

TABLE 3.29: GENERATION BY PLANT/PLANT TYPE FOR TRANSPORT ELECTRIFICATION SCENARIOS, GWH

SCENARIO	BASELINE								EV-50								EV-100							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	71	1,672	1,672	22	59	60	-	-	71	1,672	1,672	30	52	61	-	-	71	1,672	1,672	20	32	35	-	-
Yerevan CCGT-2	1,471	1,891	1,891	248	417	343	364	-	1,471	1,891	1,891	340	466	358	499	-	1,471	1,891	1,891	83	166	208	243	-
Hrazdan Unit 5	-	591	510	-	-	-	-	-	-	595	570	-	-	-	-	-	-	587	1,026	-	-	-	-	-
Local cogeneration plant	7	7	7	7	7	8	8	26	7	7	7	7	7	8	8	26	7	7	7	7	7	8	8	26
Vorotan HPP Cascade	984	984	984	977	984	984	984	598	984	984	984	984	984	984	980	607	984	984	984	509	697	744	846	503
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346	414	414	414	414	414	414	414	346	414	414	414	338	338	343	414	284
Loriberd HPP	-	-	-	-	-	-	203	203	-	-	-	-	-	-	203	203	-	-	-	-	-	-	-	203
Shnokh HPP	-	-	-	-	-	-	291	291	-	-	-	-	-	-	291	291	-	-	-	-	-	-	-	291
Small HPP (existing)	932	935	935	654	790	528	492	122	932	935	935	727	782	610	566	119	932	935	935	423	473	499	604	183
Small HPP (new)	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	4,601	4,601	4,601	4,601	4,601	-	-	-	4,601	4,601	4,601	4,601	4,601	-	-	-	8,281	8,281	8,281	8,281	8,281
Solar (existing)	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	1,645	1,811	2,328	2,770	5,689	592	1,354	1,574	1,645	1,777	2,669	3,360	6,961	592	1,354	1,413	1,484	1,562	1,665	2,824	5,871
Hydro pumped storage plant	-	-	-	-	-	-	188	376	-	-	-	-	-	188	376	564	-	-	-	-	-	-	188	357
Lithium-ion storage	-	-	-	15	8	20	20	68	-	-	-	12	9	-	61	119	-	-	-	46	39	33	17	13
Wind (existing)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	1,091	1,091	990	11	259	507	507	842	1,183	1,334	1,233	11	259	259	259	259	259	259	158
Total	**8,095**	**8,347**	**8,734**	**9,332**	**9,839**	**10,617**	**11,667**	**13,472**	**8,095**	**8,352**	**8,794**	**9,506**	**10,174**	**11,316**	**12,933**	**15,232**	**8,095**	**8,344**	**8,841**	**11,692**	**12,096**	**12,317**	**13,924**	**16,333**

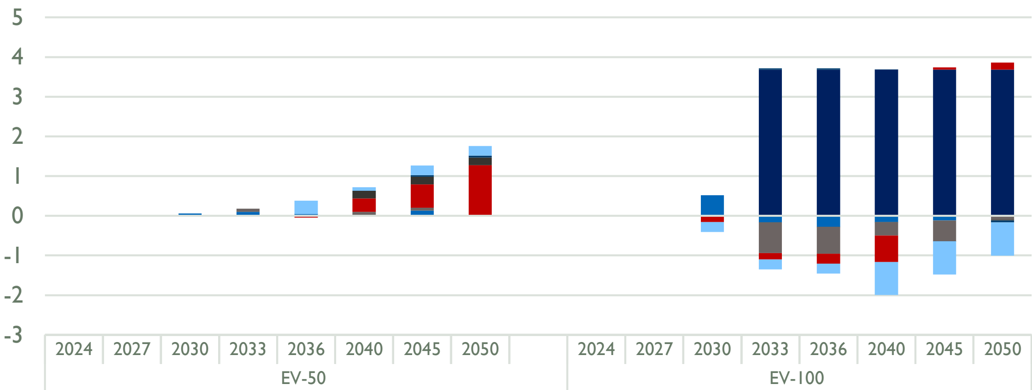


Baseline	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0
Lithium-ion storage	-	-	-	0.02	0.01	0.02	0.02	0.07
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-
Total	8	8	9	9	10	11	12	13

EV-50	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.5	0.5	0.8	1.2	1.3	1.2
Lithium-ion storage	-	-	-	0.01	0.01	-	0.1	0.1
Hydro pumped storage plant	-	-	-	-	-	0.2	0.4	0.6
Solar	0.7	1.4	1.7	1.7	1.9	2.7	3.4	7.0
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6
Hydro	2.5	2.5	2.5	2.3	2.3	2.2	2.6	1.7
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03
Gas-fired	1.5	4.2	4.1	0.4	0.5	0.4	0.5	-
Total	8	8	9	10	10	11	13	15

EV-100	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.3	0.3	0.3	0.3	0.3	0.2
Lithium-ion storage	-	-	-	0.05	0.04	0.03	0.02	0.01
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4
Solar	0.7	1.4	1.5	1.6	1.6	1.7	2.9	5.9
Nuclear	3.4	-	-	8.3	8.3	8.3	8.3	8.3
Hydro	2.5	2.5	2.5	1.4	1.7	1.7	2.0	1.6
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03
Gas-fired	1.5	4.2	4.6	0.1	0.2	0.2	0.2	-
Total	8	8	9	12	12	12	14	16

Figure 3.84: Electricity generation by power plant/type for transport electrification scenarios and Baseline Scenario, TWh



EV-50	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0	0.3	0.1	0.2	0.2
Lithium-ion storage	0	0	0	-0.004	0.001	-0.02	0.04	0.05
Hydro pumped storage plant	0	0	0	0	0	0.2	0.2	0.2
Solar	0	0	0	0	-0.03	0.3	1	1
Nuclear	0	0	0	0	0	0	0	0
Hydro	0	0	0	0.1	-0.01	0.1	0.1	0.01
Gas-fired CHPs	0	0	0	0	0	0	0	0
Gas-fired	0	0.004	0.06	0.10	0.04	0.02	0.1	0

EV-100	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	-0.2	-0.2	-0.2	-1	-1	-1
Lithium-ion storage	0	0	0	0.03	0.03	0.01	-0.003	-0.05
Hydro pumped storage plant	0	0	0	0	0	0	0	-0.02
Solar	0	0	-0.2	-0.2	-0.2	-1	0.1	0.2
Nuclear	0	0	0	4	4	4	4	4
Hydro	0	0	0	-1	-1	-0.3	-0.5	-0.1
Gas-fired CHPs	0	0	0	0	0	0	0	0
Gas-fired	0	-0.004	0.5	-0.2	-0.3	-0.2	-0.1	0

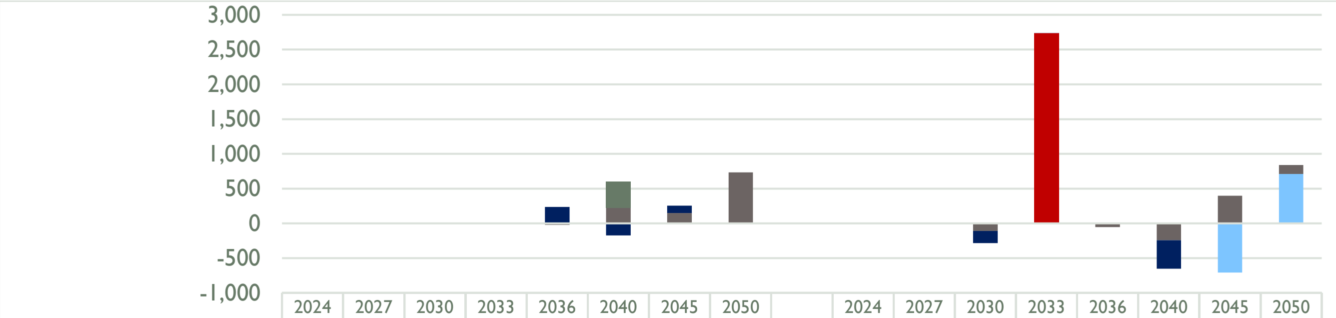
Figure 3.85: Comparison of electricity generation by power plant/type for transport electrification scenarios and Baseline Scenario, TWh

INVESTMENTS IN NEW POWER SYSTEM CAPACITY. Changes in the generation technology mix result in significant changes in total power sector investment in new generation; Table 3.30 and Figure 3.86 compare these investments between the transport electrification scenarios and the Baseline Scenario. The main driver of differences is the implementation of a new 1,080 MW NPP in the EV-100 scenario and the additional solar PV capacity in the EV-50 scenario.

The main polluting energy carrier in these scenarios remains natural gas, with more than 80 percent share in total GHG emissions in almost all milestone years.

TABLE 3.30: TOTAL POWER SECTOR INVESTMENTS IN NEW CAPACITY FOR TRANSPORT ELECTRIFICATION SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	12,854	-
EV-50	14,488	+12.7
EV-100	15,125	+17.7



	EV-50								EV-100							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	0	238	-172	105	0	0	0	-178	0	0	-412	0	0
Lithium-ion storage	0	0	0	0	0	-0.001	0	-0.01	0	0	0	0.004	0.003	-0.001	0	-0.02
Hydro pumped storage plant	0	0	0	0	0	377	0	0	0	0	0	0	0	0	0	0
Solar	0	0	0	0	-21	221	151	735	0	0	-107	0	-54	-242	398	130
Nuclear	0	0	0	0	0	0	0	0	0	0	0	2,736	0	0	0	0
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-709	709

Figure 3.86: Comparison of investments in new power system capacity for transport electrification scenarios and Baseline Scenario, millions of USD

GHG EMISSIONS changes by scenario are presented in Figure 3.87.

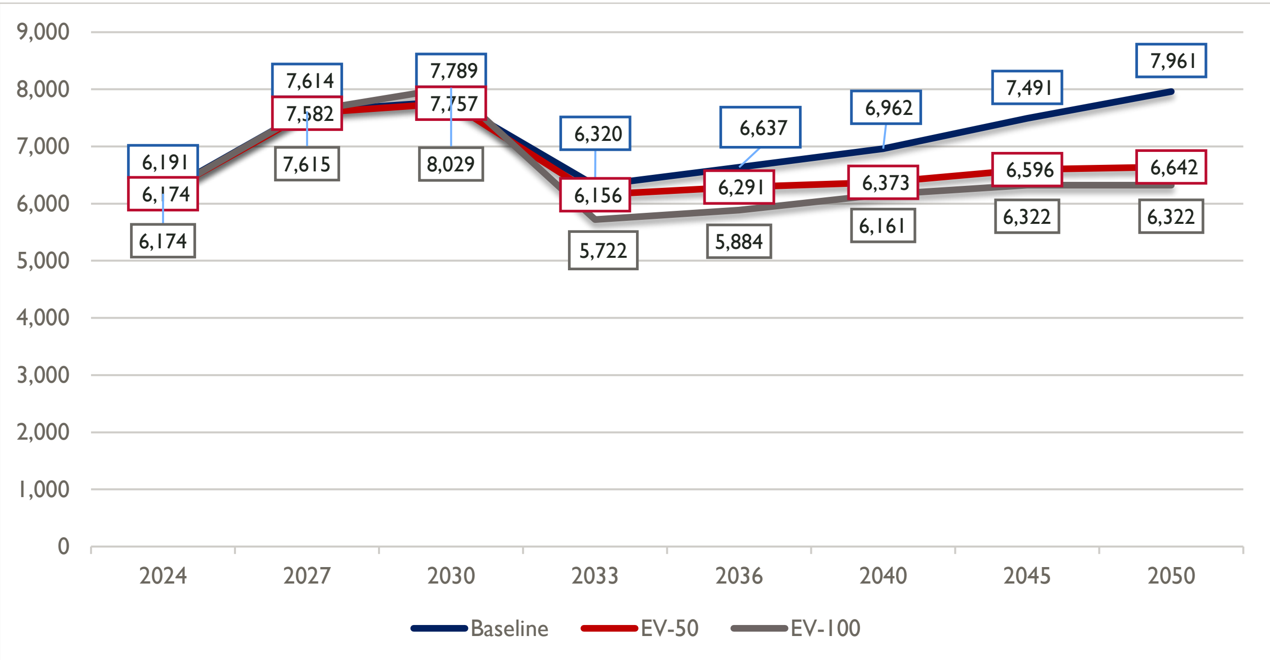


Figure 3.87: GHG emissions (CO_{2eq}) for transport electrification scenarios, kt

At the end of the planning period, the most polluting sector in the EV-100 scenario is the residential sector (34 percent), followed by transport (21 percent), the commercial and industrial sectors (each 18 percent), and agriculture (0.8 percent) and the power sector (0.3 percent). Fugitive emissions from the supply side amount to 8 percent. The EV-50 scenario sees the same sequence of polluters and nearly the same emissions shares: residential, 33 percent; transport, 24 percent; commercial and industrial, 18 percent each; agriculture, 0.7 percent; power, 0.3 percent; and supply, 8 percent.

ENERGY INDEPENDENCE levels for the transport electrification scenarios are presented in Figure 3.88.

In the EV-100 scenario, Armenia will reach a high level of energy independence in 2033 (52 percent), mainly due to the implementation of a large NPP (1,080 MW). Independence will then decrease to 51 percent until 2045 because of the need to cover increased demand with more fossil fuels. At the end of the planning horizon, the replacement of TPPs with RES will cause the independence level to peak at 53 percent.

In the EV-50 scenario, energy independence will jump to 41 percent in 2033 and then steadily increase to 44 percent between 2040 and 2050 because of the wide implementation of solar PV and wind farms.

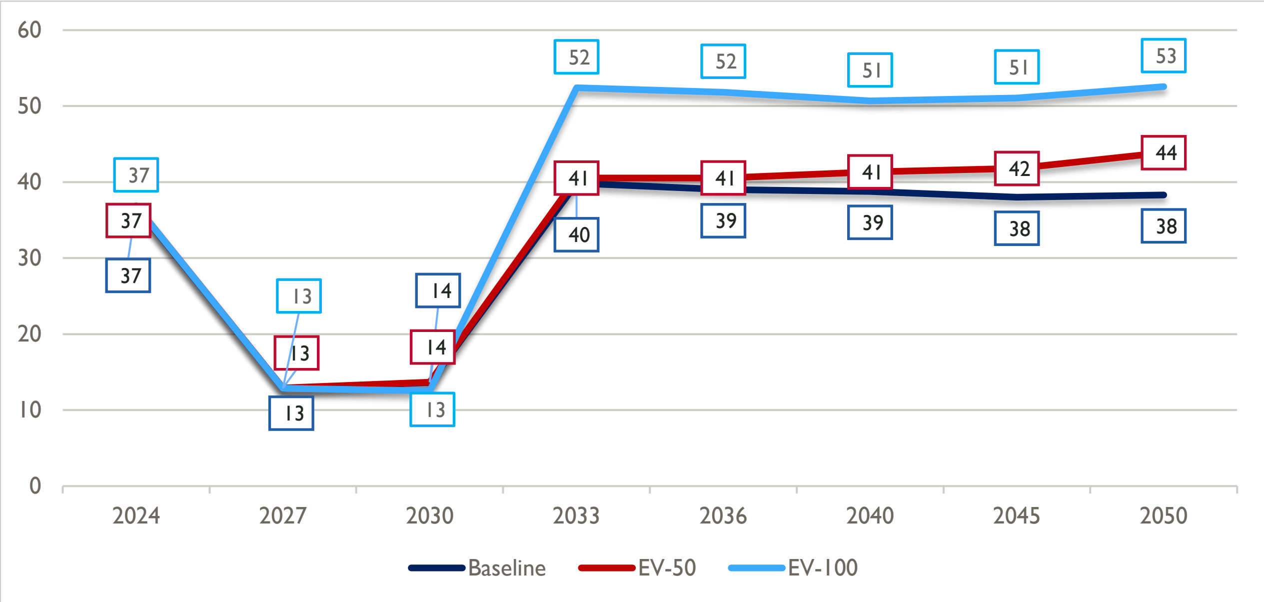


Figure 3.88: Energy independence levels for transport electrification scenarios, %

GHG EMISSIONS SCENARIO

A scenario with a carbon tax equal to that of the EU examines the least-cost configuration in case of increased carbon taxes. Based on expectations of EU carbon taxes in the coming decades a tax of $50/ton up to 2030 and $100/ton afterward have been introduced. [35][36][37][38]

[35] https://www.euractiv.com/section/emissions-trading-scheme/interview/analyst-eu-carbon-price-on-track-to-reach-e90-by-2030//
[36] https://cleanenergynews.ihsmarkit.com/research-analysis/recordhigh-price-forecasts-across-global-carbon-markets-and-st.html
[37] https://taxfoundation.org/carbon-taxes-in-europe-2022/
[38] https://www.statista.com/statistics/1284060/forecast-carbon-offset-prices-by-scenario

TOTAL SYSTEM COST will amount to $75.5 billion, which is more than 10 percent higher than in the Baseline Scenario (Table 3.31). The increase in the carbon tax is responsible for the total system cost even through in this scenario, GHG emissions are 4.3 percent lower than in the Baseline Scenario.

TABLE 3.31: TOTAL SYSTEM COST FOR GHG EMISSIONS SCENARIOS

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	67,763	-
GHG	75,493	+11.4

TPES for the GHG scenario is projected in Figure 3.89. The main difference from the Baseline Scenario comes from the earlier introduction of the 600-MW NPP, in 2027 instead of 2033. Because TPPs produce the same output more efficiently than NPPs, nuclear technology requires more primary sources than gas-fired plants. From 2033, there is no significant difference in TPES between the GHG and Baseline Scenarios (Figure 3.90). Figure 3.91 illustrates the differences in the composition of TPES in the GHG emissions scenario compared to the Baseline Scenario.

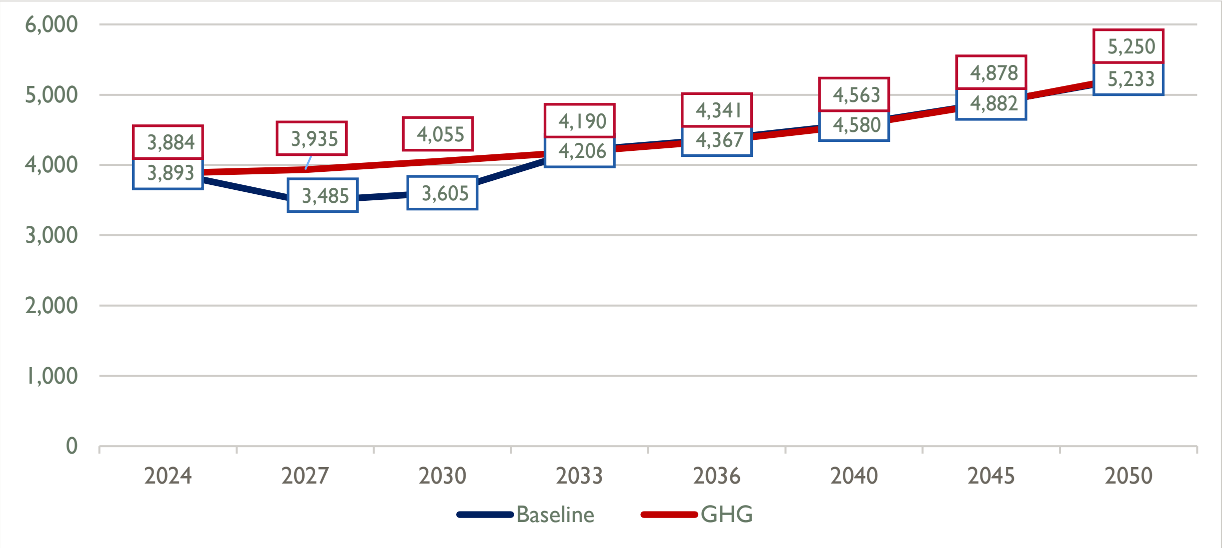


Figure 3.89: TPES for GHG emissions scenario, ktoe

FEC projected for the GHG emissions scenario is practically identical to that of the Baseline Scenario.

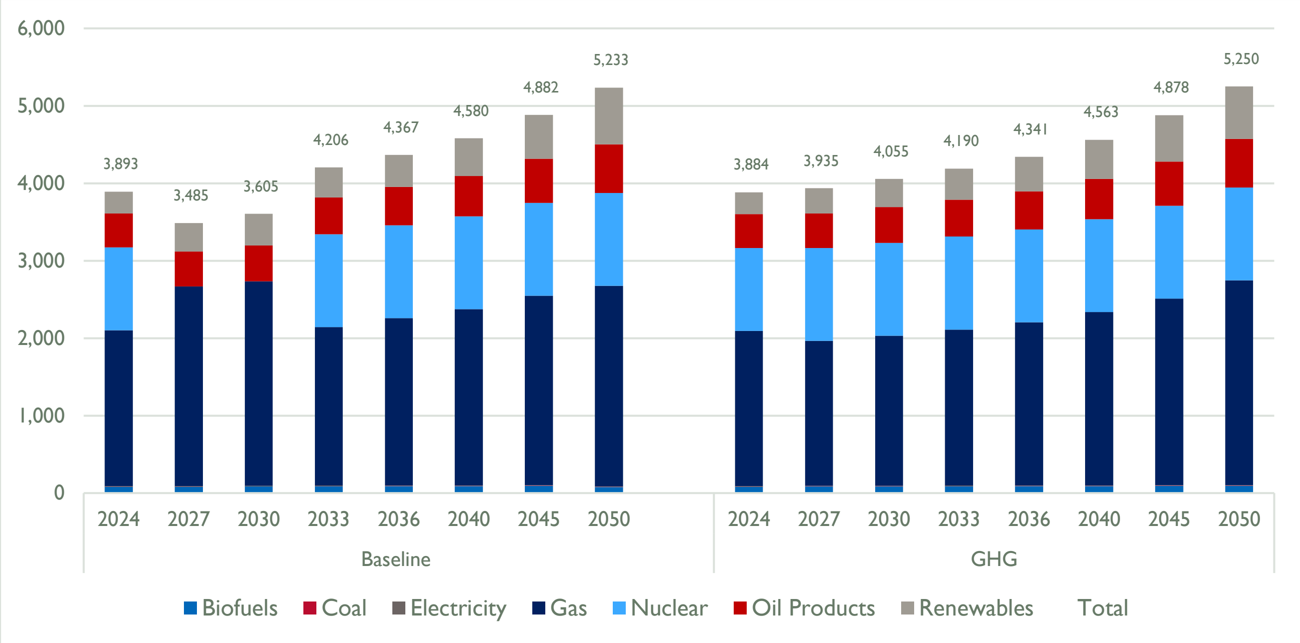
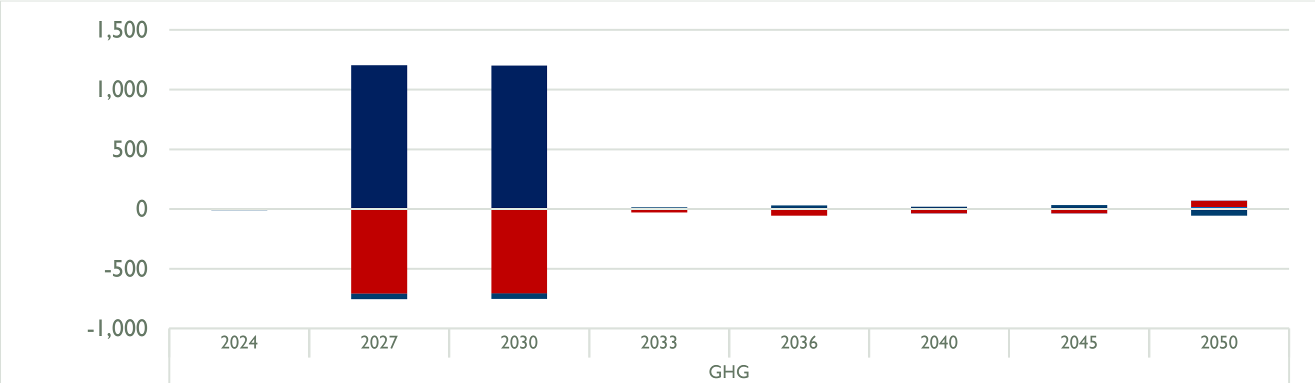


Figure 3.90: TPES by fuel type for GHG emissions scenario, ktoe



	2024	2027	2030	2033	2036	2040	2045	2050
	GHG							
Renewables	-0.1	-45	-44	13	31	19	33	-55
Oil Products	0	-2	-0.2	0	0	-0.4	-1	1
Nuclear	0	1,199	1,199	0	0	0	0	0
Gas	-8	-709	-708	-30	-57	-36	-36	54
Electricity	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Biofuels	0.02	6	3	0	0	0	0	17

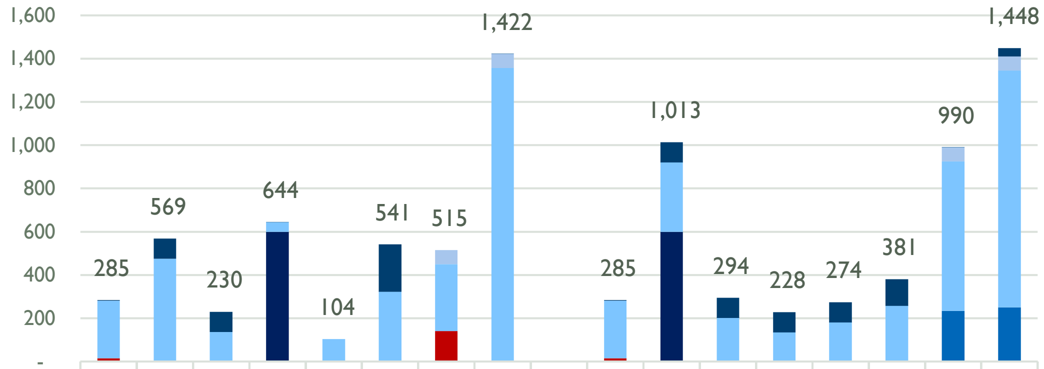
Figure 3.91: Comparison of TPES by fuel type for GHG emissions scenario and Baseline Scenario, ktoe

ELECTRICITY GENERATION TECHNOLOGIES. Table 3.32 presents the least-cost configuration of the power sector for the GHG emissions scenario, showing significant changes in generation capacity configuration for gas-fired power plants and RES, as well as for the new NPP implementation schedule. The least-cost solution is to implement a 250-MW CCGT in 2050 and a 234-MW GT in 2045, as well as to construct 191 MW more solar PV capacity and 91 MW more wind farm capacity over the planning horizon than in the Baseline Scenario. Loriberd and Shnokh HPP construction is not considered to be the least-cost solution in this scenario.

TABLE 3.32: CAPACITY BY PLANT/PLANT TYPE FOR GHG EMISSIONS SCENARIO, MW

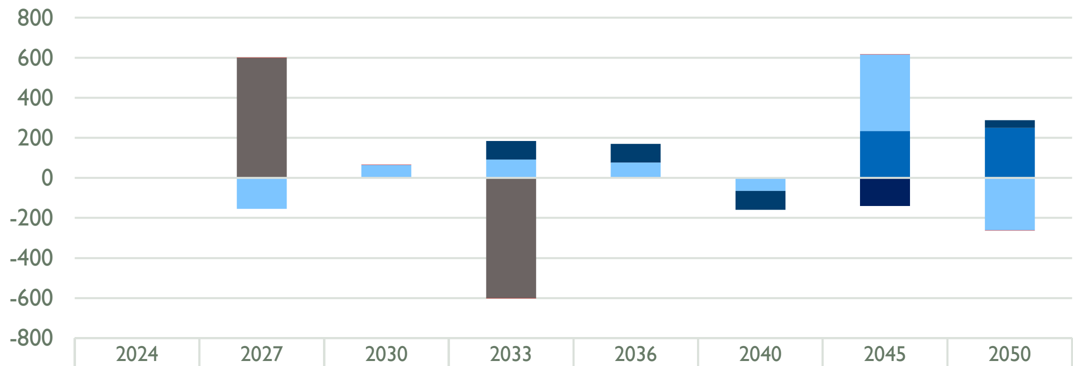
SCENARIO	BASELINE								GHG							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
CCGT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	250
Gas turbine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	234	234
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	-
Shnokh HPP	-	-	-	-	-	-	75	75	-	-	-	-	-	-	-	-
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-
NPP (new)	-	-	-	600	600	600	600	600	-	600	600	600	600	600	600	600
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,026	1,130	1,452	1,727	2,630	369	689	890	1,026	1,207	1,464	2,122	2,821
Hydro pumped storage plant	-	-	-	-	-	-	65	130	-	-	-	-	-	-	65	130
Lithium-ion storage	-	-	-	0.02	0.02	0.02	0.02	0.06	-	0.02	0.03	0.03	0.04	0.04	0.08	0.08
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	409	409	371	4	97	190	283	376	500	500	500
Total	**3,233**	**3,362**	**3,592**	**3,769**	**3,873**	**4,414**	**4,616**	**5,289**	**3,233**	**3,807**	**4,101**	**3,862**	**4,137**	**4,517**	**5,195**	**5,951**

Figures 3.92 and 3.93 provide the new capacity implementation schedule for the GHG emissions scenario over the planning horizon.



	Baseline 2024	Baseline 2027	Baseline 2030	Baseline 2033	Baseline 2036	Baseline 2040	Baseline 2045	Baseline 2050	GHG 2024	GHG 2027	GHG 2030	GHG 2033	GHG 2036	GHG 2040	GHG 2045	GHG 2050
Wind	4	93	93	-	-	219	-	-	4	93	93	93	93	124	-	38
Lithium-ion storage	-	-	-	0.02	-	0.002	-	0.04	-	0.02	0.01	0.005	0.004	0.01	0.04	-
Hydro pumped storage plant	-	-	-	-	-	-	65	65	-	-	-	-	-	-	65	65
Solar	266	476	137	44	104	322	309	1,357	266	320	201	135	181	257	691	1,095
Nuclear	-	-	-	600	-	-	-	-	-	600	-	-	-	-	-	-
Hydro	15	-	-	-	-	-	141	-	15	-	-	-	-	-	-	-
Gas-fired	-	-	-	-	-	-	-	-	-	-	-	-	-	-	234	250
Total	285	569	230	644	104	541	515	1,422	285	1,013	294	228	274	381	990	1,448

Figure 3.92: Comparison of new power plant construction for GHG emissions scenario and Baseline Scenario, MW



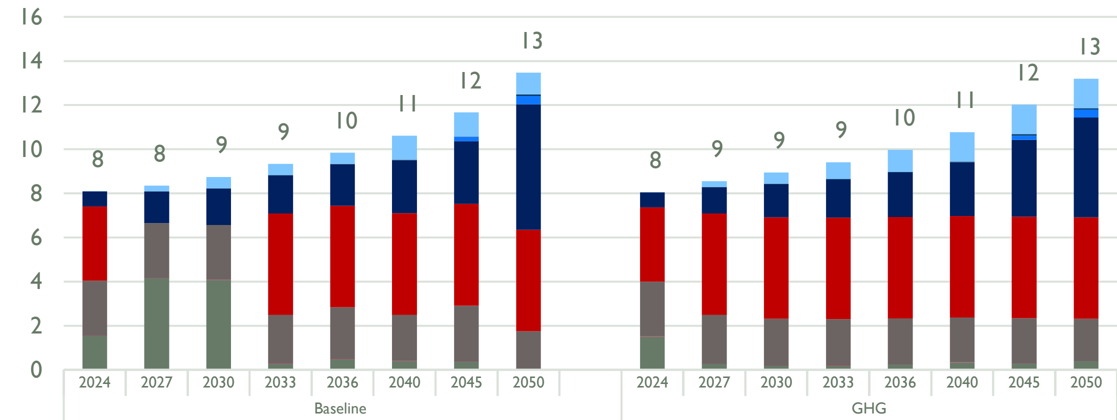
GHG	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	0	93	93	-95	0	38
Lithium-ion storage	0	0.02	0.01	-0.02	0.004	0.01	0.04	-0.04
Hydro pumped storage plant	0	0	0	0	0	0	0	0
Solar	0	-155	64	91	77	-65	382	-261
Nuclear	0	600	0	-600	0	0	0	0
Hydro	0	0	0	0	0	0	-141	0
Gas-fired	0	0	0	0	0	0	234	250

Figure 3.93: New capacity implementation schedule, GHG emissions scenario, MW

Projected generation capacity by power plant and generation technology are presented in Table 3.33 and Figure 3.94. Figure 3.95 compares electricity generation by power plant/type for the GHG emissions and Baseline Scenarios over the planning horizon.

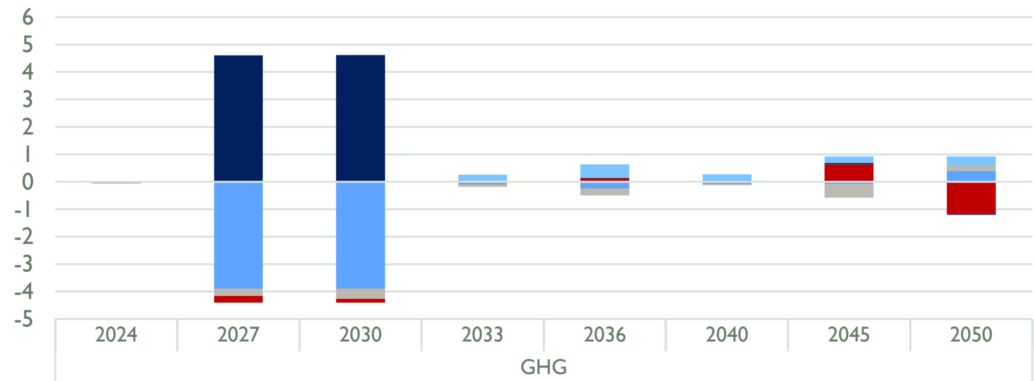
TABLE 3.33: GENERATION BY PLANT/PLANT TYPE FOR GHG EMISSIONS SCENARIO, GWH

SCENARIO	BASELINE								GHG							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
CCGT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	359
Gas turbine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	38
Yerevan CCGT	71	1,672	1,672	22	59	60	-	-	68	4	8	14	26	52	-	-
Yerevan CCGT-2	1,471	1,891	1,891	248	417	343	364	-	1,437	260	169	170	211	274	251	-
Hrazdan Unit 5	-	591	510	-	-	-	-	-	-	-	-	-	-	-	-	-
Local cogeneration plant	7	7	7	7	7	8	8	26	7	7	7	7	7	8	8	8
Vorotan HPP Cascade	984	984	984	979	984	984	984	598	984	956	984	984	984	984	984	840
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346	414	414	414	414	414	414	414	414
Loriberd HPP	-	-	-	-	-	-	203	203	-	-	-	-	-	-	-	-
Shnokh HPP	-	-	-	-	-	-	291	291	-	-	-	-	-	-	-	-
Small HPP (existing)	932	935	935	654	790	528	492	122	928	694	570	554	528	487	492	492
Small HPP (new)	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	4,601	4,601	4,601	4,601	4,601	-	4,601	4,601	4,601	4,601	4,601	4,601	4,601
Solar (existing)	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	1,645	1,811	2,328	2,770	5,689	592	1,105	1,428	1,645	1,936	2,347	3,402	4,523
Hydro pumped storage plant	-	-	-	-	-	-	188	376	-	-	-	-	-	-	188	376
Lithium-ion storage	-	-	-	15	8	20	20	68	-	12	20	24	26	36	77	45
Wind (existing)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	1,091	1,091	990	11	259	507	755	1,003	1,334	1,334	1,334
Total	**8,095**	**8,347**	**8,734**	**9,332**	**9,839**	**10,617**	**11,667**	**13,472**	**8,053**	**8,552**	**8,948**	**9,408**	**9,976**	**10,776**	**12,020**	**13,191**



	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
	Baseline								GHG							
Wind	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0	0.01	0.3	0.5	0.8	1.0	1.3	1.3	1.3
Lithium-ion storage	-	-	-	0.02	0.01	0.02	0.02	0.07	-	0.01	0.02	0.02	0.03	0.04	0.1	0.04
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4	-	-	-	-	-	-	0.2	0.4
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7	0.7	1.2	1.5	1.7	2.0	2.4	3.5	4.5
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6	3.4	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7	2.5	2.2	2.1	2.1	2.1	2.0	2.0	1.9
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-	1.5	0.3	0.2	0.2	0.2	0.3	0.3	0.4
Total	8	8	9	9	10	11	12	13	8	9	9	9	10	11	12	13

Figure 3.94: Comparison of electricity generation by power plant/type for GHG emissions scenario and Baseline Scenario, TWh



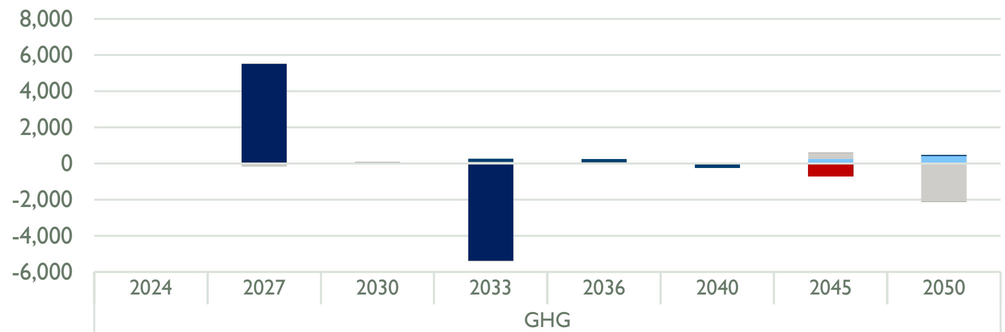
	2024	2027	2030	2033	2036	2040	2045	2050
	GHG							
Wind	0	0	0	0.2	0.5	0.2	0.2	0.3
Lithium-ion storage	0	0.01	0.02	0.01	0.02	0.02	0.1	-0.02
Hydro pumped storage plant	0	0	0	0	0	0	0	0
Solar	0	-0.2	-0.1	0	0.1	0	1	-1
Nuclear	0	5	5	0	0	0	0	0
Hydro	0	-0.3	-0.4	-0.1	-0.3	-0.04	-0.5	0.2
Gas-fired CHPs	0	0	0	0	0	0	0	-0.02
Gas-fired	-0.04	-4	-4	-0.1	-0.2	-0.1	-0.1	0.4

Figure 3.95: Electricity generation by power plant/type for GHG emissions scenario, TWh

INVESTMENTS IN NEW POWER SYSTEM CAPACITY. Changes in the generation technology mix result in significantly differences in the total power sector investment for new generation. Table 3.34 and Figure 3.96 compare investments under the GHG emissions and Baseline Scenarios. The main drivers of differences are the introduction of 484 MW of new gas-fired plants and 282 MW of RES in the GHG emission scenario.

TABLE 3.34: TOTAL POWER SECTOR INVESTMENTS FOR NEW CAPACITY IN GHG EMISSIONS SCENARIO

SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	12,854	-
GHG	11,381	-11.5



	2024	2027	2030	2033	2036	2040	2045	2050
	GHG							
Wind	0	0	0	177	176	-178	0	69
Lithium-ion storage	0	0.02	0.01	-0.01	0.002	0.003	0.02	-0.02
Hydro pumped storage plant	0	0	0	0	0	0	0	0
Solar	0	-178	69	93	76	-61	332	-2,112
Nuclear	0	5,499	0	-5,375	0	0	0	0
Hydro	0	0	0	0	0	0	-709	0
Gas-fired	0	0	0	0	0	0	247	403

Figure 3.96: Comparison of investments for new power system capacity for GHG emissions scenario and Baseline Scenario, millions of USD

GHG EMISSIONS changes in the GHG emissions scenario are presented in Figure 3.97.

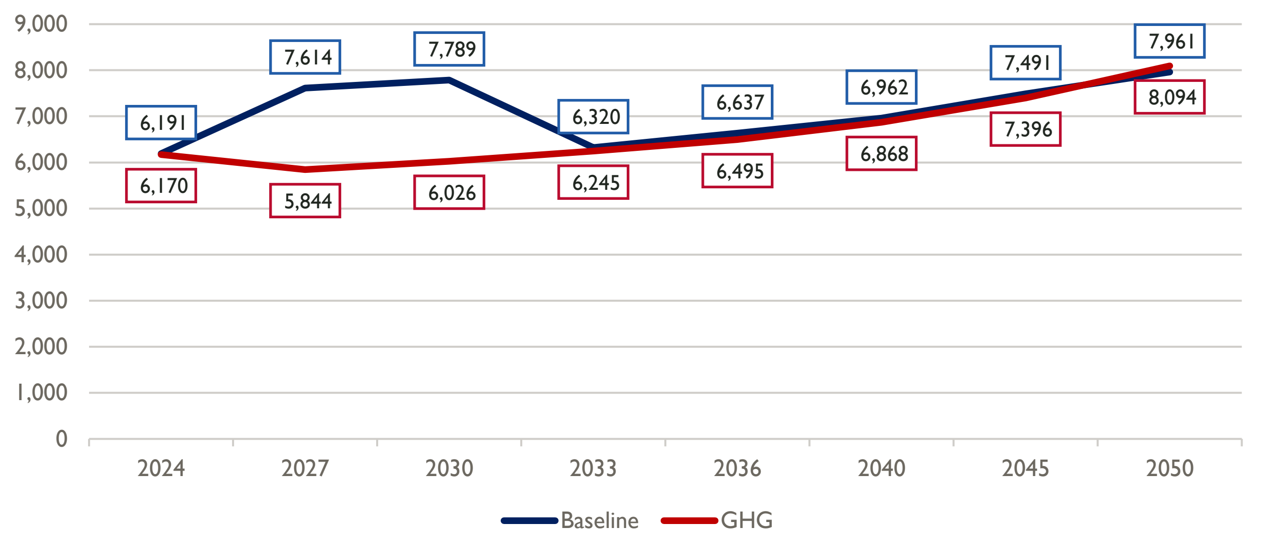


Figure 3.97: GHG emissions (CO_{2eq}) for GHG emissions scenario and Baseline Scenario, kt

The move of the introduction of the new 600 MW NPP from 2033 to 2027 is resulting in the replacement of gas-fired plants (Yerevan CCGT and Yerevan CCGT-2) and the reduction of GHG emissions. Note that after 2033 pollutants in the GHG emissions scenario almost repeat the values in the Baseline Scenario.

ENERGY INDEPENDENCE for the GHG emissions scenario presented in Figure 3.98.

Armenia's energy independence will reach its highest level in 2027 (41 percent), mainly due to the commissioning of a new 600-MW NPP, and then it will decrease to 37 percent at the end of the planning horizon. From 2033 on, it tracks the progression of energy independence in the Baseline Scenario almost exactly because the two scenarios have identical energy carrier composition.

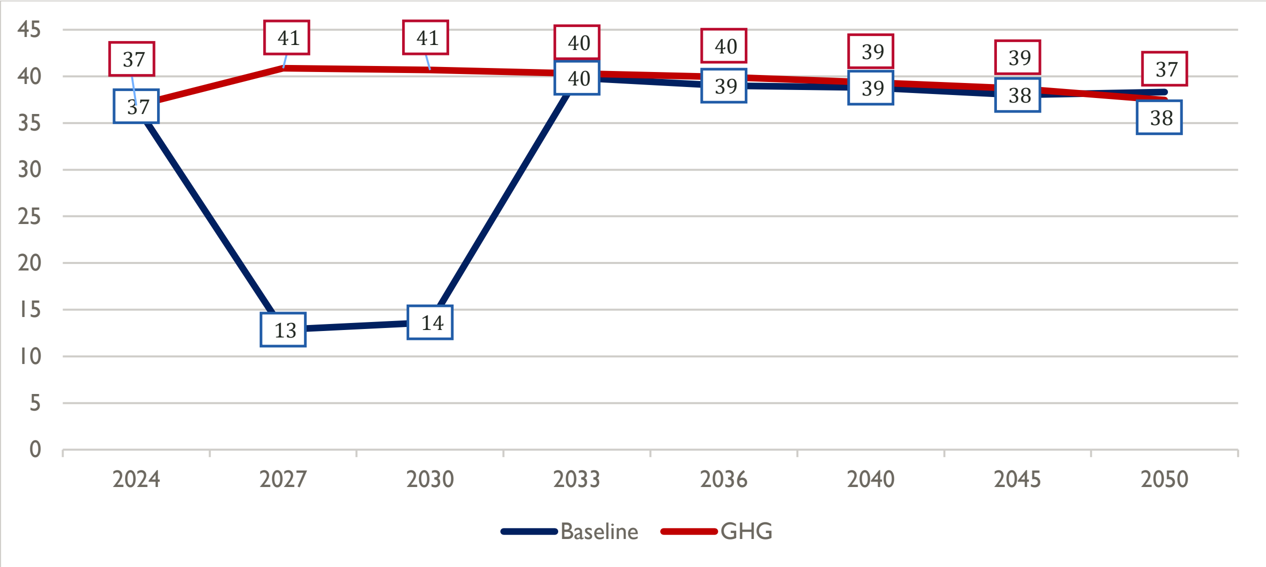


Figure 3.98: Energy independence levels for GHG emissions scenario and Baseline Scenario, %

GEORGIA ELECTRICITY IMPORT/EXPORT SCENARIOS

Two scenarios for electricity import from and export to Georgia were modeled: 300 MW of electricity export starting in 2027 during October-March period and 50 MW of electricity import during April-September period both with a load factor of 75 percent (Import/Export 300 MW scenario), and 300 MW starting in 2027 followed by 1,050 MW starting in 2040 both during October-March period and 50 MW of electricity import during April-September period, all with 75 percent load (Import/Export 1,050 MW scenario) (Table 3.35).

TABLE 3.35: GEORGIA ELECTRICITY IMPORT/EXPORT, MW

		2024	2027	2030	2033	2036	2040	2045	2050
Baseline		115	115	115	115	115	115	115	115
Import/Export 300 MW	Import	0	50	50	50	50	50	50	50
	Export	115	300	300	300	300	300	300	300
Import/Export 1,050 MW	Import	0	50	50	50	50	50	50	50
	Export	115	300	300	300	300	1,050	1,050	1,050

TOTAL SYSTEM COST will amount to $68.6 billion for the Import/Export 300 MW scenario and $70.2 billion for the Import/Export 1,050 MW scenario. A comparison with the Baseline Scenario presented in Table 3.36. In both scenarios, total system cost is higher than the baseline because of additional generation costs for increased export capacity.

TABLE 3.36: TOTAL SYSTEM COST FOR GEORGIA ELECTRICITY IMPORT/EXPORT SCENARIOS		
SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	67,763	-
Import/Export 300 MW	68,615	+1.3
Import/Export 1,050 MW	70,178	+3.6

TPES projections are presented in Figure 3.99. In both scenarios, extra energy sources cover supplemental export demand proportional to the increase in export capacity.

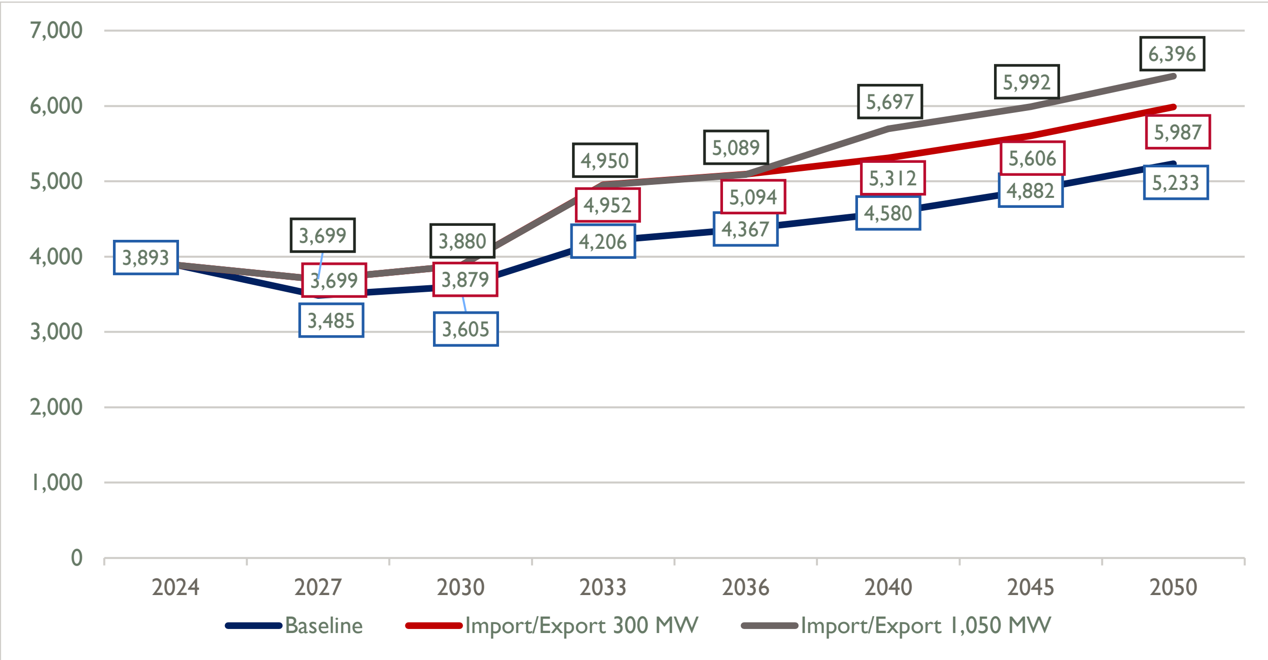


Figure 3.99: TPES for Georgia electricity import/export scenarios, ktoe

As presented in Figure 3.100, TPES increases as a result of greater use of natural gas than in the Baseline Scenario until 2027 and greater use of nuclear energy from 2033. Figure 3.101 illustrates the differences in TPES composition in the electricity Import/Export scenarios compared to the Baseline Scenario.

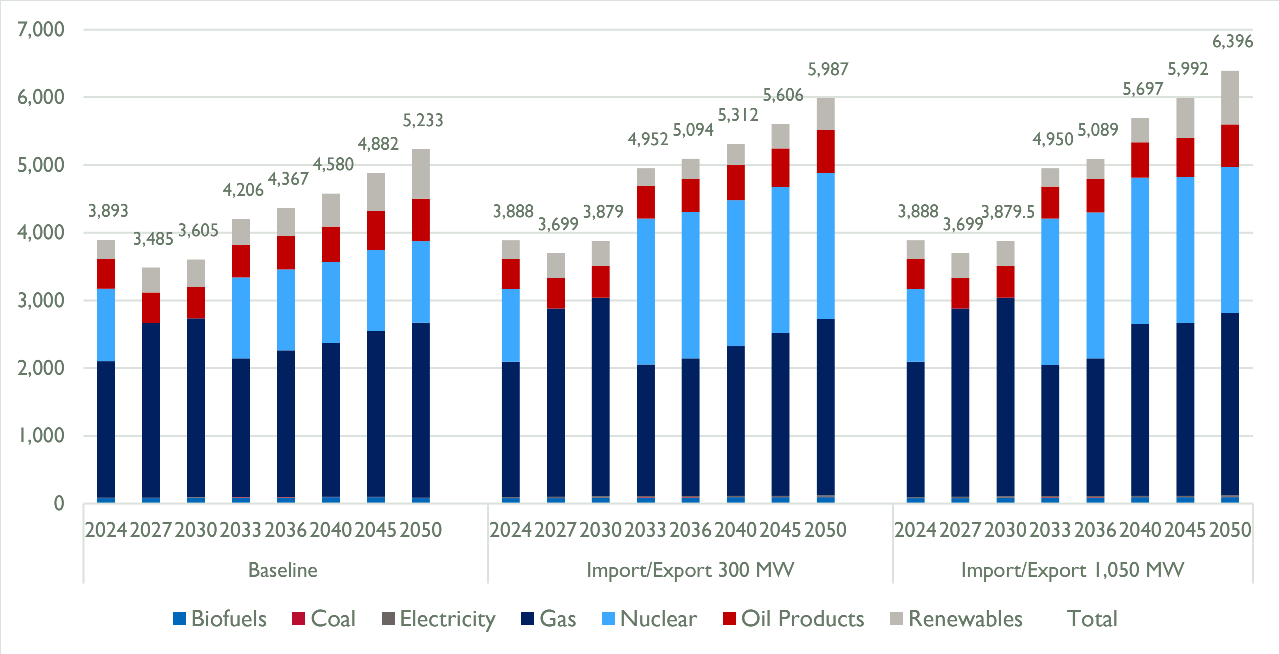
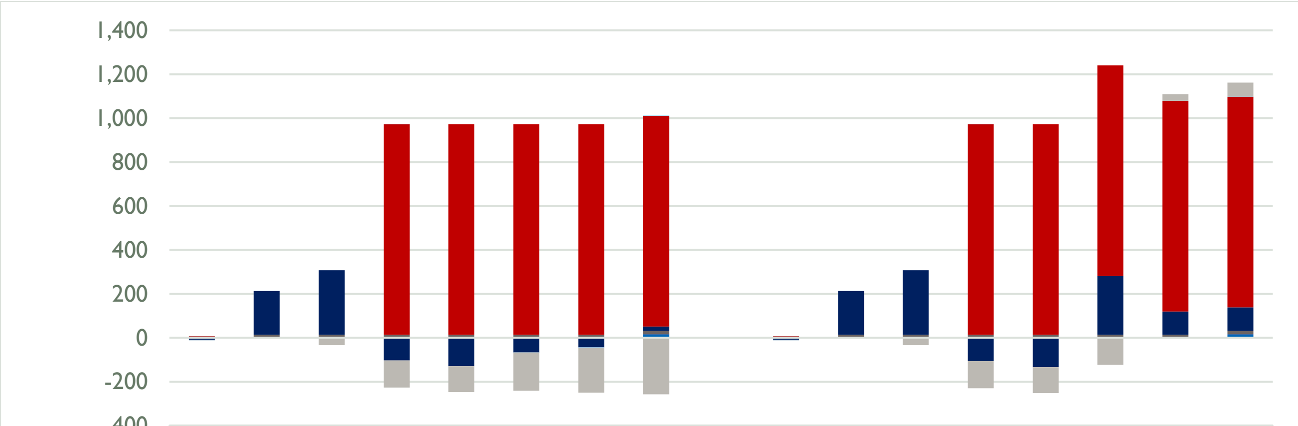


Figure 3.100: TPES by fuel for Georgia electricity import/export scenarios, ktoe



	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
	Import/Export 300 MW								Import/Export 1,050 MW							
Renewables	-0.8	0	-34	-123	-117	-175	-205	-257	-0.8	0	-34	-124	-119	-124	31	65
Oil Products	0	0	0	0	0	-0.4	-0.5	0.003	0	0	0	0	0	0	0	0.003
Nuclear	0	0	0	959	959	959	959	959	0	0	0	959	959	959	959	959
Gas	-9	199	294	-104	-129	-66	-44	21	-9	199	294	-106	-133	267	106	108
Electricity	6	14	14	14	14	14	14	14	6	14	14	14	14	14	14	14
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biofuels	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	17

Figure 3.101: Comparison of TPES for Georgia electricity import/export scenarios and Baseline Scenario, ktoe

FEC projections for both scenarios are practically identical to the Baseline Scenario.

ELECTRICITY GENERATION TECHNOLOGIES. The model's least-cost configuration for these scenarios is presented in Table 3.37, with significant differences in generation capacity configuration for nuclear, RES, and storage technologies.

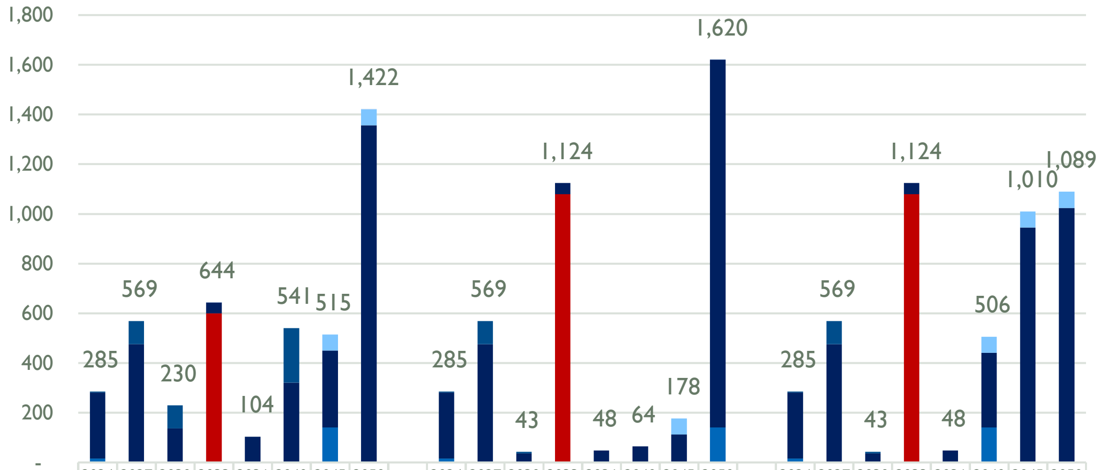
In the Import/Export 300 MW scenario, the least-cost configuration includes a 1,080-MW NPP added in 2033, which results in significantly less RES capacity and later construction of large HPPs compared with the Baseline Scenario.

TABLE 3.37: CAPACITY BY PLANT/PLANT TYPE FOR ELECTRICITY IMPORT/EXPORT SCENARIOS, MW

SCENARIO	BASELINE								IMPORT/EXPORT 300 MW								IMPORT/EXPORT 1,050 MW							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-	234	234	234	234	234	234	-	-
Yerevan CCGT-2	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-	254	254	254	254	254	254	208	-
Hrazdan Unit 5	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-	467	467	467	-	-	-	-	-
Local cogeneration plant	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Vorotan HPP Cascade	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Sevan-Hrazdan HPP Cascade	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561	561
Loriberd HPP	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	66	-	-	-	-	-	66	66	66
Shnokh HPP	-	-	-	-	-	-	75	75	-	-	-	-	-	-	-	75	-	-	-	-	-	75	75	75
Small HPP (existing)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
Small HPP (new)	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
ANPP (existing)	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-	440	-	-	-	-	-	-	-
NPP (new)	-	-	-	600	600	600	600	600	-	-	-	1,080	1,080	1,080	1,080	1,080	-	-	-	1,080	1,080	1,080	1,080	1,080
Solar (existing)	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-	49	49	49	49	49	49	49	-
Solar (new)	369	845	982	1,026	1,130	1,452	1,727	2,630	369	845	882	926	974	1,039	1,118	2,143	369	845	882	926	974	1,274	2,186	2,757
Hydro pumped storage plant	-	-	-	-	-	-	65	130	-	-	-	-	-	-	65	65	-	-	-	-	-	65	130	195
Lithium-ion storage	-	-	-	0.02	0.02	0.02	0.02	0.06	-	0.03	0.04	0.05	0.05	0.05	0.05	0.07	-	0.03	0.04	0.05	0.05	0.05	0.1	0.04
Wind (existing)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wind (new)	4	97	190	190	190	409	409	371	4	97	103	103	103	103	103	65	4	97	104	104	104	104	104	66
Total	**3,233**	**3,362**	**3,592**	**3,769**	**3,873**	**4,414**	**4,616**	**5,289**	**3,233**	**3,362**	**3,405**	**4,062**	**4,111**	**4,175**	**4,040**	**4,911**	**3,233**	**3,362**	**3,406**	**4,063**	**4,111**	**4,617**	**5,315**	**5,655**

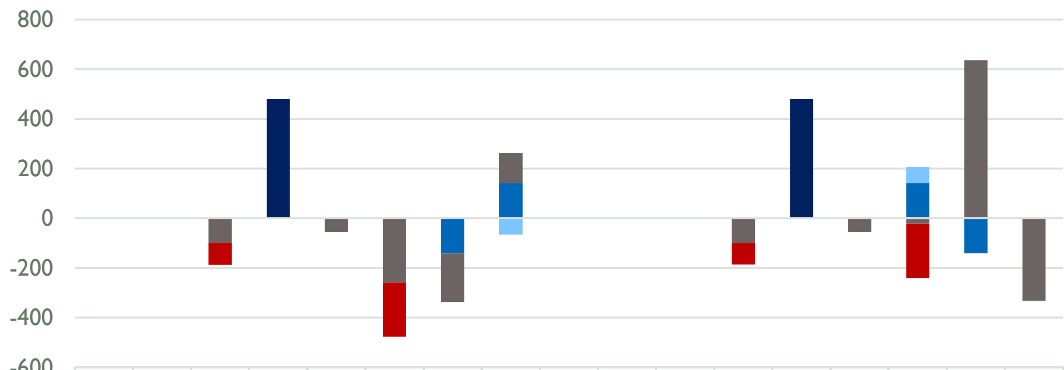
In the Import/Export 1,050 MW scenario, the least-cost configuration includes a 1,080-MW NPP starting in 2033 and more RES than in the Baseline Scenario. To ensure the proper daily operation of a large amount of variable renewable energy as well as large baseline production from the new NPP, the model chooses additional hydro pumped storage plants and lithium-ion batteries.

Figures 3.102 and 3.103 present new capacity implementation schedules for the Georgia electricity import/export scenarios and a comparison with the Baseline Scenario over the planning horizon.



	Baseline								Import/Export 300 MW								Import/Export 1,050 MW							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	4	93	93	-	-	219	-	-	4	93	6	-	-	-	-	-	4	93	7	-	-	-	-	-
Lithium-ion storage	-	-	-	0.02	-	0.00	-	0.04	-	0.03	0.01	-	-	-	-	0.04	-	0.03	0.01	-	-	-	-	-
Hydro pumped storage plant	-	-	-	-	-	-	65	65	-	-	-	-	-	-	65	-	-	-	-	-	-	65	65	65
Solar	266	476	137	44	104	322	309	1,35	266	476	37	44	48	64	113	1,47	266	476	37	44	48	300	945	1,02
Nuclear	-	-	-	600	-	-	-	-	-	-	-	1,08	-	-	-	-	-	-	-	1,08	-	-	-	-
Hydro	15	-	-	-	-	-	141	-	15	-	-	-	-	-	-	141	15	-	-	-	-	141	-	-
Total	285	569	230	644	104	541	515	1,42	285	569	43	1,12	48	64	178	1,62	285	569	43	1,12	48	506	1,01	1,08

Figure 3.102: New capacity implementation schedule in Georgia electricity import/export scenarios, MW



	Import/Export 300 MW								Import/Export 1,050 MW							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	-87	0	0	-219	0	0	0	0	-86	0	0	-219	0	0
Lithium-ion storage	0	0.03	0.01	-0.02	0	-0.002	0	-0.002	0	0.03	0.01	-0.02	0	-0.002	0.0	-0.04
Hydro pumped storage plant	0	0	0	0	0	0	0	-65	0	0	0	0	0	65	0	0
Solar	0	0	-100	0	-56	-258	-196	123	0	0	-100	0	-56	-22	636	-332
Nuclear	0	0	0	480	0	0	0	0	0	0	0	480	0	0	0	0
Hydro	0	0	0	0	0	0	-141	141	0	0	0	0	0	141	-141	0

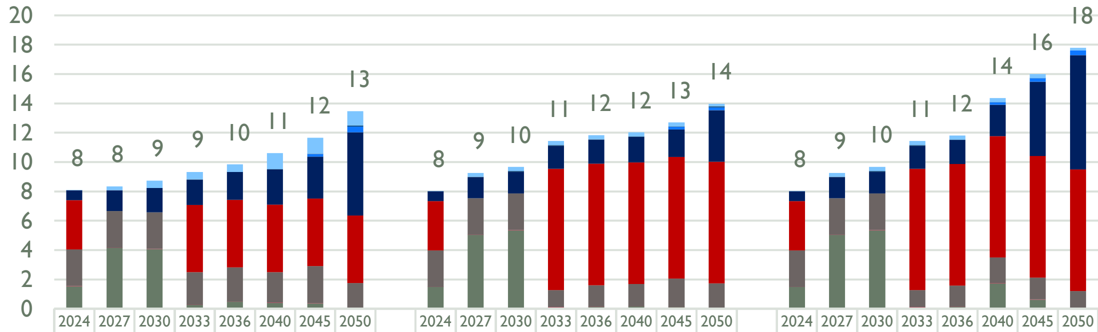
Figure 3.103: Comparison of new power plant construction for Georgia electricity import/export scenarios and Baseline Scenario, MW

Generation by plant for the electricity import/export scenarios is presented in Table 3.38.

TABLE 3.38: GENERATION BY PLANT/PLANT TYPE FOR ELECTRICITY IMPORT/EXPORT SCENARIOS, GWH

SCENARIO	BASELINE								IMPORT/EXPORT 300 MW								IMPORT/EXPORT 1,050 MW							
Power plant	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**	**2024**	**2027**	**2030**	**2033**	**2036**	**2040**	**2045**	**2050**
Yerevan CCGT	71	1,672	1,672	22	59	60	-	-	66	1,614	1,672	1	10	17	-	-	66	1,614	1,672	1	10	621	-	-
Yerevan CCGT-2	1,471	1,891	1,891	248	417	343	364	-	1,420	1,891	1,891	96	120	143	112	-	1,420	1,891	1,891	97	120	1,109	625	-
Hrazdan Unit 5	-	591	510	-	-	-	-	-	-	1,534	1,790	-	-	-	-	-	-	1,534	1,790	-	-	-	-	-
Local cogeneration plant	7	7	7	7	7	8	8	26	7	8	17	7	7	8	8	18	7	8	17	7	7	18	18	18
Vorotan HPP Cascade	984	984	984	979	984	984	984	598	984	984	984	581	653	681	772	581	984	984	984	580	651	504	450	365
Sevan-Hrazdan HPP Cascade	414	414	414	414	414	414	414	346	414	414	414	284	298	298	365	254	414	414	414	284	298	284	80	80
Loriberd HPP	-	-	-	-	-	-	203	203	-	-	-	-	-	-	-	203	-	-	-	-	-	203	203	203
Shnokh HPP	-	-	-	-	-	-	291	291	-	-	-	-	-	-	-	291	-	-	-	-	-	291	291	291
Small HPP (existing)	932	935	935	654	790	528	492	122	923	935	935	139	355	390	652	224	923	935	935	135	340	301	301	101
Small HPP (new)	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
ANPP (existing)	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-	3,374	-	-	-	-	-	-	-
NPP (new)	-	-	-	4,601	4,601	4,601	4,601	4,601	-	-	-	8,281	8,281	8,281	8,281	8,281	-	-	-	8,281	8,281	8,281	8,281	8,281
Solar (existing)	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-	79	79	79	79	79	79	79	-
Solar (new)	592	1,354	1,574	1,645	1,811	2,328	2,770	5,689	592	1,354	1,413	1,484	1,562	1,665	1,792	3,522	592	1,354	1,413	1,484	1,562	2,043	4,999	7,781
Hydro pumped storage plant	-	-	-	-	-	-	188	376	-	-	-	-	-	-	188	188	-	-	-	-	-	188	225	329
Lithium-ion storage	-	-	-	15	8	20	20	68	-	25	38	43	31	22	13	75	-	25	38	44	30	6	3	-
Wind (existing)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wind (new)	11	259	507	507	507	1,091	1,091	990	11	259	275	275	275	275	275	174	11	259	276	276	276	276	276	176
Total	**8,095**	**8,347**	**8,734**	**9,332**	**9,839**	**10,617**	**11,667**	**13,472**	**8,029**	**9,259**	**9,669**	**11,433**	**11,833**	**12,020**	**12,699**	**13,975**	**8,029**	**9,259**	**9,671**	**11,431**	**11,817**	**14,367**	**15,993**	**17,787**

Figures 3.104 and 3.105 show projected generation capacity by power plant and generation technology for electricity import/export scenarios and their differences from the Baseline Scenario.

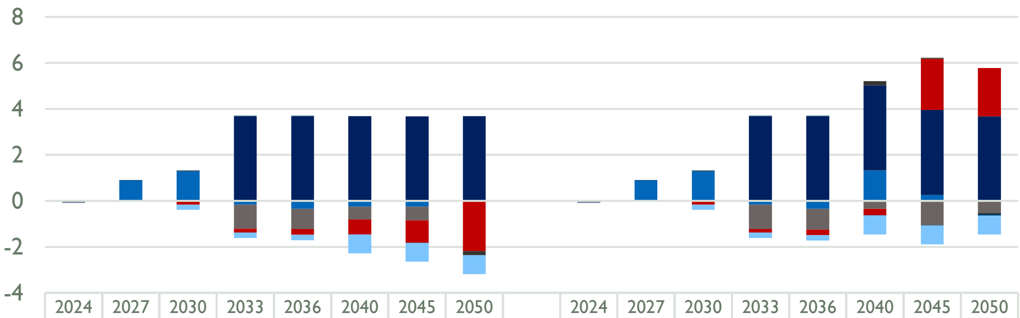


Baseline	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.5	0.5	0.5	1.1	1.1	1.0
Lithium-ion storage	-	-	-	0.02	0.01	0.02	0.02	0.07
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.4
Solar	0.7	1.4	1.7	1.7	1.9	2.4	2.8	5.7
Nuclear	3.4	-	-	4.6	4.6	4.6	4.6	4.6
Hydro	2.5	2.5	2.5	2.2	2.3	2.1	2.5	1.7
Gas-fired CHPs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03
Gas-fired	1.5	4.2	4.1	0.3	0.5	0.4	0.4	-
Total	8	8	9	9	10	11	12	13

Import/Export 300 MW	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.3	0.3	0.3	0.3	0.3	0.2
Lithium-ion storage	-	0.03	0.04	0.04	0.03	0.02	0.01	0.08
Hydro pumped storage plant	-	-	-	-	-	-	0.2	0.2
Solar	0.7	1.4	1.5	1.6	1.6	1.7	1.9	3.5
Nuclear	3.4	-	-	8.3	8.3	8.3	8.3	8.3
Hydro	2.5	2.5	2.5	1.2	1.5	1.5	1.9	1.7
Gas-fired CHPs	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02
Gas-fired	1.5	5.0	5.4	0.1	0.1	0.2	0.1	-
Total	8	9	10	11	12	12	13	14

Import/Export 1,050 MW	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0.01	0.3	0.3	0.3	0.3	0.3	0.3	0.2
Lithium-ion storage	-	0.03	0.04	0.04	0.03	0.01	0.00	-
Hydro pumped storage plant	-	-	-	-	-	0.2	0.2	0.3
Solar	0.7	1.4	1.5	1.6	1.6	2.1	5.1	7.8
Nuclear	3.4	-	-	8.3	8.3	8.3	8.3	8.3
Hydro	2.5	2.5	2.5	1.2	1.4	1.7	1.5	1.2
Gas-fired CHPs	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02
Gas-fired	1.5	5.0	5.4	0.1	0.1	1.7	0.6	-
Total	8	9	10	11	12	14	16	18

Figure 3.104: Electricity generation by power plant/type for Georgia electricity import/export scenarios, TWh



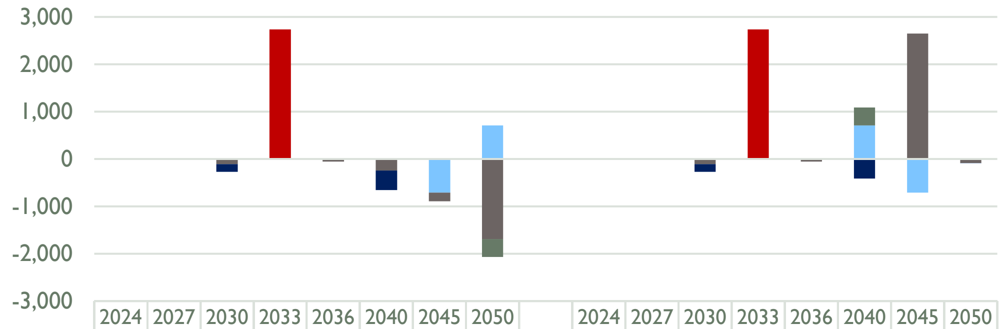
Import/Export 300 MW	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	-0.2	-0.2	-0.2	-1	-1	-1
Lithium-ion storage	0	0.03	0.04	0.03	0.02	0.001	-0.01	0.01
Hydro pumped storage plant	0	0	0	0	0	0	0	-0.2
Solar	0	0.0	-0.2	-0.2	-0.2	-1	-1	-2
Nuclear	0	0	0	4	4	4	4	4
Hydro	-0.01	0	0	-1	-1	-0.6	-0.6	-0.01
Gas-fired CHPs	0	0.001	0.01	0	0	0	0	-0.01
Gas-fired	-0.1	1	1	-0.2	-0.3	-0.2	-0.3	0

Import/Export 1,050 MW	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	-0.2	-0.2	-0.2	-1	-1	-1
Lithium-ion storage	0	0.03	0.04	0.03	0.02	-0.01	-0.02	-0.1
Hydro pumped storage plant	0	0	0	0	0	0.2	0.04	-0.05
Solar	0	0	-0.2	-0.2	-0.2	-0.3	2	2
Nuclear	0	0	0	4	4	4	4	4
Hydro	-0.01	0	0	-1	-1	-0.3	-1	-0.5
Gas-fired CHPs	0	0.001	0.01	0	0	0.01	0.01	-0.01
Gas-fired	-0.1	1	1	-0.2	-0.3	1	0.3	0

Figure 3.105: Comparison of electricity generation by power plant/type for Georgia electricity import/export scenarios and Baseline Scenario, TWh

INVESTMENTS IN NEW POWER SYSTEM CAPACITY. Differences in the generation technology mix result in differences in total power sector investment in new generation. Table 3.39 and Figure 3.106 compare investments between the electricity import/export and Baseline Scenarios. The main driver of differences is the implementation of a new NPP in both electricity import/export scenarios.

TABLE 3.39: TOTAL POWER SECTOR INVESTMENT IN NEW CAPACITY FOR ELECTRICITY IMPORT/EXPORT SCENARIOS		
SCENARIO	MILLIONS OF USD	DIFFERENCE COMPARED WITH BASELINE, %
Baseline	12,854	-
Import/Export 300 MW	12,358	-3.9
Import/Export 1,050 MW	17,791	+38.4



	Import/Export 300 MW								Import/Export 1,050 MW							
	2024	2027	2030	2033	2036	2040	2045	2050	2024	2027	2030	2033	2036	2040	2045	2050
Wind	0	0	-166	0	0	-412	0	0	0	0	-165	0	0	-412	0	0
Lithium-ion storage	0	0.04	0	-0.01	0	-0.001	0	-0.002	0	0.04	0	-0.01	0	-0.001	0	-0.02
Hydro pumped storage plant	0	0	0	0	0	0	0	-377	0	0	0	0	0	377	0	0
Solar	0	0	-107	0	-54	-242	-183	-1,690	0	0	-107	0	-54	-1	2,651	-89
Nuclear	0	0	0	2,736	0	0	0	0	0	0	0	2,736	0	0	0	0
Hydro	0	0	0	0	0	0	-709	709	0	0	0	0	0	709	-709	0

Figure 3.106: Comparison of investments in new power system capacity for Georgia electricity import/export scenarios and Baseline Scenario, millions of USD

GHG EMISSIONS differences by scenario are presented in Figure 3.107.

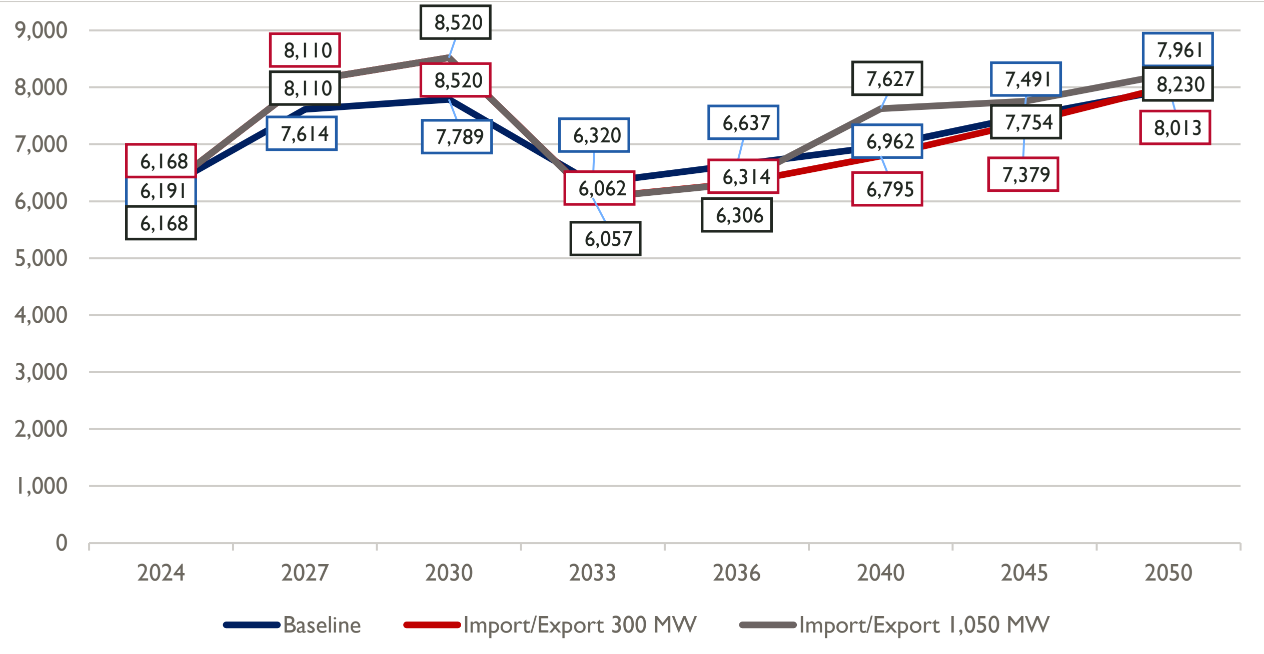


Figure 3.107: GHG emissions (CO_{2eq}) for Georgia electricity import/export scenarios, kt

The main polluting energy carrier for both scenarios remains natural gas, with around 80 percent of total GHG emissions in all milestone years. The transport and residential sectors contribute the most in both import/export scenarios (35 and around 29 percent respectively), followed by the commercial and industrial sectors (both 15 percent). The rest of emissions come from agriculture (0.6 percent) and the power sector (0.2 percent). Fugitive emissions from the supply side amount to 8 percent.

ENERGY INDEPENDENCE for the electricity import/export scenarios is presented in Figure 3.108.

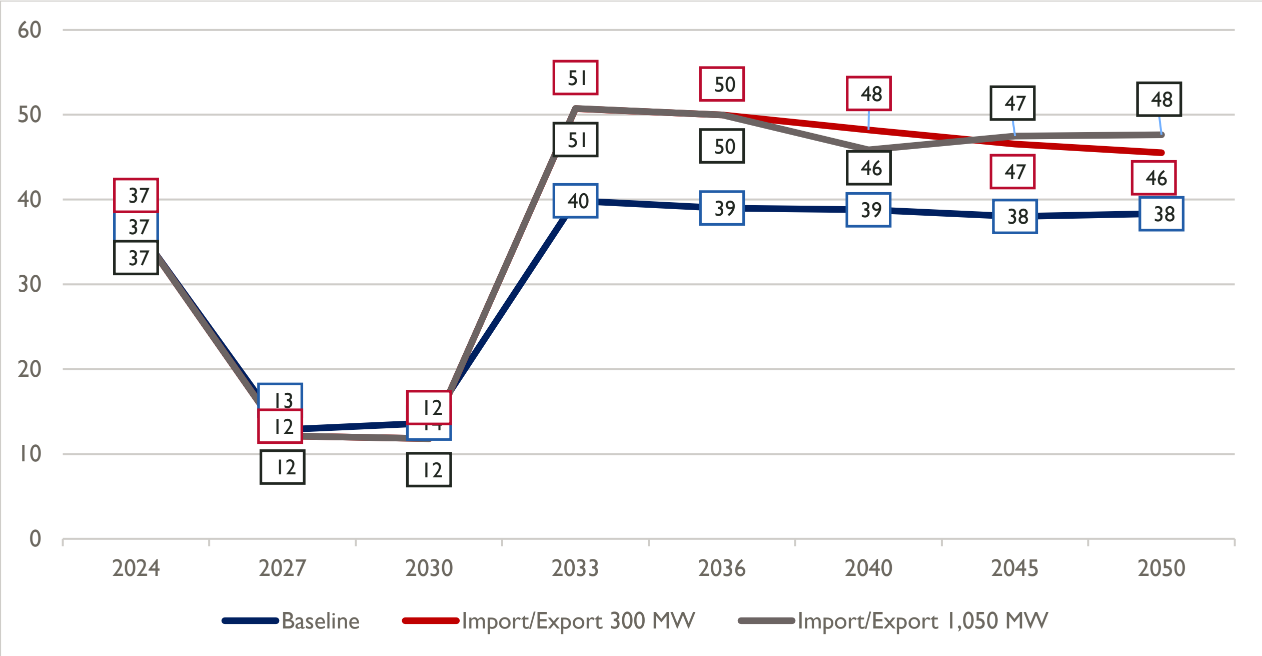


Figure 3.108 Energy independence levels for Georgia electricity import/export scenarios, %

In the Import/Export 300 MW scenario, Armenia's energy independence level is 46 percent at the end of the planning period. It falls from 51 percent in 2033 because of increased demand, which will be covered by fossil fuels.

In the Import/Export 1,050 MW scenario, energy independence level jumps to 51 percent in 2033 (the same as in the Import/Export 300 MW scenario), then falls to 46 percent in 2040 after which reaches 48 percent by the end of the planning horizon. Its divergence from the Import/Export 300 MW scenario after 2045 is a result of the implementation of more solar PV to cover increased electricity demand.

ANNEX 1 ARMENIA ENERGY BALANCE FOR BASE YEAR

TABLE A.1 ARMENIAN ENERGY BALANCE 2019, KTOE

ACTIVITY	TOTAL	COAL	OIL	NATURAL GAS	RES	NUCLEAR	DERIVED HEAT	ELECTRICITY
Production	934.2	-	-	-	290.0	644.2	-	-
Imports	2,665.4	2.7	505.2	2,120.3	12.0	-	-	25.2
International aviation bunker	-72.7	-	-72.7	-	-	-	-	-
Exports	-109.2	-	-0.6	-	-1.1	-	-	-107.6
Stock changes	-13.8	-	-30	15.5	0.7	-	-	-
TPES	3,403.9	2.7	402.0	2,135.8	301.6	644.2	-	-82.4
Transfers	-	-	-	-	-	-	-	-
Statistical differences	0.0	-	0.0	0.0	-	-	-	0.0
Transformation processes	-768.8			-576.2	-210.4	-644.2	0.7	661.3
Electricity plants	-455.2	-	-	-	-210.4	-644.2	-	399.4
Nuclear power stations (MA El. Gen.)	-455.2	-	-	-	-	-644.2	-	189.0
Hydropower stations (MA El. Gen.)	-	-	-	-	-121.7	-	-	121.7
Small hydropower stations (MA El. Gen.)	-	-	-	-	-82.2	-	-	82.2
Wind power stations (MA El. Gen.)	-	-	-	-	-0.3	-	-	0.3
Solar power stations (MA El. Gen.)	-	-	-	-	-6.2	-	-	6.2
Thermal power stations (MA El. Gen.)	-312.5			-573.7				261.2
CHP	-1.1	-	-	-2.5	-	-	0.7	0.7
Other stations	-	-	-	-	-	-	-	-
Energy industry own use	-32.3	-	-	-3.6	-	-	0.0	-28.7

TABLE A.1 ARMENIAN ENERGY BALANCE 2019, KTOE

ACTIVITY	TOTAL	COAL	OIL	NATURAL GAS	RES	NUCLEAR	DERIVED HEAT	ELECTRICITY
Distribution losses	-143.2	-	-	-95.6	-	-	-0.4	-47.1
Total final consumption	2,459.6	2.7	402.0	1,460.4	91.2		0.2	503.1
Final energy consumption	2,413.4	2.6	356.9	1,460.4	90.1	-	0.2	503.1
Industry	313.0	-	17.5	161.7	0.0	-	-	133.8
Iron and steel	19.9	-	0.0	13.9	-	-	-	6.0
Chemical and petrochemical	3.7	-	0.2	2.2	-	-	-	1.3
Non-ferrous metals	24.3	-	5.0	0.7	-	-	-	18.6
Non-metallic minerals	81.7	-	0.5	69.8	-	-	-	11.4
Transport equipment	0.1	-	-	0.1	-	-	-	0.0
Machinery	2.9	-	0.0	0.8	0.0	-	-	2.0
Mining and quarrying	84.2	-	10.8	8.4	0.0	-	-	64.9
Food, beverages, and tobacco	75.1	-	0.0	56.2	0.0	-	-	18.9
Paper, pulp, and printing	5.7	-	-	3.8	-	-	-	2.0
Wood and wood products	0.1	-	-	0.0	0.0	-	-	0.1
Textiles and leather	2.3	-	-	0.7	0.0	-	-	1.6
Construction	8.0	-	1.0	3.9	-	-	-	3.1
Non-specified (industry)	5.1	-	0.0	1.2	-	-	-	3.8
Transport	806.6	-	317.1	480.8	-	-	-	8.7
Rail, metro, other electric transport	6.6	-	-	-	-	-	-	6.6
Road	797.8	-	317.1	480.8	-	-	-	-
Aviation	1.5	-	-	-	-	-	-	1.5

TABLE A.1 ARMENIAN ENERGY BALANCE 2019, KTOE								
ACTIVITY	TOTAL	COAL	OIL	NATURAL GAS	RES	NUCLEAR	DERIVED HEAT	ELECTRICITY
Non-specified (transport)	0.7	-	-	-	-	-	-	0.7
Other sectors	1,293.9	2.6	22.5	817.8	90.1	-	0.2	360.6
Households	812.7	0.8	0.8	557.0	85.9	-	0.2	168.0
Agriculture	29.8	-	16.6	-	-	-	-	13.2
Services	451.4	1.8	5.1	260.8	4.3	-	-	179.4
Non-energy use	46.2	0.1	45.0	-	1.1	-	-	-

ANNEX 2 MODEL OVERVIEW

The TIMES model generator was developed under the IEA's Energy Technology Systems Analysis Program, an international community effort that uses long-term energy scenarios to conduct in-depth energy and environmental analyses.[39] It combines two complementary, systematic approaches to modeling energy: a technical engineering approach and an economic approach. TIMES is a technology-rich, bottom-up model generator that uses linear programming to produce a least-cost energy system, optimized according to a number of user constraints, over medium- to long-term time horizons. It is used to explore possible energy futures by contrasting scenarios.

The model is a powerful, yet user-friendly set of tools geared to facilitate the creation, maintenance, browsing, and modification of the large databases required by complex mathematical and economic models. It also enables smart exploration of the results created by such models and the creation of reports. Data and assumptions are fed into VEDA, which provides input to the TIMES code. VEDA accepts inputs from a variety of Excel files with different (flexible) structures that are tailored to work efficiently with data-intensive models. The TIMES code works in the General Algebraic Modeling Language and produces text output. VEDA reads the text and produces numerical and graphical output for the user (mainly via Excel). Figure A.1 shows VEDA2.0 data flow and files used.

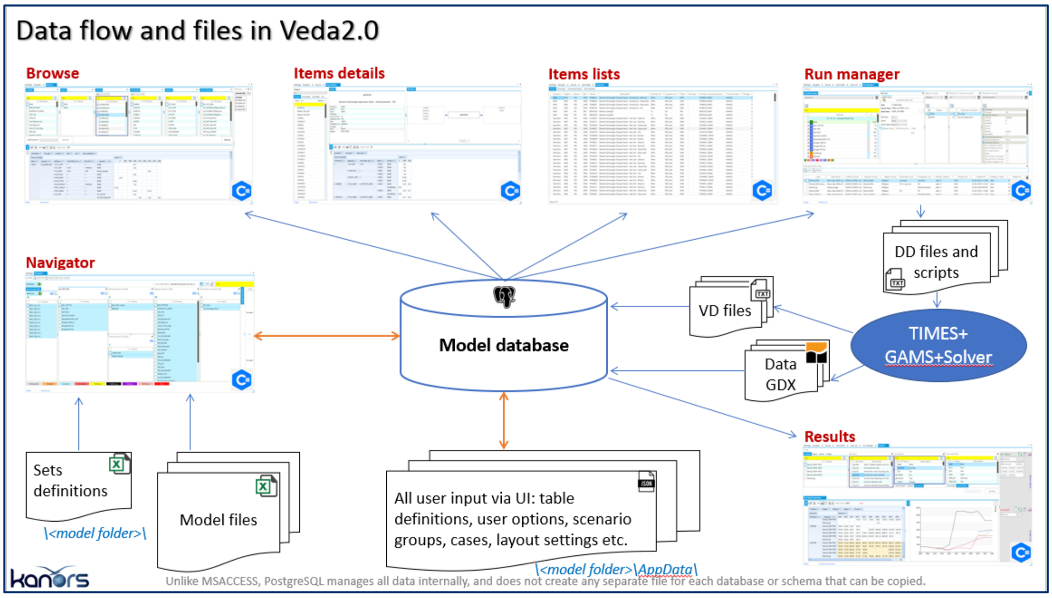


Figure A.2: Data flow and files in VEDA2.0

For LCEDP development, the Times-Armenia model was migrated to VEDA2.0. After two decades, VEDA has been completely rebuilt into a superior product that is already active on more than 150 user accounts (May 2021). VEDA 2.0 provides the following benefits for modeling:

- No limit on the size of individual scenarios or the whole model
- Three to ten times faster synchronization
- Stable application and reliable data processing
- Significantly faster view processing
- No limit on length of process, commodity, user constraints, or commodity group name. File and case names should still be under 50 characters.

[39] https://veda-documentation.readthedocs.io/en/latest/index.html