cigre SEERC

CIGRE Southeastern Region Electricity Overview:

Generation, Consumption and Renewable Energy

cigre Türkiye

TÜBİTAK

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TÜRKİYE ELEKTRİK SANAYİ BİRLİĞİ TİCARİ İŞLETMESİ
Mustafa Kemal Mahallesi Dumlupınar Bulvarı 7. Km No: 166
Çankaya - Ankara / TÜRKİYE
Yayıncı Sertifika No: 53255
www.tesab.org.tr • tesab@tesab.org.tr

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FOREWORD

Words From SEERC Chair

As one of the four regional council of CIGRE, Southeastern European Reginal Council (SEERC) aims to increase regional cooperation among experts, academics, and companies within Southeastern Europe. The population of SEERC member countries comprises more than 280 million people, and has a great potential for fast development of the power engineering sector. The close cooperation of Southeast European countries within SEERC offers better possibilities for development of the future power network and market.

CIGRE Türkiye National Committee has the chairmanship of SEERC two years, from November 2021 to November 2023. We, as CIGRE Türkiye NC, have organized numerous activities and prepared projects to increase internal cooperation of SEERC, We tried to create friendly and shareable environments to become the SEERC family during our chairmanship period.

This project book is one of the most important outputs of the chairmanship of Türkiye besides the traditional 4th SEERC Conference Istanbul. The book seeks to frame electricity system of the SEERC, countries including the current and future projections of the countries with the analysis of the experts in SEERC.

I hope the book will provide a full-fledged power system analyze for the experts, academic and research. I personally thank all CIGRE SEERC National Committees which contribute our project, organizational committee of the conference and CIGRE Türkiye National Committee for their effort to prepare this book.

Zafer BENLİ
General Manager of Electricty Generation Co.
President of CIGRE Türkiye NC
SEERC Chair

PREFACE

Energy has been an important factor shaping human life, economy, and environment throughout history. However, while energy demand is rapidly increasing around the world, it is clearly seen that energy resources are limited, and environmental impacts are becoming increasingly important. The future of energy production and consumption is of great importance at both individual and social levels. The electricity production capacities of countries have a wide range of effects, from energy independence to economic growth. Energy production and consumption, in addition to supporting economic growth worldwide, is of great importance due to its effects on the environment and public health. Sustainable development in energy is becoming increasingly important both to support economic growth and to ensure environmental sustainability. Many research and development studies are carried out on the fight against climate change and energy security at the international level.

CIGRE is one of the oldest international technical organizations in the world. CIGRE national committees have been established to share information on electrical power systems as well as to create new standards and recommendations. CIGRE Southeastern Europe Regional Council (SEERC) will bring these beautiful technical shares of CIGRE to Southeastern Europe. SEERC was established in Montenegro on 13 May 2013 and consists of members from 17 countries. The close cooperation of Southeastern European countries within the scope of SEERC offers better possibilities for the development of the future energy network and market.

Sustainable energy policies and practices of countries have become a priority at the global level. For this reason, we decided to prepare the energy vision report of SEERC countries as our 2021-2023 SEERC presidency term project, and to take this important step together that shapes the future of the energy sector and the world economy. Our report aims to provide an accurate road map for the production and consumption of energy by addressing the important developments and trends in the future energy field of Austria, Bosnia and Herzegovina, Croatia, Georgia, Greece, Kosovo, Montenegro, and Türkiye. To make energy production more sustainable, efficient, and environmentally friendly, forecasts in the field of energy production and consumption are examined and the critical role of the energy sector for countries is emphasized. The presented report will be a reflection of our commitment to leaving a better world to future generations. This book, which will provide a comprehensive evaluation of the countries' future energy production, distribution, consumption, and transformation, serves as a guide for all stakeholders of the energy sector. First, we should point out that it was a great honor for us to present our presidential revolution and term project at such a precious time as the 100th anniversary of our Republic. We would like to express our endless gratitude to all SEERC member countries who made valuable contributions to our chairmanship project with us.

Assoc. Prof. Dr. Tuğçe DEMİRDELEN
CIGRE SEERC Technical Advisory Committee Chair

Words from CIGRE Türkiye General Secretary

CIGRE has been bringing together industry and universities since 1921 to share knowledge, experience and develop standards in the field of power systems. CIGRE brings together technical experts from 90 countries around the world and has national committees in 61 countries.

CIGRE Türkiye National Committee is one of the youngest national committees in CIGRE and was established in 2014. Since its establishment, it has been carrying out comprehensive activities for the promotion of CIGRE in our country and the promotion of Türkiye at CIGRE. Our most important activity in the life of our national committee was to carry out the chairmanship of CIGRE Southeastern Europe Regional Council (SEERC), which was established in 2013. The presidency we received in Austria in 2021 was handover to Bosnia and Herzegovina on October 11, 2023.

Projects are being developed with the aim of ensuring cooperation, coordination and synergy between the member countries. The history of electrical energy sector of the member countries was developed as "SEERC History Book" prepared under the leadership of Slovenia. The Chairmanship Project carried out under the chairmanship of the CIGRE Türkiye National Committee included the overwiev of electrical energy sector present and future plans of the electrical systems of the member countries.

I thank to SEERC TAC Chair Assoc. Prof. Dr. Tuğçe Demirdelen and all our SEERC member national committees for their contribution.

Ayten SÜMER
CIGRE Türkiye General Secretary

Words from CIGRE SEERC Secretary

During the two years of Chairmanship period of CIGRE National Committee of Türkiye, we have aimed the increase cooperation and coordination within the Southeastern Regional Committee of CIGRE, and believed the succeed of mission. "Energy Outlook of SEERC" is a good sample for showing current and future energy frame of our region.

I, as CIGRE SEERC Secretary, personally thank all the writers, and member national committees for their contribution and support to the Project book.

Erkan ALAN
SEERC Secretary

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Electricity Outlook

Assoc. Prof. Dr. Tuğçe Demirdelen

1. Türkiye Electricity Outlook

1.1. Power system profile

In this report, Türkiye's power system profile is presented comprehensively. The following sections of the report give details on Türkiye's installed power capacity, new capacity commissioned, electricity generation, electricity consumption, coal power plants, nuclear power plants, natural gas and renewable energy. In addition, hydrogen generation technologies and hydrogen storage roadmaps are explained by examining the perspective of hydrogen technologies in Türkiye's energy model. Finally, Türkiye's 2035-2053 Period Strategic Foresight has been explained in a frame.

Türkiye's electricity consumption was 328.7 billion kWh in 2022, and electricity generation was 326 billion kWh. In 2022, our electricity generation was obtained 34.6% from coal, 22.2% from natural gas, 20.6% from hydraulic, 10.8% from wind, 4.7% from solar, 3.3% from geothermal and 3.7% from other sources. As of the end of December 2022, the installed power capacity of our country has reached 103,809 MW. As of the end of December 2022, the distribution of our installed power by resources [1];

- 30.4% Hydropower,
- 24.4% Natural Gas,
- 21% Coal,
- 11% Wind,
- 9.1% Solar,
- 1.6% Geothermal
- 2.5% Other Sources.

The total number of power plants in our country has increased to 11,427 (including unlicensed power plants) at the end of December 2022. Number of active power plants [1];

- 751 hydroelectric power,
- 67 coal power,
- 58 wind power,
- 63 geothermal power,
- 345 natural gas power,
- 9,353 solar power,
- 490 power plants with other sources.

In the scenario prepared by the Republic of Türkiye Ministry of Energy and Natural Resources within the scope of this study, in the 2020-2035 period [1];

- Primary energy consumption rises to 205.3 Mtoe,
- Electricity consumption reaches 510.4 TWh,
- The share of electrical energy in final energy consumption reaches 24.9%,
- Energy intensity decreases by 35.3%.

Electric installed power capacity [1];

- to 189.7 GW in total,
- to 52.9 GW in solar energy,
- to 29.6 GW in wind energy,
- Increases to 7.2 GW in nuclear energy.

The anticipated capacity to be commissioned will be 96.9 GW. The share of intermittent renewable energy sources in electricity generation rises to 34.2% and 54.7% of renewable energy sources. The share of intermittent renewable energy sources in the electricity installed capacity rises to 43.5% and the share of renewable energy sources to 64.7%. In order to meet the flexibility required in the electrical grid [1];

- Battery capacity up to 7.5 GW (2 hours charging time),
- Electrolyzer capacity up to 5.0 GW,
- Demand-side participation reaches 1.7 GW.

1.2. Installed electricity capacity

The installed electricity capacity, which was 95.9 GW in 2020, is planned to increase to 189.7 GW in 2035. The share of renewable energy sources, which was 52.0% of the installed power in 2020, will reach 64.7% by 2035. Hydroelectric power plants reach an installed power value of 35.1 GW in the medium-long term. Wind energy installed power reaches 29.6 GW and solar energy installed power rises to 52.9 GW [1].

In addition to the Akkuyu Nuclear Power Plant, which is currently under construction, new nuclear power plants are needed in our country [2]. The total installed power of geothermal and biomass power plants will reach 5.1 GW. Installed power by sources is shown in Figure 1.

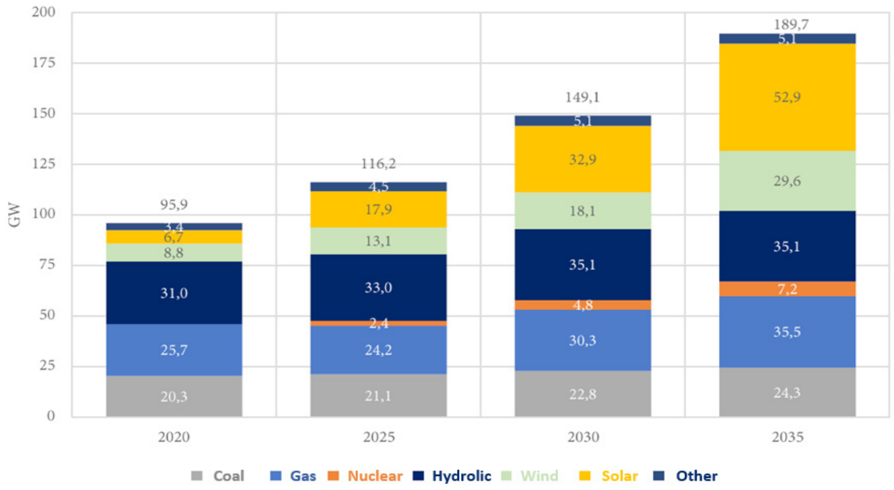


Figure 1. Installed power by sources

1.3. New capacity commissioned

The amount of new capacity to be commissioned in the 2021-2035 period is at the level of 96.9 GW. A new capacity of 21.6 GW in the 2021-2025 period, 34.3 GW in the 2026-2030 period, and 41.0 GW in the 2031-2035 period should be commissioned in our country. 74.3% of the said installed power increase consists of renewable energy sources, the majority of which are solar and wind energy. Annual new capacity for solar and wind energy averages 3.1 and 1.4 GW, respectively. There will be a decrease in the installed power of the power plants that will be decommissioned due to the end of their lives.

However, the effect of the new capacity to be commissioned on the total installed capacity is higher. The new capacity commissioned in five-year periods is shown in Figure 2.

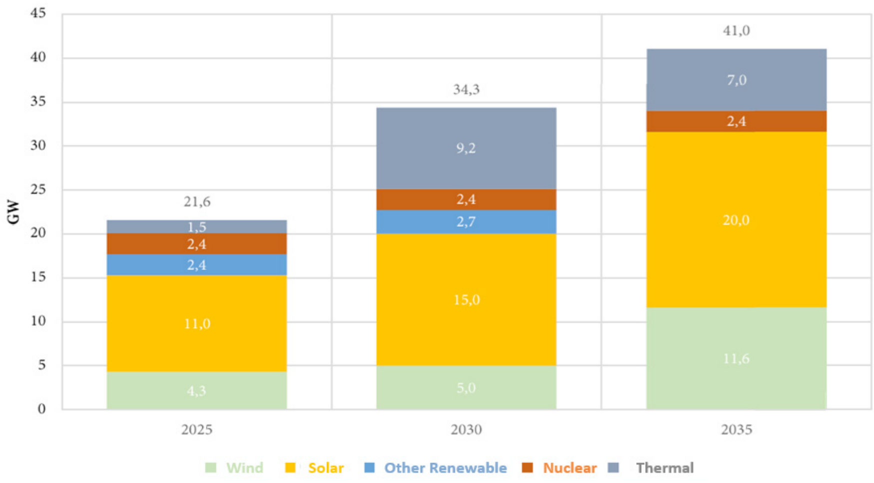


Figure 2. New capacity commissioned in five-year periods

1.4. Electricity generation

The share of intermittent renewable energy sources, which was 11.7% in electricity generation in 2020, will gradually increase to 34.3% until 2035. Similarly, the share of renewable energy sources, which was 42.4% in electricity generation in 2020, increases to 54.8% by 2035. Currently, the share of hydroelectric power plants, which have the largest share in the installed power, is planned to be 17.3% in 2035, as they are approaching the maximum installed power potential. Natural gas power plants may contribute higher or lower than the values shown periodically, as they offset possible variations in electricity generation from other sources.

Electricity from coal power plants, which have a share of 34.5% in generation in 2020, will continue to decrease until 2035. Carbon prices for the electricity and heat generation sector will determine the share of electricity generation from coal plants. However, it is anticipated that the capacity support mechanism applied to base/flexible load power plants to ensure electricity supply security will continue in the plan period. In addition, no investment decision is taken by the proposed model at this stage for a new coal or natural gas power plant with carbon capture technology in the period until

2035. It is possible for coal to make a higher-than-expected contribution to electricity generation with the acceleration of the decline in prices due to technological developments. Electricity generation based on resources and distribution of electricity generation by resources are shown in Figure 3 and Figure 4, respectively.

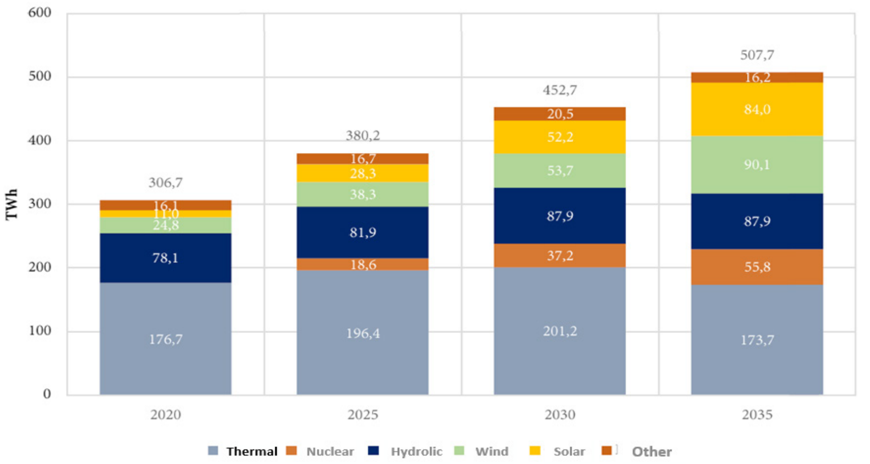


Figure 3. Electricity generation based on resources

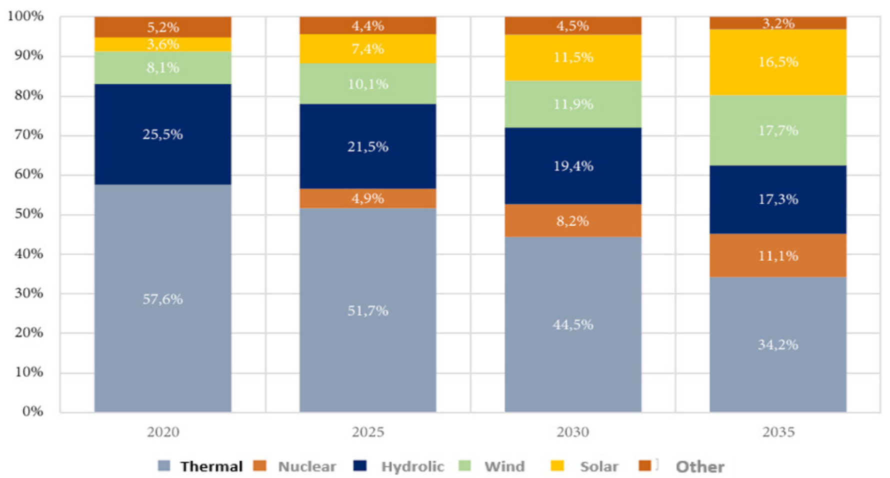


Figure 4. Distribution of electricity generation by resources

With the integration of intermittent renewable energy sources, the need for flexibility in energy systems is increasing. The need for flexibility; It is possible to meet with methods such as increasing the interconnection capacity between neighboring countries, battery storage technologies and hydrogen production with electrolyzers [3].

Battery capacity increases according to the rate of introduction of intermittent renewable energy sources and reaches 7.5 GW in 2035. The capacity of the electrolyzer increases depending on the amount of hydrogen and synthetic methane that needs to be mixed with natural gas to reduce greenhouse gas emissions. The evolution of battery capacity and evolution of electrolyzer capacity are shown in Figure 5 and Figure 6, respectively.

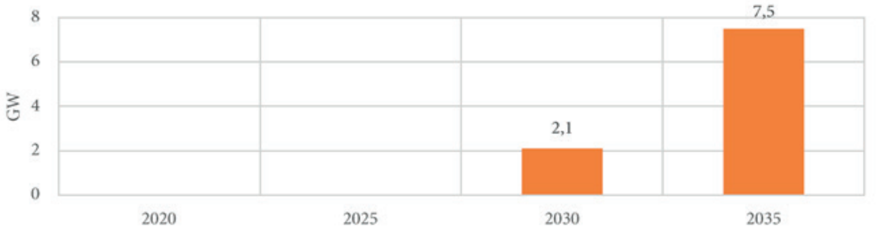


Figure 5. The evolution of battery capacity

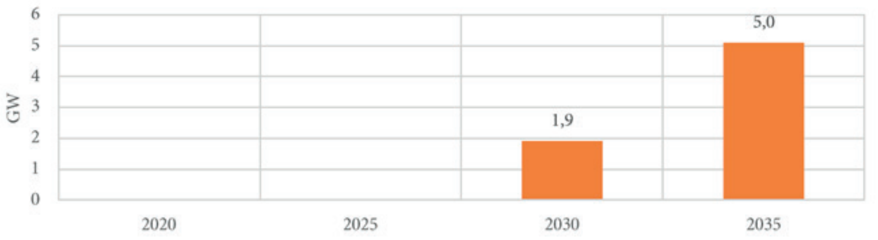


Figure 6. Evolution of electrolyzer capacity

1.5. Electricity consumption

Electricity consumption, which increased from 128 TWh to 306.1 TWh with an annual average increase of 4.4% in the 2000-2020 period, reaches 510.5 TWh with an annual average increase of 3.5% until 2035. During the forecast period, annual average electricity consumption is expected to increase by

3.7% in the industry sector, 2.3% in the residential sector, and 2.2% in the services sector. The share of electrical energy, which has a rate of 21.8% in the final energy consumption in 2020, reaches 24.9% in 2035. Electricity consumption by sectors is shown in Figure 7.

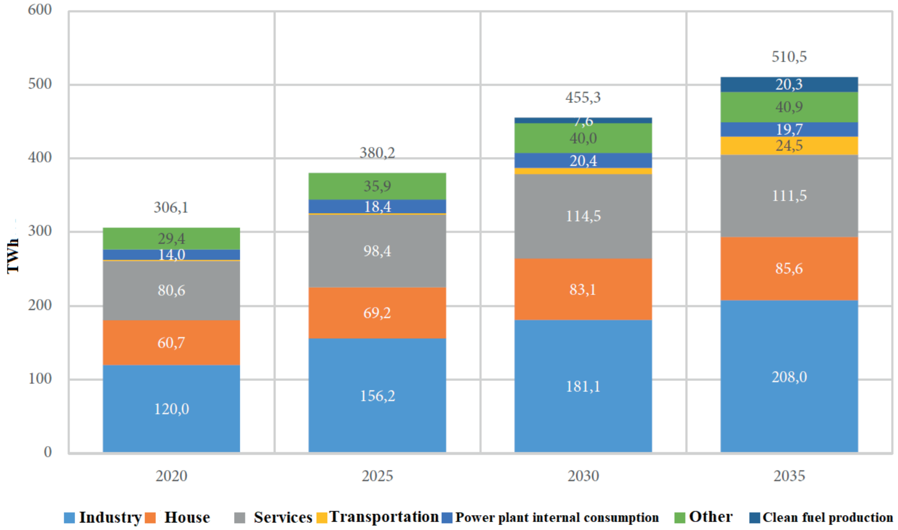


Figure 7. Electricity consumption by sectors

1.5.1. Primary energy consumption

The primary energy consumption of our country in 2020 was 147.2 Mtoe. By 2035, primary energy consumption rises to 205.3 Mtoe. Primary energy consumption, which increased by an annual average of 3.1% in the 2000-2020 period, increases by 2.2% in the 2020-2035 period. Primary energy consumption per capita, which was 1.7 toe/person in 2020, rises to 2.1 toe/person. The share of renewable energy sources in primary energy consumption, which was 16.7% in 2020, rises to 23.7% by 2035.

Nuclear energy, on the other hand, reaches 5.9% by 2035. The share of fossil resources, which was 83.3% in 2020, will be 70.4% until 2035. While the share of coal decreases to 21.4%, oil decreases to 26.5% and natural gas to 22.5%. Primary energy consumption and distribution of primary energy consumption by sources are shown in Figure 8 and Figure 9, respectively.

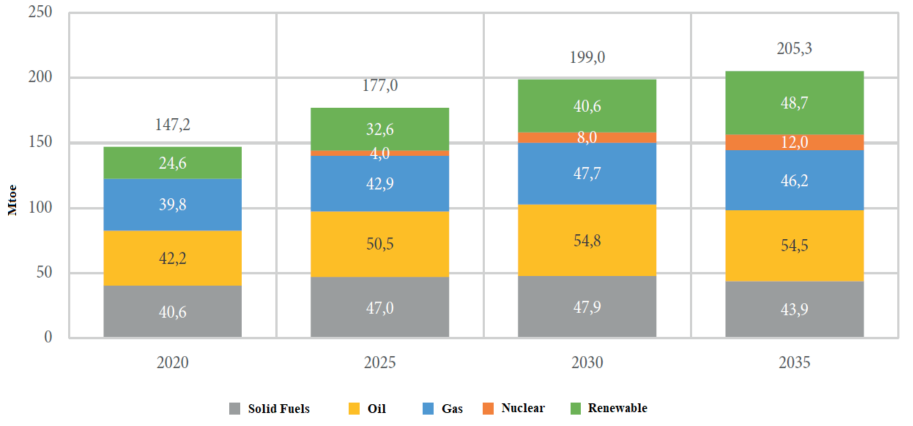


Figure 8. Primary energy consumption by sources

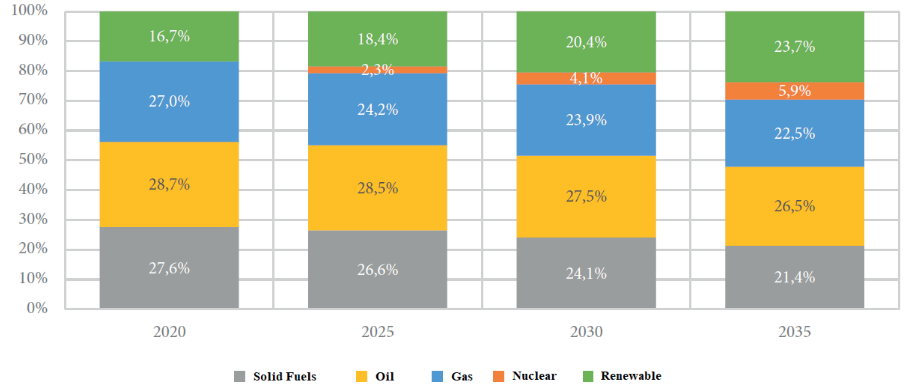


Figure 9. Distribution of primary energy consumption by sources

1.5.2. Final energy consumption

The final energy consumption, which was 105.5 Mtoe in 2020, rises to 148.5 Mtoe by 2035. The share of the industrial sector, which has the highest share in final energy consumption with 34.4% in 2020, rises to 38.7% by 2035. The 40.1% share of the housing and services sector in the total decreases to 34.9% by 2035.

Final energy consumption and distribution of final energy consumption by sectors are shown in Figure 10 and Figure 11, respectively.

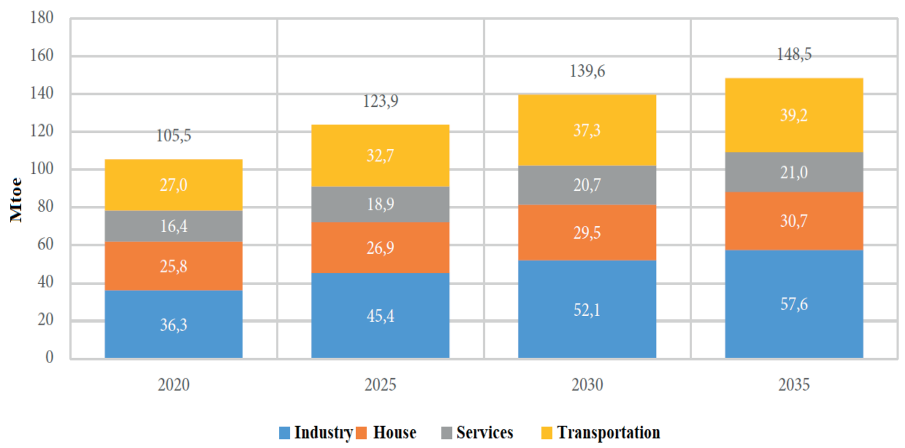


Figure 10. Final energy consumption by sectors

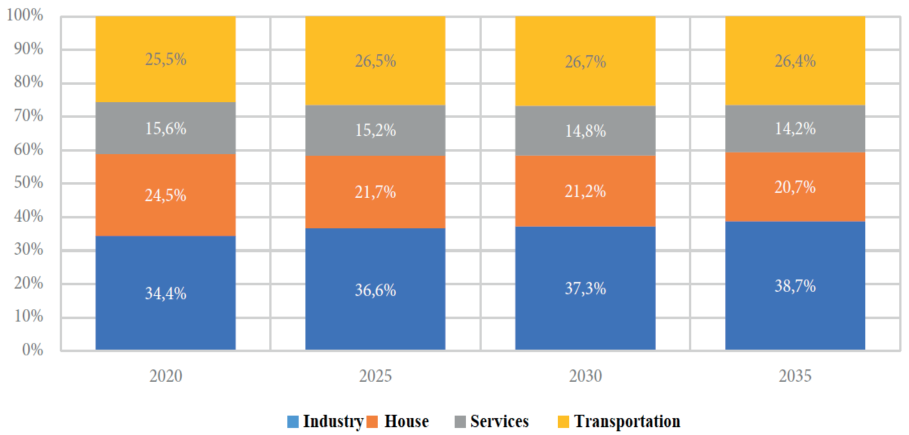


Figure 11. Distribution of final energy consumption by sectors

1.6. Coal power plants

Considering the problems and difficulties encountered in the reserve development process of the existing planned sites, it is predicted that 1.7 GW of domestic coal power plants will be included in the system by 2030. In terms of imported coal power plants, a new imported coal power plant with an installed power of 1.3 GW was put into operation in 2022.

1.7. Nuclear power plants

In the Turkish Energy Model, new investment decisions are taken to minimize the total system cost and the use of resources is determined. In this framework, the total installed capacity of nuclear power plants in the system reaches 7.2 GW by 2035.

1.8. Natural gas

Currently, there is no large power natural gas power plant under construction. It is assumed that 2.4 GW of installed power, the processes of which continue until 2030, will be activated. It is assumed that approximately 10 GW of new natural gas combined cycle power plant investment can be commissioned until 2035 in addition to the said investments in order to manage the imbalance that may be created by intermittent renewable energy plants in the system and to contribute to the sustainability of energy supply-security.

The capacity of small-scale gas power plants, which are mostly used to meet the heat need in the industry and where electricity and heat are produced together, increase by 0.2 GW in the 2021-2025 period and by 0.4 GW in the 2026-2030 period.

1.9. Renewable energy

Considering the renewable energy potential of our country, it is planned to increase the share of intermittent renewable energy sources such as wind and solar in total electricity generation. In this direction, the installed power in 2035 is expected:

- 29.6 GW in wind energy (24.6 GW onshore, 5 GW offshore)
- 52.9 GW in solar energy.

For other renewable energy sources, the installed power rises to 35.1 GW in hydroelectric power plants and 5.1 GW in geothermal and biomass power plants.

1.10. Hydrogen and synthetic methane production

In order to reduce emissions in the Turkish Energy Model, natural gas used in industrial facilities needs to be mixed with other clean fuels such as hydrogen and synthetic methane. It is possible to establish different mixture assumptions for these fuels.

Accordingly, the share of hydrogen in gas mixtures to be used for fuel in 2035 has been determined as 3.5%. In line with the policies chosen above, it is planned to reach an electrolyzer capacity of 5.0 GW by 2035. However, hydrogen obtained with electricity produced from clean sources and carbon captured by carbon capture technologies is used to produce synthetic methane.

However, it is evaluated in the Turkish Energy Model that synthetic methane can be used in the years after 2035 [4]. The green, blue and turquoise hydrogen storage technologies roadmaps are shown in Figure 12, Figure 13 and Figure 14, respectively.

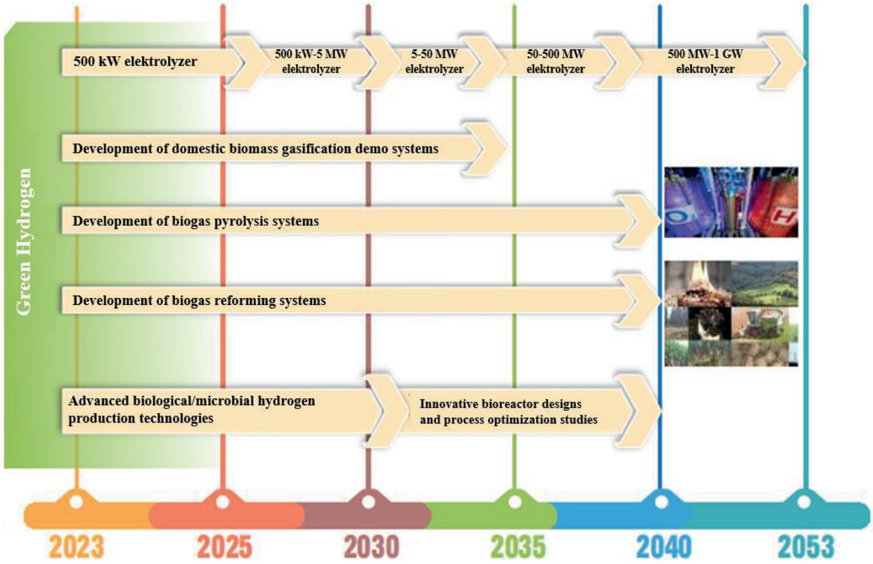


Figure 12. The green hydrogen production technologies roadmap

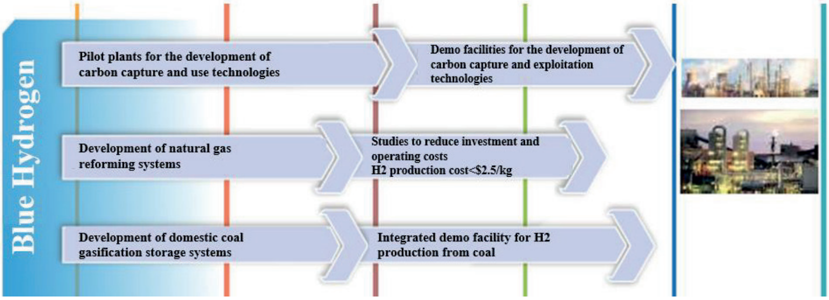


Figure 13. The blue hydrogen production technologies roadmap

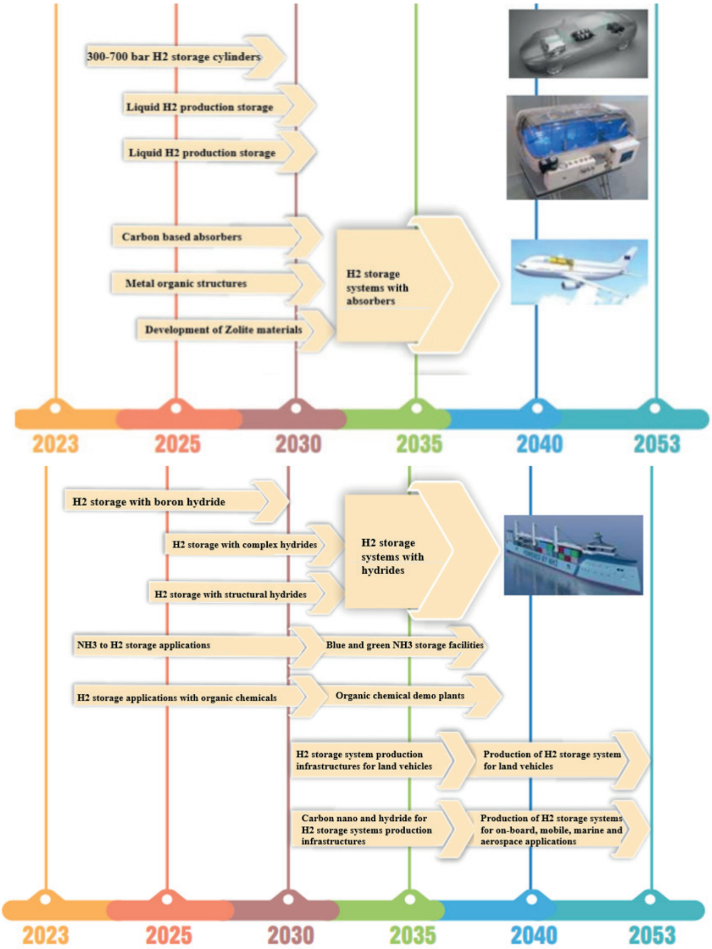


Figure 14. The turquoise hydrogen storage technologies roadmap

The potentially critical role of hydrogen is increasing worldwide [5]. Strategy documents and regulations that will shape the future of hydrogen continue to increase. Existing gaps in the value chain, which covers all processes from the production of hydrogen to its final use, are being studied in detail. It is known that hydrogen, which is one of the important arguments for achieving net zero emissions, will add great value to our lives. It is of great importance to establish forums for the exchange of information between all stakeholders and national and local governments on hydrogen technologies.

Since these technologies concern many sectors in the ecosystem, it is important to inform all stakeholders about the issue and to carry out inclusive studies.

For the development of a domestic green hydrogen market in our country, it is necessary to harmonize the current legislation with a clear vision of the energy to be obtained from hydrogen and to develop technical standards in line with international standards regarding the production, distribution, storage and end-use processes of green hydrogen. The targets and policies prepared by evaluating the needs and solution proposals of our country with the studies carried out in the world are presented below:

- Reducing the cost of green hydrogen production to below \$2.4/kgH_2 by 2035 and \$1.2/kgH_2 by 2053
- To ensure that the installed power capacity of the electrolyzer reaches 2 GW in 2030, 5 GW in 2035 and 70 GW in 2053
- Revising existing legislation to make it suitable for "hydrogen production, transport, storage and usage"
- Establishing incentive processes for the use of domestic equipment in the production and storage of green hydrogen
- Creating certificate programs for "green hydrogen" and ensuring the traceability of these programs
- To encourage R&D and P&D for the development and production of domestic and national technologies (electrolyzer, fuel cell, etc.)
- Establishing public and private sector partnerships to encourage commercial demand and investments

- To cooperate internationally on issues related to the industry, technology, standards and certification development, supply chain and trade opportunities
- To encourage the widespread use of green hydrogen in all relevant sectors, especially in sectors where carbon emissions are difficult to reduce (chemistry, iron steel, transportation, glass, ceramics, etc.)
- To ensure continuity in employment by raising qualified manpower in hydrogen Technologies
- To carry out R&D studies for the production of hydrogen and synthetic gas from lignite and organic wastes
- To increase the share of renewable energy production and use in order to increase green hydrogen production
- Contributing to the gradual decarbonization transformation of the heat sector by mixing hydrogen into existing natural gas lines
- To use domestic resources, especially boron mine, in hydrogen storage
- Exporting surplus green hydrogen or ammonia to the world and especially to the European market with our domestic technologies

1.10.1. Hydrogen production technologies

A primary energy source is needed for hydrogen production. Hydrogen production is diversified according to the type of these sources.

If hydrogen is produced with renewable energy, it is defined as "green hydrogen", if produced from fossil fuels using carbon dioxide (CO_2) capture systems, "blue hydrogen", if produced from fossil fuels without CO_2 by processes such as pyrolysis, "turquoise hydrogen", if produced with nuclear energy "pink hydrogen", It is defined as "gray hydrogen" if it is obtained from the reformation of the gas, and "brown hydrogen" if it is obtained without capturing CO_2 from coal by gasification method [6]. The production of decarbonized hydrogen is essential to achieving emission reduction targets. Hydrogen production methods by source are shown in Figure 15.

Technology	Primary Energy/Electricity Source	Carbon Footprint ($kgCO_2/kgH_2$)	Cost ($/$kgH_2$)
Water electrolysis	Renewable Energy	<1	4,0-9,0
Water electrolysis	Nuclear Energy	<2	3,5-7,0
Pyrolysis	Fossil Fuel	<3	1,25-2,20
Steam methane reforming with carbon capture	Natural Gas, Coal	<4	1,5-3,00
Steam methane reforming without carbon capture	Natural Gas	8-10	0,5-1,70
Gasification	Coal	>20	1,0-2,2

Figure 15. Hydrogen production methods by source

As fuel and raw material, hydrogen supports many aspects of the economy and our daily lives, especially in the energy and chemical sectors [7]. Considering the increase in energy consumption both in the world and in our country, it is clear that hydrogen will play an important role in terms of environmental effects. According to current plans, low-carbon hydrogen demand is expected to exceed 100 ktH_2/year in industrial applications and gas networks by 2030. Hydrogen will be achieved through the following four main benefits:

- To incorporate more renewable energy into the system,
- To make the heat sector carbon emission-free,

- To produce hydrogen from domestic coal using CO_2 capture technologies,
- To increase the use of boron compounds for the storage of hydrogen.

Energy storage technologies should be used to balance electricity generation from renewable energy sources. It is one of the methods of mixing 2-6% hydrogen into natural gas distribution lines. In Türkiye, it means giving 1-3 billion m^3 H_2 of this to the system.

According to the "Medium-Term Program (2023-2025)" published in the Official Gazette dated September 4, 2022, and numbered 31943, within the scope of the ongoing resource-efficient and competitive green transformation policies in the EU, which is our main export market, for our country to reach 2053 net zero emission targets, it is stated that necessary steps will be taken in all sectors. However, in our country;

- Green technology R&D projects, especially in agriculture, industry, transportation and energy sectors, will continue to be supported in order to establish the green transformation infrastructure, and the investment ecosystem of technologies that contribute to emission reduction such as green hydrogen and energy storage will be developed,
- On the way to the net zero emission target, a medium-term low-carbon growth strategy will be put forward, the additional investment amount that the sectors will need for green transformation will be determined, and various support mechanisms will be planned in order to maintain their competitiveness,
- Access to climate finance will be developed by taking into account the needs of the private sector, and investments that increase efficiency, have transformative qualities, have high added value, limit the increase in greenhouse gas emissions and increase green skills will be given priority.

In the 12th Development Plan (2024-2028) and MENR 2024-2028 Strategic Plan prepared by the Presidency of the Republic of Türkiye Strategy and Budget Department, the hydrogen issue will be addressed as a priority, and it is planned to include targets in this direction.

1.10.2. Requirements, solutions and roadmaps in hydrogen technologies

- After Türkiye ratifies the Paris Agreement, the rate of green hydrogen use will increase rapidly in sectors such as transportation, petrochemistry, iron and steel, fertilizer and cement.
- Studies will be carried out to use low-cost hydrogen near the production area in energy-intensive sectors such as iron and steel.
- There will be a significant increase in the number of hydrogen vehicles for indoor cargo transportation and long-distance heavy cargo transportation.
- Plans and research will be performed for the use of hydrogen in the maritime and aviation sectors, which cause a significant part of global CO_2 emissions.
- Projects and pilot studies will continue to meet the heat need in buildings and industry by adding hydrogen to natural gas or using it directly in gas networks.
- The blue hydrogen that Türkiye will produce from its domestic resources will be effective in the transition to a hydrogen economy in various sectors and a part of its hydrogen need will be met in this way.
- It is aimed to increase energy supply security, environmental sustainability and quality of life (clean air, water and soil) with the use of green hydrogen produced with our energy resources.
- Although Türkiye is heavily dependent on fossil fuel imports for energy, it has doubled its renewable electricity generation led by hydroelectric, solar and wind power over the last decade. Considering its solar and wind resource potential and especially low PV installation costs, it is clear that Türkiye will achieve further growth in renewable energy. However, the acceleration of domestic electrolyzer development studies and the fact that significant developments have already been recorded in this field in the world will enable the use of green hydrogen with electrolyzer in every field by using electricity obtained from renewable energy, which is the domestic source of our country.

- Due to the increase in the share of renewable energy sources such as wind and sun in total electrical energy generation and the intermittent nature of these sources, energy storage becomes a necessity for both technical and economic reasons. This situation requires consideration of hydrogen production from excess electrical energy as an alternative energy storage tool.
- It is predicted that the need for hydrogen will increase gradually in the production of hydrocarbon-based fuels and all kinds of materials for the evaluation of carbon after CO_2 capture within the scope of combating climate change.
- Deficiencies in the production of domestic and national electrolyzers in our country will be identified and special project calls will be created in this context, and the development of electrolyzers will be ensured. In this way, the needs of our country in electrolyzer technologies, which are of critical importance in the production of green hydrogen, will be met without being dependent on foreign sources.
- For mass production of domestic and national electrolyzers;
    - Electrolyser cell and module designs,
    - Production of catalyst, electrode, membrane and membrane electrode units,
    - Development of system control hardware and software,
    - Test infrastructure will be established with university and industry collaborations.
- International companies with a high technology readiness level in the production of electrolyzers and their sub-components will be supported to transfer technology.
- Necessary infrastructure and economic support will be determined by determining the current situation and technology readiness level regarding hydrogen production from lignite. In this way, while a part of the hydrogen need will be met, domestic coal gasification and hydrogen production technologies will also be developed. An inventory of organic wastes that can produce hydrogen by gasification will be made. Pilot

plants will be put into operation, the technology level will be increased, sub-industry capabilities will be developed and academic research will be increased in order to produce hydrogen by using our country's existing domestic resources and organic wastes most efficiently.

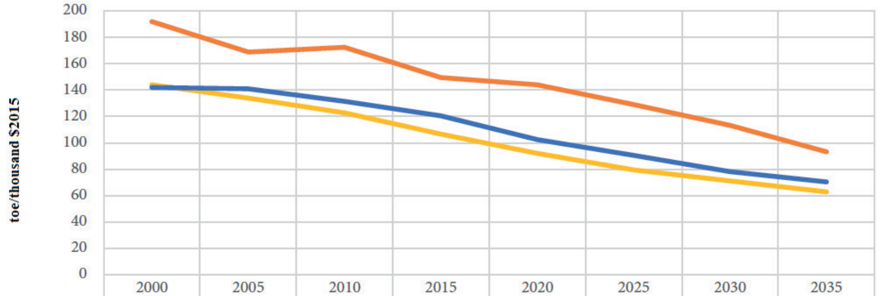
- Producing the necessary materials for the production of pipes suitable for the transmission and distribution of hydrogen will both meet the domestic need and increase the variety of exported products.
- The possibilities of storing hydrogen in underground salt caves, as well as in natural gas storage, will be explored in order to create the large-volume storage capability that will be needed with the widespread use of hydrogen.
- The hydrogen production potential of our country and the areas where it can stand out in hydrogen technologies will be determined and its export potential will be evaluated. Necessary collaborations will be established in line with export targets, and design, production, work, performance standards and targets will be determined for systems, products and services to be used in hydrogen technology.
- Our country has an important geopolitical position. During the transition to hydrogen, cooperation between European and Asian countries in the production, transportation, export and use of hydrogen will make a significant contribution to the rapid spread of hydrogen technologies. Cooperation with countries will be developed in all areas from hydrogen production to transmission and marketing.

1.11. Other flexible energy sources

In addition to the flexibility provided by conventional electricity generation technologies to the system, electrolyzer capacity and battery storage technologies have the ability to contribute to the energy system. The rapidly increasing installed capacity of intermittent renewable power plants also increases the flexibility needed in the system. Accordingly, the battery storage capacity in the system (assuming a charging time of 2 hours) will increase to 7.5 GW by 2035. In the studies in the literature, the ratio of theoretical contribution to peak demand that can be obtained with demand-side participation has been taken into account. The capacity, which actively contributes to the system in the direction of load reduction and load increase on the demand side, rises to 1.7 GW.

1.12. Energy efficiency

In the 2000-2020 period, the energy intensity in our country decreased by 25%. In Germany and France, the said change was realized in the band of 28-36%. Considering the results obtained for Germany and France in the EU Reference Scenario 2050 study, energy intensity decreases by 50-56% in the 2000-2035 period. For our country, it is predicted that the improvement in energy intensity will be 51% in the same period. These recovery rates are similar to the expected recovery in Germany and France. Energy intensity development over the years 2000-2035 is shown in Figure 16.



	2000	2005	2010	2015	2020	2025	2030	2035
Türkiye	191,9	168,7	172,4	149,4	144,0	129,0	113,3	93,2
Germany	144,0	134,0	122,7	106,7	92,0	79,5	71,1	62,8
France	142,0	141,0	131,5	120,4	102,4	90,4	78,1	70,3

Figure 16. Energy intensity development over the years 2000-2035

1.13. 2035-2053 period strategic foresight

- The development of electric vehicles is important for the electricity sector in our country. In order to reach the 2053 net zero emission target, the number of electric vehicles needs to increase gradually. In the development of the number of electric vehicles until 2035, the scenarios provided by the Ministry of Industry and Technology were taken into account, and the projections for 2053 were created by keeping the same trend.

- Within the framework of the upper emission limit target determined for the electricity and heat generation sector and the carbon prices selected accordingly, new investment decisions are taken in the Turkish Energy Model in a way that minimizes the total system cost and the use of resources is determined.
- The share of renewable energy sources in primary energy consumption, which was 16.7% in 2020, rises to 50% by 2053. Nuclear energy, on the other hand, has a share of 29.3%.
- The share of fossil resources, which was 83.3% in 2020, will be 20.8% in 2053. While the share of coal decreases to 3.6%, oil decreases to 5.6% and natural gas to 11.7%.
- Electricity consumption, which rose from 128.3 TWh to 306.7 TWh with an annual average increase of 4.4% in the 2000-2020 period, shows an annual average increase of 4.5% until 2053.
- It is seen that the rate of increase after 2035 in electrical energy consumption, which is expected to increase by 3.5% in the 2020-2035 period, should increase more rapidly with the increase of the share of electrical energy in final energy consumption in order to reach the net-zero emission target determined for 2053. In this way, the annual average rate of increase in electrical energy consumption rises to the level of 5.2% in the 2035-2053 period.
- The share of renewable energy sources, which was 42.4% in 2020, increases to 69.1% by 2053. The share of intermittent renewable energy sources, which was 11.7% in electricity generation in 2020, gradually rises to 61.4 until 2053. This value is in line with the projections of organizations such as the IEA and the International Renewable Energy Agency (IRENA) and the share of renewable energy sources in the EU's 2050 Reference Scenario study.
- The share of hydroelectric power plants, which currently have the largest share in the installed power, falls below 10% in the long run due to the fact that they are approaching the maximum installed power potential and the increase in total electricity generation.
- The share of natural gas power plants, which contributed 23.1% to generation in 2020, is declining in the long run. Natural gas power plants may

contribute higher or lower periodically, as they offset possible variations in electricity generation from other sources.

- Electricity generation from coal power plants, which have a share of 34.5% in generation in 2020, continues to decrease until 2053. However, this does not mean that the coal power plants in the system will be decommissioned before they expire. All the power plants in the system remain active even if their contribution to electricity generation decreases until the end of their technical life, and contributes to the system with reserve capacity and flexibility. In electricity generation from coal plants, carbon prices for the electricity and heat generation sector will play a decisive role.
- The initial investment cost estimates of coal and natural gas power plants with carbon capture technology are accepted as 4113 $/kW and 2450 $/kW, respectively, and it is estimated that these values will decrease by an average of 0.85% annually until 2053. The efficiency value for the said power plants is accepted as 36.5% in coal and 51% in natural gas. In addition, no investment decision is taken by the model at this stage for a new coal or natural gas power plant with carbon capture technology in the period until 2053. However, it is possible for coal to make a higher contribution to electricity generation than the results in this study if the decline in technology prices accelerated and the said technologies were put into use. In this case, the required nuclear power plant installed power may also decrease.
- Depending on the need for flexibility in the system, it is considered that tools such as batteries, electrolyzers and demand-side participation will increasingly contribute to the system.
- Depending on the targeted and actual share of intermittent resources in total generation, the nuclear power plant capacity needed in line with the 2053 net-zero emission target will vary, and its share in the installed power is predicted to reach 8.4%. In order to realize the development of the installed power of the nuclear power plant within a reasonable investment plan, the upper limit of the capacity that can be put into use in five-year periods has been increased gradually.
- To reach the net-zero emission target set for 2053, it is necessary to mix natural gas used in different sectors with other clean fuels such as

hydrogen and synthetic methane. Accordingly, the share of hydrogen in the gas mixture in terms of energy equivalent has been determined in line with the studies of the Turkish Energy, Nuclear and Mining Research Institute (TENMAK) within the scope of 2030-2035. In the studies in the literature, generally accepted ratios were taken into account and the mixing ratio for natural gas was gradually increased to 12% in hydrogen and 30% in synthetic methane.

- The electrical energy that will be needed for hydrogen and synthetic methane production has been increasing rapidly since 2035, as in the transportation sector, and the share of the electrical energy to be used for this purpose in the total electricity consumption reaches 17.6%.

Acknowledgment

While preparing this report, Türkiye National Energy Plan and Türkiye Hydrogen Technologies Strategy and Roadmap data have been used, so thank you to the Republic of Türkiye Ministry of Energy and Natural Resources.

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Klemens Reich, Michael Schrammel, Kerstin Weindl

1. Austrian Energy Demand

1.1. Current state

Austria had an overall primary energy consumption of 1,311 PJ in 2020 [1]. In recent years about 2/3 (e.g., 67 % in 2020) of the national energy consumption was covered by imports. This significant dependency on imports was also identified as a possible supply security problem and negatively affected the federal foreign trade balance. In the last 15 to 20 years, a decoupling between economic growth (GDP) and energy consumption has been achieved.

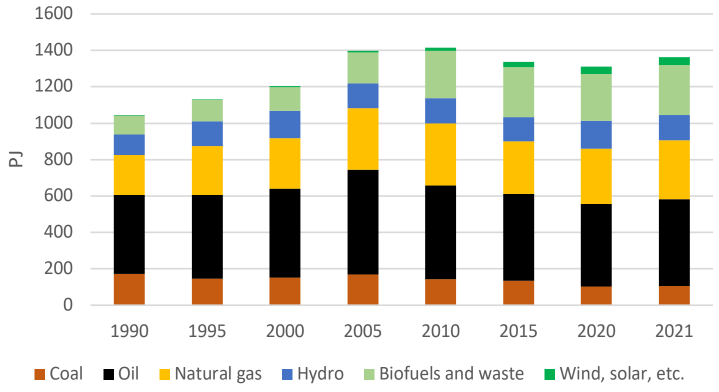

Figure 1. Historic primary energy consumption of Austria per energy source (data source: [1])

1.2. Government goals for the energy supply of Austria

The Austrian administration formulates for the year 2030 the federal goal of 100 % of electricity production from renewable sources (national balance) [2] [3] [4]. By 2030, the legislative goal is a minimum coverage of 32 % of the gross domestic energy consumption by climate-neutral energy sources [4]. Full coverage of the gross domestic energy consumption by climate-neutral energy sources is in focus for 2040 [4].

Further, for the national production of renewable gas, an annual output of 5 TWh is set as the goal for 2030 [2].

1.3. Development goals in energy demand/energy efficiency

Based on Austria's current primary energy consumption and the national goal of a climate-neutral energy supply in 2040, the energy demand must decrease whereas energy efficiency must increase significantly.

In 2023, the Austrian parliament is expected to consent to a new version of the energy efficiency law, which has been effective since 2014. The current draft for this law gives a maximum overall domestic final energy consumption of 920 PJ (70% of the consumption in 2020) for 2030 and 736 PJ (56% of the consumption in 2020) for 2040.

As preparatory work, the Austrian Environment Agency (Umweltbundesamt) calculated the energy efficiency goals for a scenario of 100 % climate-neutral energy sources in the year 2040 [5]. Figure 2 shows the sectoral final energy consumption expectations presented by the survey. Without increased energy efficiency, the final energy consumption in Austria must be reduced to approximately 850 PJ in 2030 and 700 PJ in 2040. This leads to a corresponding primary energy consumption of 1,050 PJ in 2030 and 840 PJ in 2040. With a focus on energy efficiency, reducing the final energy consumption to 820 PJ (2030) and 630 PJ (2040) respectively is possible. The primary energy consumption will decrease to 1,006 PJ in 2030 and 767 PJ in 2040.

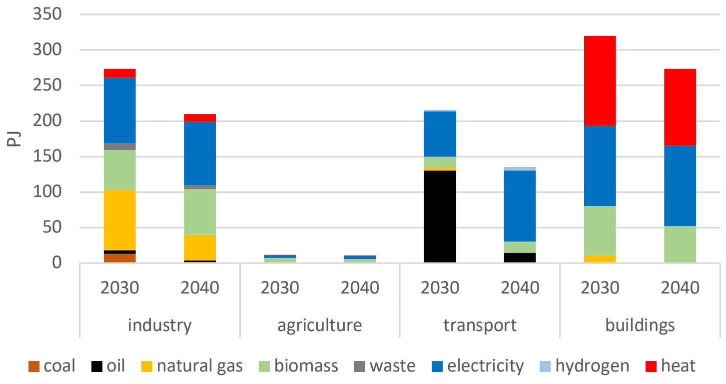

Figure 2. Final energy consumption scenarios per sector in 2030 and 2040 asuming full coverage of demand by climate-neutral energy sources in 2040 (data source: [5])

2. Austrian Electricity Sector Overview

Austrian electricity production is traditionally dominated by renewable production based on hydropower. Therefore, the base for decarbonizing the electricity supply based on renewable energy sources is very good.

2.1. Domestic electricity consumption and production

2.1.1. Domestic electricity production and consumption from the past till today

Austrian domestic electricity production is dominated by hydropower (see Figure 3). About two-thirds of the annual generation is based on this renewable energy source. Run of river hydropower, especially on the Danube River, dominates the production. In 2021, nearly 80 % of the national electricity production came from renewables.

The last coal fired power plant was shut down in the third quarter of 2019. The recommissioning of some coal-fired power plants was an early-stage concept by the Austrian administration during the crisis in the gas markets in 2022. The government dropped the plans for reconnecting these plants to the grid due to economic reasons, issues regarding coal supply in the short term, and the expected long time to get the plants operating again.

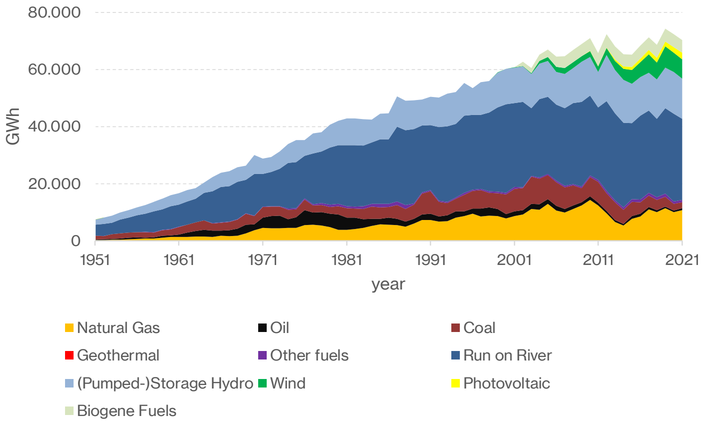

Figure 3. Historical gross electricity production in Austria per primary energy source (data source: E-Control)

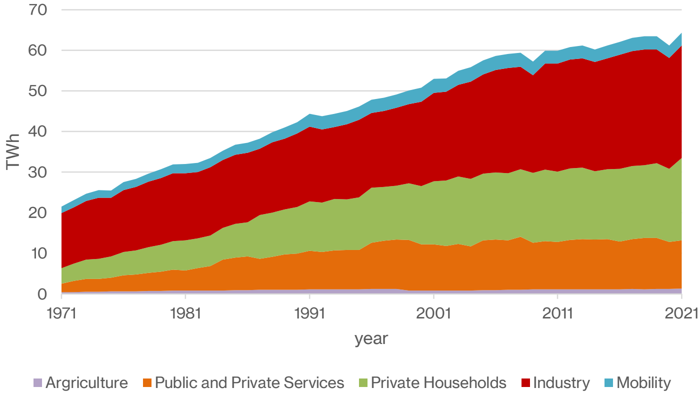

Figure 4. Historical electricity consumption in Austria per sector (data source: Statistik Austria)

2.1.2. Federal goals for domestic electricity production in future

The current Austrian administration amended the overall goals for the energy sector for the year 2030. In 2030, the net electricity production should be 100 percent from renewable sources like hydropower, wind power, photovoltaics, and biomass [2] [4].

An additional 27 TWh of annual electricity production is necessary to accomplish this goal until 2030. The most significant potential in increasing production lies in the photovoltaics sector, with additional 11 TWh of production. Regarding electricity production by wind power plants, additional 10 TWh and 5 TWh for production in hydropower plants are set as goals. The administration identified a potential to increase production of about 1 TWh (see Figure 5) for the biomass sector.

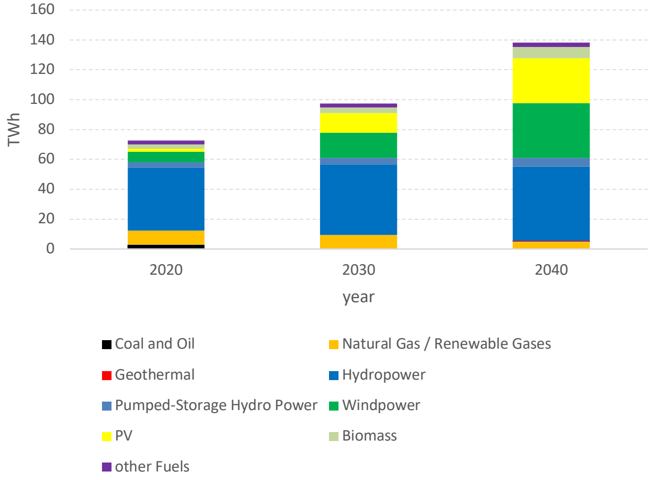

Figure 5. Estimated electricity generation per technology (data source: [4] and Österreichs Energie)

The interest representation of the Austrian electricity industry (Österreichs Energie) predicts an increase of domestic electricity consumption by +90 % (compared to the year 2020) by 2040 (see Figure 6). The main drivers are named as domestic hydrogen production, electrification of industrial processes, and electrification of mobility [6] [7] (see Figure 6). A slight increase in demand is expected for space heating and direct electricity usage.

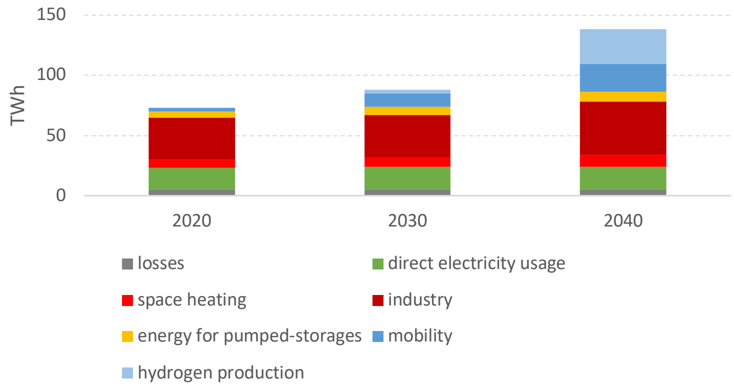

Figure 6. Estimated electricity demand per sector in 2030 and 2040 (data source: Österreichs Energie)

Austrian electricity production has traditionally a large share of Austria's electricity production lies in hydropower. Based on the country's topography, this technology is widely used. From the ecological point of view, a further increase in production by constructing new large-scale plants is limited. Therefore, hydropower focusses on repowering existing large-scale plants [2] and developing or recommissioning existing, small-scale hydropower plants. Further potential for increasing electricity generation is seen in expanding the generation capacity of existing pumped-storage hydropower plants (see Figure 7).

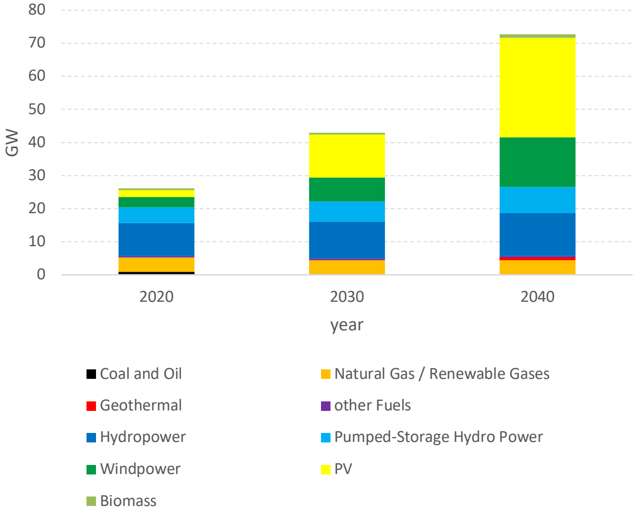

Figure 7. Estimated development of generation capacity to achieve goals for 2030 and 2040 (data source: Österreichs Energie)

Photovoltaics (+1,500 %) and wind power (+470 %) have the most significant potential for increasing generation capacity. For other technologies, only a small development potential is in sight today (see Figure 7).

Further development of pumped-storage hydropower for storing supply-led generation from wind power and photovoltaics is also named as a key technology. Austria has a large infrastructure in pumped-storage hydropower in the western parts of the country. A possible increase in generation capacity is estimated to be about 165 %. The very most of this capacity growth lies in adding additional generators to existing plants. Only a few new dam projects are in a very early stage of development in 2023. The realisation of those projects is insecure because of their huge ecological impact.

Construction of new nuclear power plants through all political parties and stakeholders in Austria is not an option for additional electricity production capacity. The commissioning of new nuclear power plants is forbidden by federal constitutional law [8] and not supported by the public.

2.2. The Austrian power grid infrastructure

The Austrian power grid infrastructure is operated by two TSOs; Austrian Power Grid AG (APG) and Vorarlberger Übertragungsnetz GmbH (VÜN), as well as 122 DSOs. The electricity infrastructure in Austria is historically grown. The distribution grid is dominated by about ten large DSOs, many of them owned by the federal states or large cities. However, there are also small DSOs (usually municipal utilities) operating their grid in very small regions. Those small DSOs are typically connected to other, larger DSOs.

The overall supply reliability of Austrian grid customers can be qualified as excellent. The customer-related supply interruption duration was about 38 minutes in 2021; the customer-related mean interruption frequency was about 0.67 1/a [9].

2.2.1. Current electricity infrastructure

The Austrian electricity infrastructure has an overall length of 264,961 km. Table 1 presents the overall system lengths per voltage level and type.

The transport grid, mainly operated by APG, uses voltage levels 220 kV and 380 kV; the voltage levels 110 kV and below are used for the distribution systems. Today's transport grid in Austria is based on overhead lines. The DSO Wiener Netze GmbH operates the 380 kV cable infrastructure (see Table 1) in Austria's capital, Vienna. Wiener Netze is the only DSO in Austria operating a 380 kV infrastructure. In the western part of Austria, the regional DSO TINETZ Tiroler Netze GmbH operates a large 220 kV overhead lines-based distribution grid in Tyrol.

Table 1. System lengths of Austrian power grid per voltage level and type in the year 2021. Table contains transmission and distribution system together (data source: E-Control)

System lengths					
Voltage Level	**Overhead Lines**		**Cable**		**Sum**
	km	**Share in %**	**km**	**Share in %**	**km**
380 kV	3,004	1.1	54	0.0	**3,058**
220 kV	3,735	1.4	8	0.0	**3,744**
110 kV	10,809	4.1	808	0.3	**11,616**
Medium Voltage	23,106	8.7	44,998	17.0	**68,104**
Low Voltage	29,107	11.0	149,332	56.4	**178,439**
Total	**69,762**	**26.3**	**195,200**	**73.7**	**264,961**

2.2.2. National goals for power grid development

The national and European goals for expanding renewable electricity production foresee reinforcement and expansion of the existing grid. On TSO-Level, the largest Austrian TSO, Austrian Power Grid AG (APG), published the national grid development plan 2021 [10] the following key facts till 2031:

- New transmission lines in the transport grid with an expected path length of about 240 km

- Voltage upgrading to higher voltage levels for about 110 km of existing power lines
- Renewal of about 290 km of existing lines
- 20 new substations on "green field" till 2030 for reinforcement of connection of distribution grids
- 50 new transformers with a total rated power of about 18,000 MVA

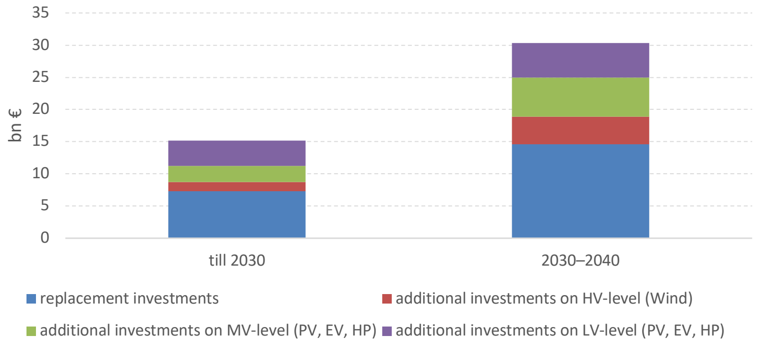

Figure 8. Estimated investment costs in Austrian electricity infrastructure to meet energy transition goals for 2030 and 2040 (data source: Österreichs Energie)

The national energy industry expects investment costs in the infrastructure of about 15 bn Euro in the period till 2030 [6]. Roughly half of the expenses stem from replacing existing infrastructure to increase transmission capacity and meet future requirements on the power system (see Figure 8). The power industry expects further investments of about €30 bn from 2030 till 2040.

3. Austrian strategy for hydrogen, renewable gas, and synthetic chemical energy storage

The Austrian government formulated and presented a national hydrogen strategy in 2022 [7]. The strategy bases on the national decarbonisation strategy #mission2030 [3] as well as the decarbonisation and renewable energy goals given by law [4]. Due to the role of hydrogen as a pre-product for synthetic chemical energy storages and e-Fuels, the national hydrogen strategy covers these topics in a fundamental form.

In the formation process of the hydrogen strategy involved diverse stakeholders from national and international industries and the energy sector.

Domestic consumption of natural gas lies at about 100 TWh (2021). About 124 GWh stem from production and injection into the gas grid of methane in natural gas quality from renewable sources. Current analysis shows a potential for an annual output of 20 TWh of methane from biogenic residual materials [11].

The demand of gaseous energy carriers in the relevant sectors in Austria is forecasted to between 89 TWh and 138 TWh in 2040 [11]. Difficult to decarbonize sectors and industrial processes which directly need the gas will be preferred in the process.

In 2021, the industry's direct demand for hydrogen lied at about 140,000 metric tons [7]. In 2040, the annual demand for gaseous energy carriers in the chemical industry will reach 29.1 TWh, for the steel industry 26.2 TWh, and for other industries 8.7 TWh [11]. About 4.5 TWh of the demand on gaseous energy carriers is decidedly needed as methane gas. For the rest of the demand,a direct use of hydrogen is expected.

Hydrogen as part of the mobility sector is only foreseen for difficult to decarbonize by using battery electric solutions such as long-distance road traffic, aviation, and shipping. An expectation of the future demand for gaseous energy carriers for the transport sector is because of the current different solutions, which are partly in an early stage of technological development and not part of the national hydrogen strategy.

Hydrogen-based space heating is because of the lack of efficiency not in focus. Other technologies, like heat pumps, are preferred on the administrative side for this sector.

3.1. Principles for the Austrian hydrogen sector

Austria's administration distinguishes between renewable hydrogen and climate-neutral hydrogen. The national hydrogen strategy classifies hydrogen based on electrolysis using electricity from renewable sources and hydrogen based on biomass from sustainable sources as renewable hydrogen.

Hydrogen produced from natural gas is classified as climate-neutral if CO_2 if the process is fully captured and no greenhouse gases are emitted. Nuclear energy is specifically classified as not sustainable and is not seen as a renewable energy source [7].

The Austrian government sees a national hydrogen economy as an essential part of reaching climate neutrality of the economy in 2040. Therefore, following principles were formulated by the administration [7]:

- Climate-neutrality in 2040

  Hydrogen contributes to the energy system's decarbonization and achieving climate neutrality in Austria in 2040.
- Climate-neutral Hydrogen

  Compatibility to achieve climate neutrality is only ensured using climate-neutral hydrogen.
- Priorate Sectors

  The contribution of hydrogen to reach climate neutrality is maximised by focusing on sectors that are otherwise hard to decarbonise.
- Efficiency and Cost-effectiveness

  Energy efficiency and cost-effectiveness are essential guiding principles regarding the transformation of the energy system.
- Hydrogen Infrastructure

  On the way to climate neutrality, the gas infrastructure is gradually converted into a targeted hydrogen infrastructure.

3.2. Hydrogen sector development

As formulated in the principles for the Austrian hydrogen sector, climate-neutral hydrogen should replace 80 % of fossil-based hydrogen in the energy intense industries until 2030. 1 GW electrolyser capacity is needed by 2030 to reach this target. As part of a planned supporting framework electrolysers are supported by direct subsidies, reduced grid tariffs, and exemption from charges [4].

Facing the national goal of 100 % renewable domestic electricity production in 2030, electrolysis is also seen as an integral part of the electrical power system to raise the flexibility of demand and ensure system stability. The focus lies on the utilization of local synergies for efficient coupling electrical power system and gas infrastructure. On a national level, the infrastructure development is coordinated by the Austrian grid infrastructure plan (Österreichischer Netzinfrastrukturplan (ÖNIP)).

As demonstrated in Figure 6, an additional electrical energy consumption of 3 TWh in 2030 respectively and 29 TWh in 2040 is expected for the domestic hydrogen production. In comparison to the forecasted needs of renewable gaseous carriers presented in this chapter, it is obvious that Austria can only produce part of the demand on its own. Therefore, an integral part of the climate-neutral hydrogen strategy lies in the constitution of international partnerships.

To leverage the national hydrogen transport system, the conversion of the existing natural gas pipeline infrastructure to a hydrogen pipeline infrastructure is planned. A blending of hydrogen and natural gas is less important; due to the prioritization of applications for hydrogen use the focus lies on separate transport systems for these two gasses [7].

Storage of hydrogen is essential in the future of hydrogen economics. Austria has a large natural gas storage infrastructure in natural caverns which can most likely be used for storing hydrogen in gaseous form. The industry-led research project "Underground Sun Storage" [12] is testing the large-scale use of this type of storage for future hydrogen infrastructure.

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Sabina Dacic-Lepara, Senad Salkic, Elvisa Becirovic

1. Bosnia and Herzegovina Electricity Outlook

1.1. Introduction

Although Bosnia and Herzegovina (B&H) has evidently been failing to meet its obligations within the energy sector for years due to a complex and dysfunctional political framework, the energy sector is still one of the strongest economic sectors in Bosnia and Herzegovina with a long tradition and enormous potential and opportunities for further development and investment. Bosnia and Herzegovina has committed to transposing parts of the EU legal framework into its national legislation with the aim of:

- Establishing a common market,
- Aligning its energy sector with EU rules,
- Improving security of supply,
- Incentivizing investments,
- Protecting the environment, etc.

The concept of today's energy in Bosnia and Herzegovina is based on the economic paradigm of the 1970s in general, which is characterized by energy-intensive and inefficient use of energy in the sectors of generation and consumption of electricity, heating, cooling and transport. That is why energy has a dominant influence on emissions with the greenhouse effect (GHG emissions) in Bosnia and Herzegovina (over 70% of total emissions) as well as emissions of pollutants that increase the level of pollution at the local/ regional level, endangering the environment and human health.

The transformation of the energy sector, especially the electric power sector (EPS), began with the signing of the Treaty Establishing Energy Community (EnC), which was ratified in 2006. With this Treaty, B&H undertook to gradually take over parts of the acquis of the European Union (EU) by transposing into its laws the requirements and rules of the corresponding EU directives and regulations in the areas of: security of supply, competition, environmental protection, energy infrastructure, energy efficiency and use energy from renewable sources. In this respect, Bosnia and Herzegovina is currently in the process of joining the internal market of the European Union as an end result.

Currently, draft document of integrated National Energy and Climate Plan (NECP) is prepared and this document still needs to be accepted and approved by government [1].

The NECP of Bosnia and Herzegovina [2] establishes links between the existing elements of the strategic framework, and defines a new approach that introduces stronger cooperation between the sectors, but all with the aim of establishing a clear and efficient implementation framework based on an intersectoral approach. This new, integrated strategic approach must ensure a smooth process of decarbonisation of the energy sector in 2030, aiming for the criterion of carbon neutrality in 2050. The pillars of this strategic approach are set according to the dimensions defined in the Energy Union Strategy (COM/2015/080)[1], namely:

- Dimension 1A: Decarbonisation: Reduction and removal of greenhouse gas emissions

1 https://eur-lex.europa.eu/legal-content/EN/TXTPDF/?uri=CELEX:52015DC0080&from=EN

- Dimension 1B: Decarbonisation: Renewable energy sources
- Dimension 2: Energy efficiency
- Dimension 3: Security of supply
- Dimension 4: Internal energy market
- Dimension 5: Research, competitiveness and innovation

The framework of NECP defines the following main indicators for monitoring:

- Total emission of greenhouse gases
- Primary energy consumption (PEC)
- Final Energy Consumption (FEC)
- Share of renewable sources in gross final energy consumption

In the scenario prepared (until year 2030)

- Total emission of CO2 with LULUCF[2] decreses to 15,6 MtCO2
- Primary energy consumption (PEC) rises to 6844 ktoe,
- Final energy consumption (FEC) reaches to 4339 ktoe,
- Share of RES in the total gross final consumption reaches 43,6 % - The share of electrical energy in final energy consumption reaches 23.26%

This plan envisages an increase in electricity generation capacity in Bosnia and Herzegovina by 2030. Significant growth is expected in the capacity of renewable energy power plants, while no increase in capacity from fossil fuel combustion plants is planned. Additionally, the plan introduces new subcategories of renewable energy power plants, specifically addressing capacity within incentive programs and the formation of Renewable Energy Communities (RECs).

2 Land use, land-use change, and forestry (LULUCF), also referred to as Forestry and other land use (FOLU), is defined as a "greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use such as settlements and commercial uses, land-use change, and forestry activities.

On the other hand, a significant increase in the capacity for the production of electricity from hydropower is predicted, most of which will be obtained through the construction of new capacities of large hydropower plants. The capacities of small hydropower plants and renewable energy community hydropower plants are also growing, but with significantly smaller capacities.

Also, an increase in wind farm capacity is expected, most of which are large wind farms without support, while a smaller part is directed through support programs and renewable energy communities.

Finally, a significant increase in the capacity to produce electricity from photovoltaic plants is predicted, of which the dominant plants are plants for the production of electricity for the market and for own consumption within the framework of prosumer status. Also, one part of the capacity is planned to be established through renewable energy communities.

This report gives a comprehensive outlook of Bosnia and Herzegovina power system and information about future planned generation capacities and activities in energy/electricity market of Bosnia and Herzegovina with a brief overview of the National Energy and Climate Plan by 2030 with special emphasis on the power sector.

2. Power System Profile

2.1. Installed capacity of generation facilities

The total installed power of generation facilities in Bosnia and Herzegovina in 2022 amounts to 4,655.62 MW, of which 2,076.6 MW in larger hydroelectric power plants, 2,065 MW in thermal power plants, and 134.6 MW in larger wind power plants. The installed power of small hydropower plants is 181.89 MW, solar power plants 101.56 MW, biogas and biomass power plants 2.71 MW, small wind power plants 0.40 MW, while 92.85 MW is installed in industrial power plants [3]. List of large generation facilities in Bosnia and Herzegovina is given in Table 1.

Table 1. Large generation facilities

Hydropower plants	Installed capacity per unit (MW)	Total installed capacity (MW)	Termal power plants	Installed capacity (MW)	Available capacity (MW)
Trebinje I	2x54+63	171	TUZLA	715	635
Trebinje II	8	8	Tuzla G3	100	85
Dubrovnik (B&H+Cro.)	126+108	234	Tuzla G4	200	182
Čapljina	2x210	420	Tuzla G5	200	180
Rama	80+90	170	Tuzla G6	215	188
Jablanica	6x30	180	KAKANJ	450	398
Grabovica	2x57	114	Kakanj G5	110	100
Salakovac	3x70	210	Kakanj G6	110	90
Mostar	3x24	72	Kakanj G7	230	208
Mostarsko blato	2x30	60	GACKO	300	276
Peć-Mlini	2x15,3	30,6	UGLJEVIK	300	279
Jajce I	2x30	60	STANARI	300	283
Jajce II	3x10	30	**Wind power plants**	**Installed capacity per unit (MW)**	**Total installed capacity (MW)**
Bočac	2x55	110	Mesihovina	22x2,3	50,6
Višegrad	3x105	315	Jelovača	18x2	36
			Podveležje	15x3,2	48

2.2. Electricity generation

In Bosnia and Herzegovina, 15,035.96 GWh of electricity was generated in 2022, which is 2,019 GWh, or 11.8% less compared to the previous year. In contrast to 2021, in which hydrological conditions were favorable, in 2022 the hydrological situation was significantly worse, especially in the second half of the year, and production in hydropower plants decreased by 1,855 GWh or

29.4% and amounted to 4,459 GWh. And the total generation in thermal power plants decreased, by 192 GWh or 2.0%, and amounted to 9,629 GWh [3].

Wind farms connected to the transmission system produced 390 GWh, which is 2.2% more than the previous year.

Generation from smaller renewable sources amounted to 536.89 GWh, which is 3.5% more than in 2021. Unfavorable hydrological conditions were reflected in the generation in this category as well, in which small hydropower plants have a dominant share with 406.75 GWh (433.41 GWh in 2021).

The generation of solar (photovoltaic) power plants recorded a significant percentage increase (58.4%) of still relatively small amounts - 117.05 GWh were produced in 2022, and 73.89 GWh in 2021. A dynamic growth in the generation of solar power plants is noticeable, although a certain part of the capacity (according to estimates of 23 MW) and generated amounts of energy from these sources cannot be recorded, due to the specific status of electricity generation for own needs.

A total of 13.06 GWh (11.34 GWh in 2021) was generated in the four existing biomass and biogas power plants.

Electricity generation in wind farms connected to the distribution system in 2022, as in the previous year, amounted to 0.03 GWh. 20.70 GWh were generated in power plants of industrial producers.

20.70 GWh were generated in power plants of industrial producers. The structure of generation during the previous ten years is shown in Figure 1.

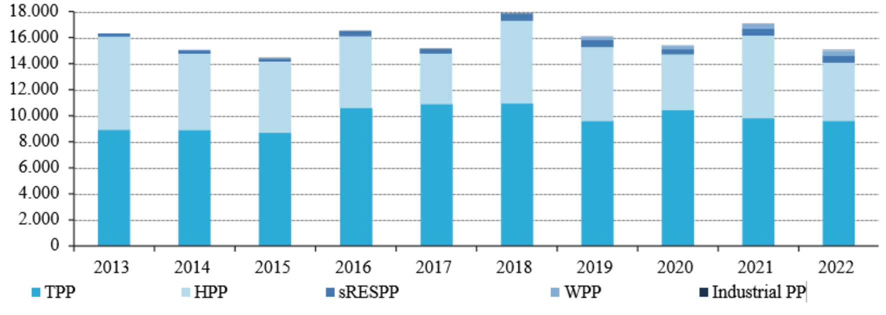


Figure 1. Structure of electricity generation in B&H during the previous ten years (GWh) [3]

2.3. Electricity consumption

The total consumption of electricity in Bosnia and Herzegovina was 12,058 GWh and was reduced by 112 GWh, or 0.9% compared to the previous year. The consumption of customers connected to the transmission system (HV customers) decreased by 3.9% and amounted to 1,124 GWh [3]. In Figure 2 is given the structure of electricity consumption in Bosnia and Herzegovina.

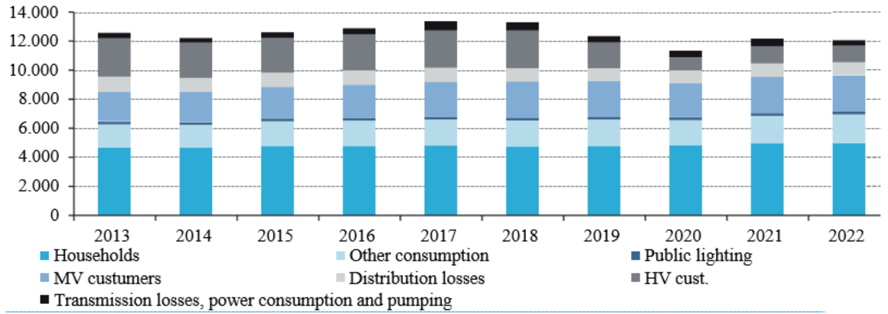


Figure 2. Structure of electricity consumption in B&H during the previous ten years (GWh) [3]

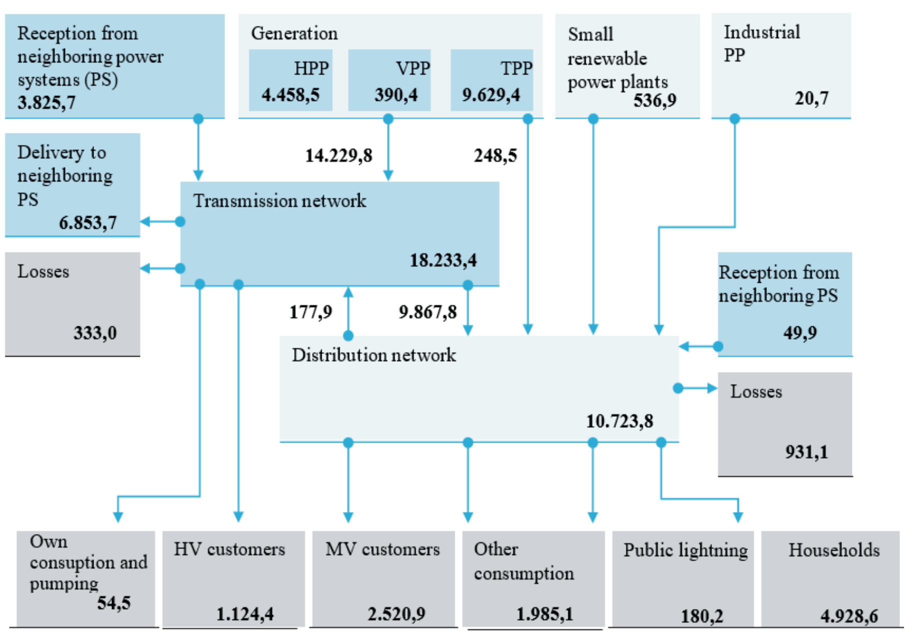


Figure 3. Realized balance quantities in 2022 (GWh) [3]

Distributive consumption was 10,546 GWh (an increase of 0.9%). The largest increase (3.9%) was recorded in the category 'other consumption' (small customers, i.e. commercial customers connected to 0.4 kV). The consumption of customers connected to 10 kV voltage increased by 1.4%, and decreased by 2.8% in the case of customers connected to 35 kV voltage. Household consumption was 4,929 GWh (an increase of 0.3%). The total download of electricity from the transmission system was 11,047 GWh, which is 116 GWh less than in 2021 or 1.0%.

The difference between total production and consumption in Bosnia and Herzegovina, i.e. the balance surplus in 2022, was 2,978 GWh, which ranks B&H, along with Bulgaria (a surplus of 12,200 GWh), as the only countries in Southeast Europe with a surplus in the electricity balance.

Although in Bulgaria, due to the application of the greenhouse gas emission unit trading system within the EU, expensive permits are purchased for the emission of greenhouse gases in production, the operation of thermal power plants has become profitable due to the increase in wholesale prices. An overview of the balance electricity quantities achieved in 2022 is given in Figure 3.

2.4. Electrical transmission system of Bosnia and Herzegovina

During the year 2022, several contracts on the construction, reconstruction and rehabilitation of portable facilities were realized, which increases the security of supply of electricity customers. A new 220/110 kilovolt (kV), 150 megavolt ampere (MVA) transformer was put into operation in one of the existing substations, and two new 110/x kV, 40 MVA transformers.

A new 110/x kV substation was built, which is connected to the power grid by the input-output system to the 110 kV transmission line, which creates two new 110 kV transmission lines. List TSO facilities in Bosnia and Herzegovina are given in Table 2.

Table 2. TSO facilities [3]

Transmission lines		Interconnections	
Nominal voltage of the transmission lines	Length (km)	Nominal voltage of the transmission lines	Length (km)
400 kV	865,93	400 kV	865,93
220 kV	1.520,09	220 kV	1.520,09
110 kV	4.038,08	110 kV	4.038,08
110 kV – cable line	34,66	110 kV – cable line	34,66

Substations			Transformers		
Type of substation	Number of substation	Installed capacity (MVA)	Transmission ratio of the transformers	Number of transformers	Installed capacity (MVA)
TS 400/x kV	10	5.980,5	TR 400/x kV	14	4.900,0
TS 220/x kV	8	1.423,0	TR 220/x kV	13	1.950,0
TS 110/x kV	135	5.662,0	TR 110/x kV	250	6.215,5

Figure 4 shows map of the electric power system of Bosnia and Herzegovina with operational areas of Elektroprijenos B&H and distribution areas of electric companies (December 31, 2022).

2.5. Power system operation

During 2022, the electricity system of B&H worked stably and without major problems. All users of the system are enabled to work functionally according to the defined quality standards. All planned and subsequently requested works in the transmission network in the function of maintenance have been carried out. In the past year, the maximum hourly load of the electric power system of 1,893 MW was recorded on January 25, 2022 at the eighteenth hour, the day on which the maximum daily consumption of 38,667 MWh of electricity was also achieved. The minimum hourly load of 678 MW was recorded in the sixth hour on June 12, 2022, which is 73 MW more than the lowest hourly load in several previous decades, which was achieved in the fourth hour on May 25, 2020. The minimum daily consumption of 22,842 MWh was recorded on June 12, 2022. The maximum and minimum hourly load for the previous ten years is shown in Figure 5.

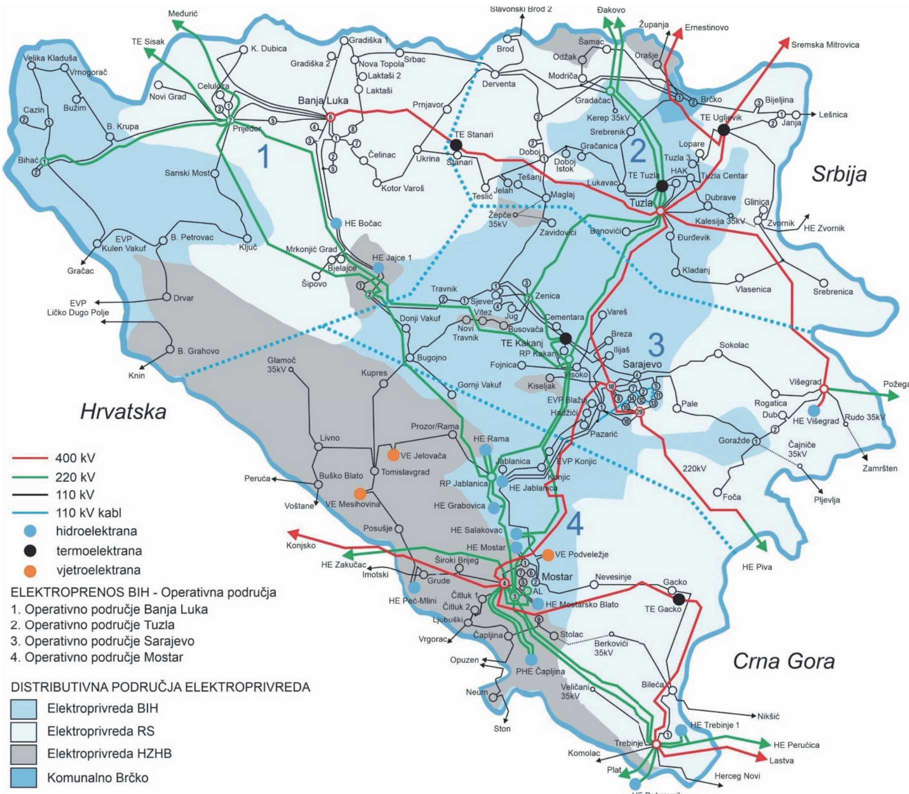


Figure 4. Map of the electric power system of Bosnia and Herzegovina with operational areas of Elektroprijenos B&H and distribution areas of electric companies (December 31, 2022) [3]

Unwanted deviations from the declared exchange programs with neighboring power systems in 2022 amounted to a total of 79 GWh for hours in which a deficit was registered in the regulatory area of Bosnia and Herzegovina, and for hours when a surplus of electricity was registered, a total of 25 GWh.

Data on unsupplied electricity ENS (Eng. Energy Not Supplied) due to unplanned supply interruptions (ENSnepl), as well as on unsupplied electricity due to planned interruptions (ENSpl) in the electric power system of B&H in the previous five years, are given in Table 3.

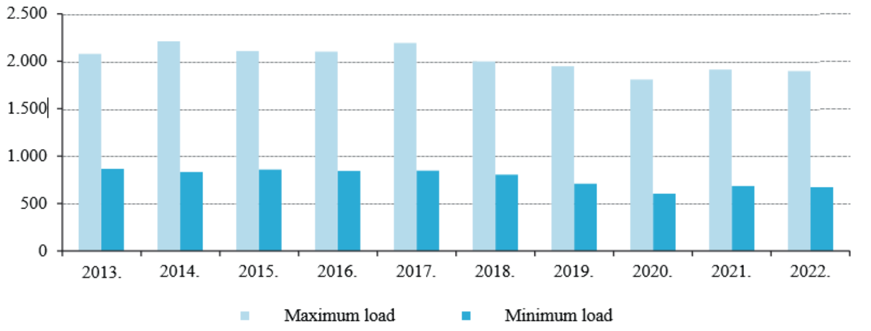


Figure 5. Maximum and minimum hourly load in the period 2013 - 2022 (MW) [3]

Table 4 contains data on power supply continuity, that is, the average duration of interruptions on the high-voltage transmission network AIT (Average Interrupted Time).

Table 3. Unsupplied electrical energy due to downtime on the transmission network [3]

	2018		2019		2020		2021		2022	
	MWh	min	MWh	min	MWh	min	MWh	min	MWh	min
ENSnepl	1.181,83	13.661	1.095,03	21.370	393,01	11.825	678,07	14.788	664,03	9.086
ENS_{pl}	1.377,39	24.297	1.100,55	17.178	543,35	9.998	690,82	9.503	1029,15	13.835
Total	2.559,22	37.958	2.159,59	38.548	936,36	21.823	1.368,89	24.291	1693.18	22.921

Table 4. Average duration of interruptions on the transmission network by month (min) [3]

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
AIT2018	0,2046	9,5267	3,2354	1,7183	2,2664	6,3035	3,0782	5,2013	3,3805	0,1153	3,1875	0,2781
AIT2019	0,1233	14,0321	8,8927	10,0696	3,3278	9,0077	13,4418	3,6580	9,3859	6,2718	0,6274	0,9416
AIT2020	0,5982	5,3980	1,4336	1,0986	3,6368	7,3068	4,3183	2,5052	12,0331	4,7252	3,1260	2,2014
AIT2021	0,4481	0,7509	3,9080	2,1174	3,9190	5,1968	4,4001	5,9464	4,9027	5,9328	4,5592	3,7586
AIT2022	0,2022	0,2739	3,7850	0,6587	17,4503	3,6111	3,6504	3,5146	0,0283	7,2689	2,1352	2,9838

During the 2022, tertiary regulation was engaged 78 times (as tertiary regulation 'up' 59 times, of which 12 times in October, and as tertiary regulation 'down' 19 times, of which seven times in November 2022). However, the nominated amount of tertiary regulation was often not to the required extent. In 2022, there were 475 outages on the 400, 220 and 110 kV transmission network, of which 77 outages were 400 kV transmission lines, 156 outages were 220 kV transmission lines, 198 were 110 kV transmission line outages, 27 were 400/220 kV, 400 MVA transformer outages, one 400/110 kV, 300 MVA transformer outage, and 16 220/110 kV, 150 MVA transformer outages.

In the past year, 63 outages of thermoblocks and 10 outages of hydrogen generators were registered. The missing energy in the system was compensated by engaging the tertiary reserve.

During the year 2022, in the electric power system of Bosnia and Herzegovina, the no-voltage status of buses was registered 55 times, of which 25 times on 400 kV buses for a duration of 74 hours and 43 minutes, seven times on 220 kV buses for a duration of 6 hours 36 minutes and 23 times on 110 kV buses for a duration of 56 hours and 36 minutes.

Their largest number occurred in the period from May to September, when the dominant number of atmospheric discharges was registered, which in most cases was the reason for the power outage.

As in previous years, in 2022 the voltage conditions in the electric power system were often above the values prescribed by the Network Code, especially in the 400 kV and 220 kV networks. The highest voltage in the 400 kV network was registered when a voltage of 447.27 kV was measured. The highest voltage in the 220 kV network (261.06 kV) was measured in May. During January, the highest voltage of 125.10 kV was measured in the substation on the 110 kV network. The main cause of the occurrence and duration of excessively high voltages is the lightly loaded 400 kV transmission lines in periods of low consumer load, which generate a large amount of reactive energy.

The occurrence of excessively high voltages is a problem of a regional character, and therefore solutions to this problem are also sought at the regional level.

Tables 5 and 6 present the SAIFI and SAIDI indicators for the previous five years. Table 3 takes into account only outages caused by events on the network under the jurisdiction of Elektroprijenos B&H (TSO B&H), and Table 4 also takes into account outages on medium-voltage taps in substations of Elektroprijenos B&H caused by disruptions in the distribution network, which are significantly less favorable, considering the branching and size of the distribution network, as and its more frequent susceptibility to different types of failures.

Table 5. SAIFI and SAIDI indicators for the transmission network [3]

		2018	2019	2020	2021	2022
	Planned ouateges	0,76	0,64	0,42	0,47	0,51
SAIFI	Unplanned outages	0,69	0,99	0,53	0,74	0,75
	Total	**1,45**	**1,63**	**0,95**	**1,21**	**1,26**
	Planned ouateges (min/cust.)	94,68	73,71	39,71	51,78	61,69
SAIDI	Unplanned outages (min/cust.)	53,31	63,24	31,67	26,39	30,62
	Total (min/cust.)	**147,99**	**136,95**	**71,38**	**78,17**	**92,32**

SAIFI (System Average Interruption Frequency Index) indicates the average number of power interruptions per customer during the year. SAIDI (System Average Interruption Duration Index) indicates the average duration of power interruptions in minutes per customer during the year.

Table 6. SAIFI and SAIDI indicators for the transmission network, including outages of medium voltage drains caused by interruptions in the distribution network [3]

		2018	2019	2020	2021	2022
	Planned ouateges	3,33	2,76	2,57	2,96	2,67
SAIFI	Unplanned outages	4,96	4,93	4,63	4,47	3,94
	Total	**8,29**	**7,69**	**7,19**	**7,43**	**6,61**
	Planned ouateges (min/cust.)	255,11	239,55	189,52	205,69	316,50
SAIDI	Unplanned outages (min/cust.)	314,55	453,10	382,64	359,62	279,45
	Total (min/cust.)	**569,66**	**692,68**	**572,16**	**565,31**	**595,95**

2.6. Electricity market in Bosnia and Herzegovina

Electricity market in Bosnia and Herzegovina is consisted of wholesale electricity market and electricity retail market. The wholesale electricity market covers trade of electricity between licensed electricity companies for generation, supply of electricity and its trade. The electricity retail market covers supply of final buyers by licensed electricity companies for electricity supply.

The total consumption of electricity in Bosnia and Herzegovina in 2022 was 12,058 GWh, which is 0.9% less than in the previous year. Customers connected to the transmission system took over 1,124 GWh or 3.9% less, and customers connected to the distribution system 10,546 GWh or 0.7% more than the previous year.

Of this amount, 9,615 GWh refers to the takeover of end customers, and 931 GWh to distribution losses. Total sales to end customers amounted to 10,739 GWh and is 0.6% higher than sales in the previous year. The number of electricity customers in B&H at the end of the year was 1,590,197, of which 1,461,843 were households, and 128,354 were customers in all other consumption categories (Table 7).

Table 7. Number of customers of electricity in B&H by categories of consumption [3]

Supplier	110 kV	35 kV	10 kV	Other consumption	Households	Public lightning	Total
Elektroprivreda B&H	11	64	947	66.865	724.425	4.944	797.256
Elektroprivreda RS	6	30	1.034	31.315	522.643	211	555.239
Elektroprivreda HZHB	2		274	16.301	182.318	2.080	200.975
Komunalno Brčko		1	76	3.730	32.457	457	36.721
Other suppliers			3	3			6
Total	**19**	**95**	**2.334**	**118.214**	**1.461.843**	**7.692**	**1.590.197**

Competent regulatory commissions in Bosnia and Herzegovina do not establish tariff positions for customers in those categories of consumption which according to the legislation can no longer be regulated. At the end of 2014, the regulation of supply tariffs for all customers ended, except for households and customers from the 'other consumption' category (commercial customers connected to 0.4 kV) who have the status of 'small customer', and the practice of tariff regulation for distribution services was retained. As of January 1, 2015, all customers of electricity in B&H can choose their supplier on the market. Customers who do not choose a supplier on the market can be supplied with public suppliers at prices for public supply, and households and small customers within the framework of the universal service at regulated prices. All households in Bosnia and Herzegovina and the largest number of customers from the 'other consumption' category used the possibility of supply within the framework of the universal service during 2022. The average price of electricity for these customers amounted to 8.06 euro cents/kWh and is 3.8% higher than in 2021, when it was 7.77 euro cents/kWh. At the same time, the average price for households was 7.38 euro cents/kWh (increase of 2.9%), while the average price for customers from the category 'other consumption' was 9,75 euro cents/kWh and was higher by 4.7% compared to 2021. The regulatory commissions in B&H are working on the gradual removal of inherited cross-subsidies between certain categories of customers, which is taking place in accordance with good international regulatory practice, while avoiding the so-called of 'tariff shocks'. The trend of changes in the ratio of average prices for small commercial customers and households is visible in Figure 6.

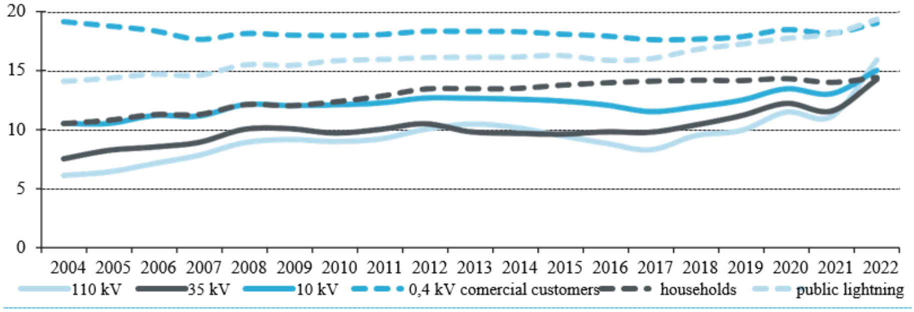


Figure 6. Average electricity prices by categories of customers, excluding VAT (euro cents/kWh) [3]

According to data from 2022, the cross-subsidy between these categories is 29.8% on average. There is a clear need to reduce cross-subsidies, which respects the basic regulatory principle of reflecting real costs in price formation. This enables market competition in the supply of households, that is, it opens the possibility for market suppliers to offer more favorable prices and be competitive in that segment of the market as well. The average prices by public suppliers and customer categories in 2022 are shown in Figure 7.

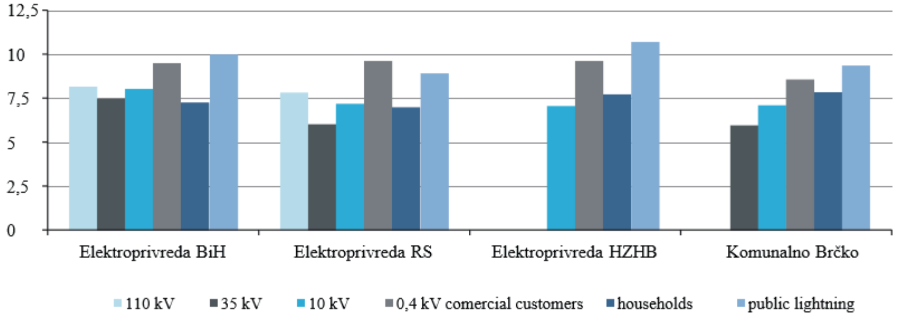


Figure 7. Average prices of electricity in power companies, without VAT (euro cents/kWh) [3]

On the retail market in Bosnia and Herzegovina, since January 1, 2016, the first supplier changes were registered for customers connected to the distribution system, since then their number varies from month to month. In 2022, the majority of customers were supplied with their traditional suppliers (so-called 'incubants'). A significant increase in wholesale prices caused a decrease in competition on the retail market. In the previous period, tens of thousands of customers changed the terms of supply by changing the contract with their former traditional suppliers, thus choosing the supply offer that best suits their needs on the open market. 6,911.40 GWh (64.4% of the total consumption of end customers) were delivered to customers who are supplied under the universal service, and 3,827.58 GWh (35.6%) were delivered to customers for whom prices are not regulated. Trading on the wholesale market in B&H is significantly more dynamic, which is based on bilateral arrangements for the purchase and sale of electricity between suppliers. Although this market is still not institutionalized (there is no market operator or electricity exchange), the result of numerous bilateral contracts is significant - in 2022, 18 licensed entities were active, which achieved a turnover of 2,180 GWh in internal transactions on the market. In addition, cross-border transactions were registered in the total volume of 4,815 GWh, of which exports amounted to 3,947 GWh, and imports 868 GWh.

2.6.1. Cross-border trade

The good connection of the power system of Bosnia and Herzegovina with the neighboring power systems enables a high level of cross-border exchange of electricity. Due to a significant reduction in generation, the export of electricity decreased, and in 2022, 3,947 GWh were exported, which is 36.1% less than in the previous year. The import of electricity amounted to 868 GWh and decreased by 37.6% compared to the previous year. The largest volume of cross-border trade in electricity was carried out at the border with Montenegro Goro, then on the borders with Serbia and Croatia (Table 8).

Table 8. Cross-border trade by borders including registered transit [3] (GWh)

Country	Export	Import
Croatia	2.312,1	1.353,2
Serbia	2.065,2	1.678,9
Montenegro	2.967,0	1.232,8
Total	**7.344,3**	**4.264,9**

During the year 2022, the transit of electricity through the B&H transmission system was registered in the amount of 3,397 GWh, which is a decrease of 243 GWh or 6.7% compared to the year 2021. Transit flows have a specific significance because they are used as a basic element in the calculation of income and expenses within the Billing Mechanism between transmission system operators (ITC mechanism).

As the calculation of the ITC mechanism, due to the complex and long-term procedure, is significantly delayed, the complete data for 2021 was only co-published at the end of 2022. According to these data, the total expenditure realized by B&H amounts to 1,688,530 EUR, which means that for the second time in a row, B&H does not record income within the defined time frame. According to the calculation rules of the ITC mechanism, increased transit flows increase income, while an increase in export and import flows affects a decrease in income, i.e. an increase in expenses. The total income of Bosnia and Herzegovina based on the annual auctions of cross-border transmission capacities for the year 2022 is 8,777,301 EUR, and this is the highest income achieved at annual auctions so far. In contrast to the earlier period when the highest price was achieved at the border with Croatia, in the direction from B&H to Croatia, in recent years there has been a noticeable trend of increasing exports at the eastern borders of B&H and higher prices for transmission capacities at these borders. So this year, the highest price was reached at the border with Montenegro in the amount of €3.55/MWh in the direction from Bosnia and Herzegovina to Montenegro, which is 74.4% more than the previous year.

In accordance with the Methodology for creating tariffs for electricity transmission services, independent system operator and auxiliary services, Elektroprijenos of Bosnia and Herzegovina (TSO of Bosnia and Herzegovina) is the beneficiary of all revenues based on the allocation of the right to use cross-border transmission capacities, as well as revenues generated by the application of the Payment Mechanism between transmission operators system.

2.7. Electricity consumption forecast for the next 10 years

According to the Network Code of BiH: "The indicative production development plan contains three scenarios of consumption growth in the next 10 years (lower, base and higher) based on information on the expected development of electricity consumption provided by operators of the distribution system and Users and own analyses."

The forecast of electricity consumption on the B&H transmission network, which is based on the predicted increase in GDP, is given in Table 9, and the average annual increase is 1.2%.

Table 9. Forecast of electricity consumption in BiH based on correlation with GDP [4]

Year	Estimated real GDP growth	Increase in electricity consumption
2024	2,75%	1,2%
2025	2,75%	1,2%
2026	2,75%	1,2%
2027	2,75%	1,2%
2028	2,75%	1,2%
2029	2,75%	1,2%
2030	2,75%	1,2%
2031	2,75%	1,2%
2032	2,75%	1,2%
2032	2,75%	1,2%

The forecast of consumption based on the data submitted by transmission network users is shown in Table 10, and the average increase in total consumption on the BiH transmission network for the period 2024-2033 in the base scenario is 1.1%, in the higher scenario 2.2% and to the lower scenario 1.1%.

Table 10. Electricity consumption forecast on the BiH transmission network in GWh for the period 2024-2033 based on the data provided by the Transmission Network User [4]

User	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Total consumption (h.s.)	11.832,5	12.142,3	12.404,4	12.672,7	12.947,5	13.228,9	13.517,1	13.812,2	14.114,5	14.424,0
Higher scenario (%)		2,6	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2
Total consumption (l.s)	11.709,4	11.891,9	12.022,0	12.153,7	12.287,1	12.422,2	12.559,0	12.697,6	12.837,9	12.979,9
Lower scenario (%)		1,6	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1

NOSBiH (Independent system operator of Bosnia and Herzegovina) also made its own analysis, based on historical data on consumption in the period 2001-2022 years. By extrapolating over the characteristic consumption function (power curve or power curve) for the considered period, the equation of the curve that describes consumption is obtained in the form:

$$y = 9143{,}2 \cdot x^{0{,}0846}$$

After including these values in the planning period of 2023-2033, an average increase in consumption in the amount of 1.02% is obtained. This percentage increase was used for the base (realistic) consumption forecast scenario.

The percentage increase for the lower (pessimistic) consumption scenario is taken from the Indicative Plan 2023-2032 and it amounts to 0.4%.

The higher (optimistic) scenario was made by averaging the values obtained by the forecast over GDP (1.2%) and the average increase for the higher scenario according to the data provided by the User (2.2%), resulting in an average annual increase of 1.7%.

In this way, three scenarios are obtained:

- Pessimistic scenario – lower scenario (average annual increase of 0.4%)
- Realistic scenario – base scenario (average annual increase of 0.94%)
- Optimistic scenario – higher scenario (average annual increase of 1.7%)

Forecasted values of consumption on the BiH transmission network for the period 2024-2033 years for the three scenarios described above are given in Table 11 (transmission losses should be added to this consumption).

As the initial value of the forecast, the realization from the year 2022 was taken, in which there was a slight increase in consumption compared to the year 2021 in the amount of 0.22%.

Table 11. Forecast of electricity consumption on the B&H transmission network for three scenarios for the period 2023 – 2033 [4]

Year	Realistic scenario		Pessimistic scenario		Optimistic scenario	
	(GWh)	Growth (%)	(GWh)	Growth (%)	(GWh)	Growth (%)
2022	11.112	0,22%	11.112		11.112	
2023	11.216	0,94%	11.156	0,40%	11.301	1,7%
2024	11.322	0,94%	11.201	0,40%	11.493	1,7%
2025	11.428	0,94%	11.246	0,40%	11.688	1,7%
2026	11.536	0,94%	11.291	0,40%	11.887	1,7%
2027	11.644	0,94%	11.336	0,40%	12.089	1,7%
2028	11.754	0,94%	11.381	0,40%	12.295	1,7%
2029	11.864	0,94%	11.427	0,40%	12.504	1,7%
2030	11.976	0,94%	11.473	0,40%	12.716	1,7%
2031	12.088	0,94%	11.518	0,40%	12.932	1,7%
2032	12.202	0,94%	11.565	0,40%	13.152	1,7%
2033	12.317	0,94%	11.611	0,40%	13.376	1,7%

Forecast of consumption on the BiH transmission network for the period 2024-2033 years, for three scenarios, and realization of consumption in the period 2004-2022 years are given in Figure 8.

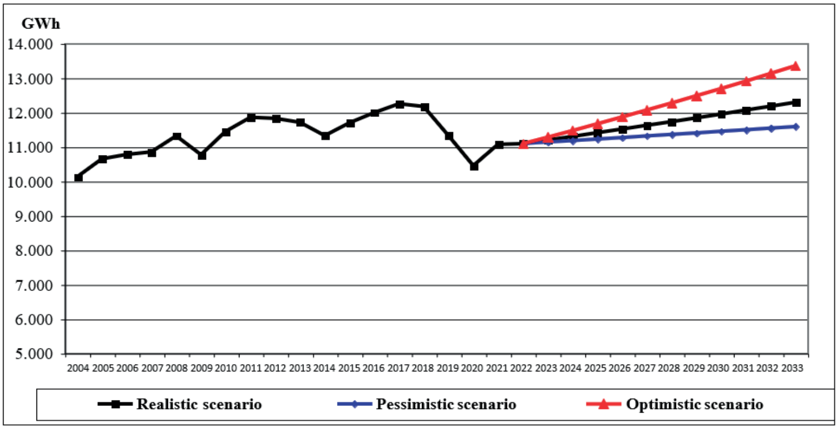


Figure 8. Forecast of consumption on the BiH transmission network for the period 2024-2033 and realization of consumption in the period 2004- 2022 [4]

The average percentages of consumption growth in all scenarios for the base and higher scenarios are somewhat lower than the percentages in the previous Indicative Production Development Plan (IPDP 2023-2032), while they remained the same for the lower scenario. The starting (base) year is 2022, in which there was a slight increase in consumption compared to the previous year (0.22%).

The forecast value of consumption in 2023, in all three scenarios, is lower than the value predicted by the balance sheet for 2023. The balance sheet for the year 2023 was prepared on the basis of data provided by users (power companies and direct consumers).

Taking into account the above, we can conclude that the consumption trends are in line with the goals for achieving energy efficiency, because the forecasted consumption values are significantly lower compared to the predictions in the earlier IPDP.

2.8. Energy and power balance on the transmission system for the next 10 years

Electricity balances for the planning period 2024-2033 years were done for three consumption scenarios: "pessimistic" - lower consumption scenario, "realistic" - base consumption scenario and "optimistic" - higher consumption scenario, described in chapter 6, as well as for two production scenarios, with and without new unit 7 - 450 MW in TPP Tuzla.

Data on the planned production and power of new (balanced) production capacities are attached to the existing production capacities, and a 10-year balance of energy and power on the transmission network of Bosnia and Herzegovina was formed by comparison with three consumption scenarios.

Given the dependence of HPP production on hydrological conditions, the production of all HPPs is planned on the basis of the average hydrological year, that is, data provided by power companies (Table 12).

Table 12. Generation of existing facilities on the BiH transmission network for the years 2024-2033[4]-[7]

GENERATION	(GWh)									
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
TOTAL HPPs	5.570,3	5.570,3	5.570,3	5.570,3	5.570,3	5.570,3	5.570,3	5.570,3	5.570,3	5.570,3
TOTAL TPPs	9.447,9	9.464,3	10.320,3	9.082,6	9.267,6	8.997,1	8.583,7	8.706,4	8.674,4	8.643,4
TOTAL WPPs	405,2	405,2	405,2	405,2	405,2	405,2	405,2	405,2	405,2	405,2
TOTAL EXISTING FACILITIES	15.423,4	15.439,8	16.295,8	15.058,1	15.243,1	14.972,6	14.559,2	14.681,9	14.649,9	14.618,9

In Tables 13 and 14 the generation of new HPPs and TPPs on the B&H transmission network according to the data provided by the Users is given, while in Table 15 and 16 the generation of new WPPs and SPPs is given.

Table 13. Generation of new HPPs on the B&H transmission network for the period 2024-2033 [4]-[7]

GENERATION	(GWh)									
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
NEW HPPs	82,3	82,3	82,3	82,3	373,1	411,4	411,4	411,4	411,4	411,4

Table 14. Generation of new TPPs on the B&H transmission network for the period 2024-2033 [4]-[7]

GENERATION	(GWh)									
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
NEW TPPs	60,0	60,0	60,0	2.686,9	2.686,9	2.686,9	2.686,9	2.686,9	2.686,9	2.686,9

Table 15. - Generation of new WPPs on the B&H transmission network for the period 2024-2033 [4]-[7]

GENERATION	(GWh)									
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
NEW WPPs	1315,8	1990,4	1990,4	1990,4	1990,4	1990,4	1990,4	1990,4	1990,4	1990,4

Table 16. Generation of new SPPs on the B&H transmission network for the period 2024-2033 [4]-[7]

GENERATION	(GWh)									
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
NEW SPPs	650,1	686,5	720,0	717,7	717,0	716,6	715,9	715,1	714,4	713,7

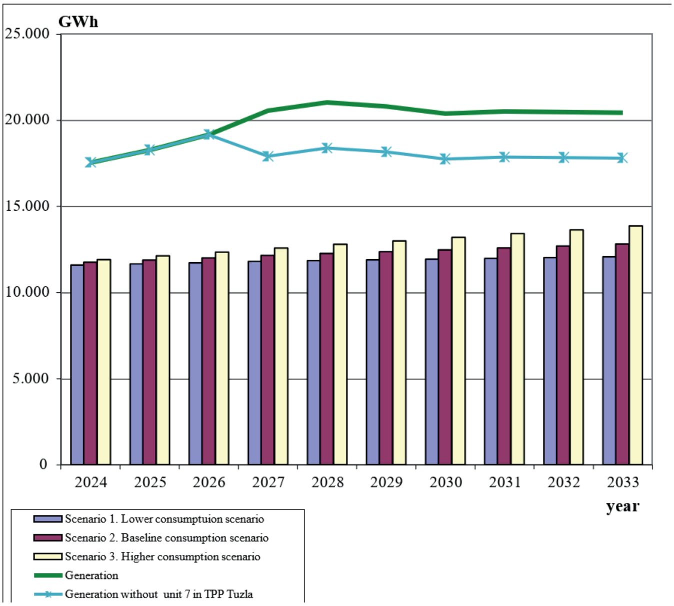


Figure 9. Three scenarios of consumption and two scenarios of production (with and without the new unit 7 in TPP Tuzla) of existing and new balanced production facilities for the period 2024-2033 [4]

Table 17. Generation of electricity on the B&H transmission network by type of source [4]-[7]

GENERATION	(GWh)									
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
TE	9.507,9	9.524,3	10.380,3	11.769,5	11.954,5	11.684,0	11.270,6	11.393,3	11.361,3	11.330,3
PsHPP ČAPLJINA	200,0	200,0	200,0	200,0	200,0	200,0	200,0	200,0	200,0	200,0
RES	7.823,6	8.534,7	8.568,1	8.565,9	8.855,9	8.893,9	8.893,1	8.892,4	8.891,7	8.890,9
RES (%)	44,63%	46,74%	44,75%	41,71%	42,15%	42,80%	43,67%	43,41%	43,47%	43,54%
TOTAL	17.531,5	18.259,0	19.148,4	20.535,4	21.010,4	20.777,9	20.363,7	20.485,7	20.453,0	20.421,2

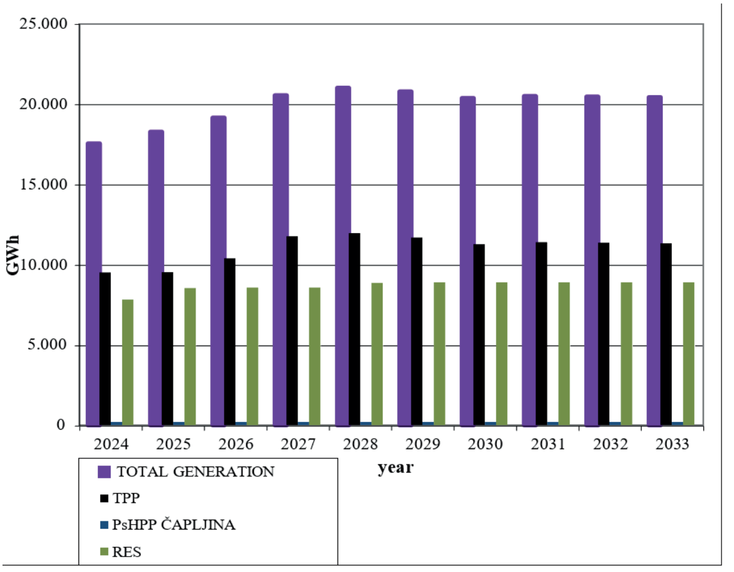


Figure 10. Generation of electricity on the B&H transmission network by type of source for the period 2024-2033 [4]

Figure 9 shows three consumption scenarios and the planned production of existing and new balanced production capacities for the period 2024-2033 years, as well as an additional scenario of production without the constructed unit 7 of the Tuzla TPP. In Tables 17 and 18 and in Figures 10 and 11 electricity production on the BiH transmission network and installed power by sources are given: thermal power plants (TE), renewable sources (HE+VE+SE), and separately PHE Čapljina. In Figures 10 and 11 electricity generation on the BiH transmission network and installed power by sources are given: thermal power plants (TE), renewable sources (HE+VE+SE), and separately PHE Čapljina.

Table 18. Installed generation capacities by type of source in Bosnia and Herzegovina [4]

(MW)	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
TPP	1.987,5	1.987,5	1.987,5	2.327,5	2.127,5	2.127,5	2.127,5	2.127,5	2.127,5	2.127,5
PsHPP ČAPLJINA	440,0	440,0	440,0	440,0	440,0	440,0	440,0	440,0	440,0	440,0
RES	2.738,5	2.900,6	2.900,6	2.900,6	3.075,6	3.075,6	3.075,6	3.075,6	3.075,6	3.075,6
RES (%)	53,01%	54,44%	54,44%	51,17%	54,50%	54,50%	54,50%	54,50%	54,50%	54,50%
TOTAL	**5.165,9**	**5.328,1**	**5.328,1**	**5.668,1**	**5.643,0**	**5.643,0**	**5.643,0**	**5.643,0**	**5.643,0**	**5.643,0**

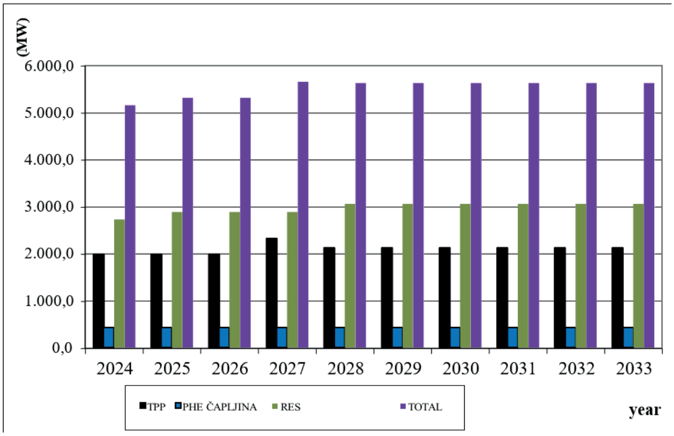


Figure 11. Installed power of balanced production capacities in BiH by type of source for the period 2024-2033 years

2.9. Bosnia and Herzegovina integrated energy and climate plan

The National Energy And Climate Plan of Bosnia and Herzegovina (NECP) establishes links between the existing elements of the strategic framework, and defines a new approach that introduces stronger cooperation between the sectors, but all with the aim of establishing a clear and efficient implementation framework based on an intersectoral approach. The integrated energy and climate plan in Bosnia and Herzegovina by 2030 is an integral part of the overall long- term approach to achieving carbon neutrality by 2050. This integrated strategic approach must ensure a smooth process of decarbonisation of the energy sector in 2030, aiming for the criterion of carbon neutrality in 2050. The pillars of this strategic approach are set according to the dimensions defined in the Energy Union Strategy (COM/2015/080) namely:

- Dimension 1A: Decarbonisation: Reduction and removal of greenhouse gas emissions
- Dimension 1B: Decarbonisation: Renewable energy sources
- Dimension 2: Energy efficiency

- Dimension 3: Security of supply
- Dimension 4: Internal energy market
- Dimension 5: Research, competitiveness and innovation

For each dimension, this plan defines the goals of the dimensions, as well as the accompanying operational goals from which further activities on the implementation of policies and measures from the framework of this plan follow. Also, the strategic approach defines the main indicators for monitoring progress on the implementation of the plan, expressed in numerical values for reducing greenhouse gas emissions, reducing the use of primary energy, reducing final energy consumption, and the share of renewable sources in the total gross final energy consumption. The content of the goals by dimensions is given in the following Figure.

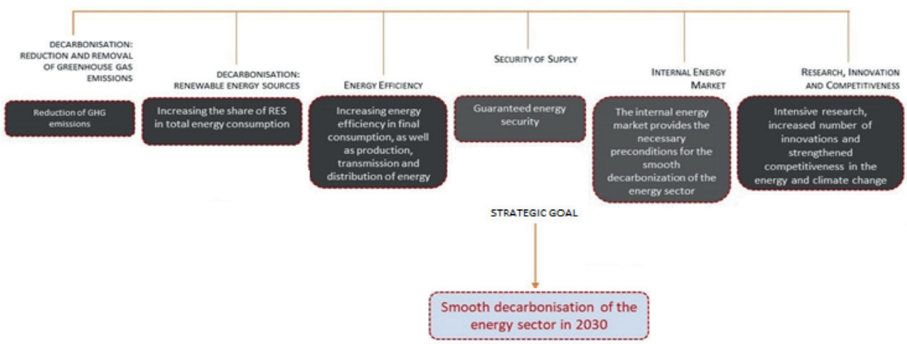


Figure 12. Strategic approach to the development of the energy sector according to the decarbonisation criteria by 2030 in Bosnia and Herzegovina [2]

The success of the implementation of the goals of the Bosnia and Herzegovina Integrated Energy and Climate Plan depends on the effectiveness of the prescribed policies and measures. The framework of this plan defines the following main monitoring indicators:

- Total emission of greenhouse gases
- Primary energy consumption (PEC)
- Final Energy Consumption (FEC)
- Share of renewable sources in gross final energy consumption

2.9.1. Values of the main indicators for achieving the goals

2.9.1.1. Total emission of greenhouse gases

The integrated energy and climate plan in Bosnia and Herzegovina by 2030 is an integral part of the overall long-term approach to achieving carbon neutrality by 2050. The carbon neutrality criterion directs the development of the energy sector in such a way that in 2050 greenhouse gas emissions will be allowed in an amount equivalent to greenhouse gas sinks from land use, land-use change and forestry (LULUCF). In the long term, this represents a gradual reduction of emissions, which affects the movement of total Primary Energy Consumption (PEC) and Final Energy Consumption (FEC), for which the planning framework, of which NECP 2030 is a part, prescribes appropriate policies and measures aimed at achieving carbon neutrality.

The level of ambition in implementation will not be constant throughout the entire period, so it is important to determine the key stages of implementation and to project trends for them. In this regard, this plan introduces tentative key stages, namely:

- The introductory phase of the decarbonisation process by 2030
- Phase 2: Accelerated decarbonisation in the period 2030-2040
- Phase 3: Achieving carbon neutrality by 2050

The basic indicator of the process of achieving carbon neutrality is the emission of greenhouse gases. The approximate projections of this indicator are given in the following table 19:

Table 19. Values of framework indicators of greenhouse gas emissions at the transition between phases [2]

MtCO2	2022	2030	2040	2050
Total CO2 emission without LULUCF - Baseline	26.44	27.39	19.63	16.24
Total CO2 emission without LULUCF - Policy	25.35	22.15	13.35	6.78
LULUCF	-6,04	-6,5	-6.662	-6.668
Net emissions - Policy	19.31	15.65	6.69	0.11

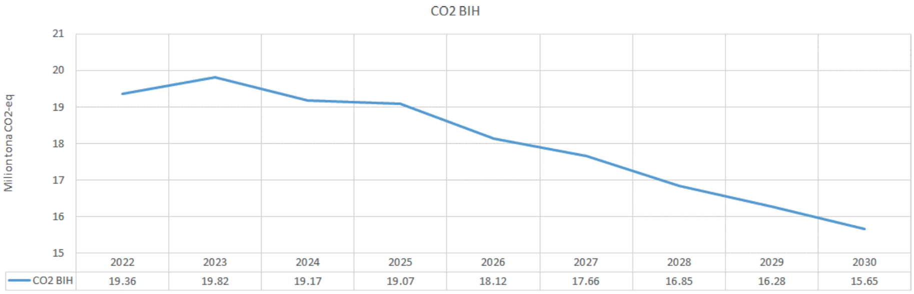


Figure 13. The trajectory of reducing CO2-eq emissions with LULUCF in Bosnia and Herzegovina 2022-2030 [2]

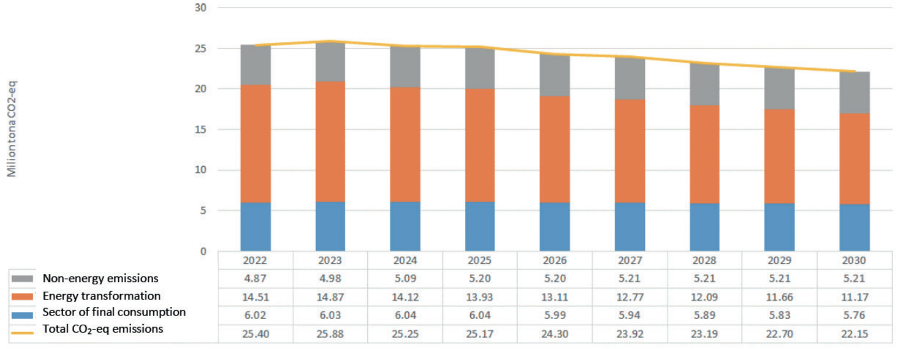
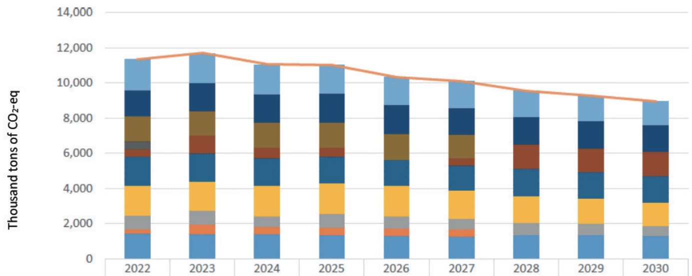


Figure 14. The trajectory of reducing CO2-eq emissions without LULUCF in Bosnia and Herzegovina 2022-2030, by sectors [2]

The integrated energy and climate plan of Bosnia and Herzegovina defines the target value for the reduction of greenhouse gas emissions in 2030. This value is obtained as a result of planning the development of the entire energy sector, based on the sector decarbonisation and compliance with the criteria defined in order to achieve carbon neutrality by 2050. In this regard, the following goal is set:

Total CO_2-eq emission with LULUCF in 2030	15.65 $MtCO_2$
Total CO_2-eq emission without LULUCF in 2030	22.15 $MtCO_2$
Total emission of CO_2-eq with LULUCF in 1990	26.62 $MtCO_2$
Emission reduction in 2030 compared to 1990 (with LULUCF)	41.21%

The goal implies a gradual reduction of CO2-eq emissions in the period 2022-2030 according to the trend shown in the Figure 13, and distributed according to three basic emission sectors (Figure 14), namely.



	2022	2023	2024	2025	2026	2027	2028	2029	2030
TE Ugljevik 300 MW	1,785.0	1,728.8	1,694.7	1,641.9	1,599.4	1,536.3	1,493.9	1,442.7	1,384.5
TE TZ6 215 MW	1,469.9	1,584.4	1,594.2	1,635.7	1,649.1	1,518.7	1,584.3	1,547.1	1,501.9
TE TZ5 200 MW	1,405.5	1,404.3	1,453.5	1,448.8	1,467.6	1,369.4	-	-	-
TE TZ3 100 MW	486.1	-	-	-	-	-	-	-	-
TE TZ 4 200 MW	394.2	980.7	593.7	495.3	-	397.1	1,355.4	1,337.8	1,370.6
TE Stanari 300 MW	1,659.0	1,603.1	1,568.6	1,517.5	1,477.0	1,418.3	1,547.9	1,520.7	1,499.9
TE Petroleum products	0.8	0.7	0.7	0.7	0.6	0.6	0.5	0.5	0.5
TE KK7 230 MW	1,692.8	1,691.3	1,712.2	1,744.9	1,759.1	1,592.0	1,525.0	1,442.4	1,365.7
TE KK6 110 MW	779.2	764.5	629.6	788.2	669.5	635.7	689.7	638.1	514.0
TE KK5 110 MW	220.4	540.6	424.2	423.1	419.4	409.2	-	-	-
TE Gacko 300 MW	1,448.2	1,400.1	1,370.7	1,326.8	1,292.1	1,241.4	1,355.7	1,338.8	1,321.3
Total emissions from electricity production	11,341.2	11,698.5	11,042.0	11,023.0	10,333.7	10,118.6	9,552.4	9,268.1	8,958.5

Figure 15. Target emissions of greenhouse gases from electricity production in Bosnia and Herzegovina, 2022-2030 [2]

Considering the high share in total emissions, the key sector for achieving the goals of reducing emissions by 2030 is the electric power sector. The sectoral target for emissions from the power industry is:

Emissions from the power sector in 2030	8.96 $MtCO_2$

Figure 15 shows the trend of emissions from the power sector in the period 2022 - 2030:

2.9.1.2. Primary energy consumption (PEC) and Final energy consumption (FEC)

This strategic approach to reducing greenhouse gas emissions is based on changes in the energy sector, both in the domain of energy transformations, which is reflected in the value of the PEC indicator, and in the domain of the final energy consumption sector, which is seen in the value of the FEC indicator. The approximate values of these indicators, for the planning "Policy" scenario, at the transition between phases are shown in the following table:

Table 20. Values of PEC and FEC framework indicators at the transition between phases

ktoe	2022	2030	2040	2050
Primary energy consumption (PEC)	7,245.9	6,843.7	5,584.6	3,583.3
Final energy consumption (FEC)	4,327.6	4,339.0	3,825.4	3,066.5

Based on the analysis of the results obtained by modelling the trends of energy and climate indicators in Bosnia and Herzegovina, in accordance with international obligations, primarily by fulfilling the goals of the EU energy strategy, transferred by the Energy Community Treaty, energy efficiency goals for Bosnia and Herzegovina by 2030 are defined. These goals define the values of the following indicators:

- Primary Energy Consumption (PEC)
- Final Energy Consumption (FEC)

Based on these considerations, the energy efficiency goals in Bosnia and Herzegovina for energy consumption savings by applying energy efficiency measures, for the period by 2030, are as follows:

Primary energy consumption in 2030	6.844.0 ktoe

Final energy consumption in 2030	4.339.0 ktoe

Accordingly, this plan defines a reduction in primary energy consumption, while a slight increase in final energy consumption is expected by 2030. The trajectories of PEC and FEC indicator values are shown in the following Figure.

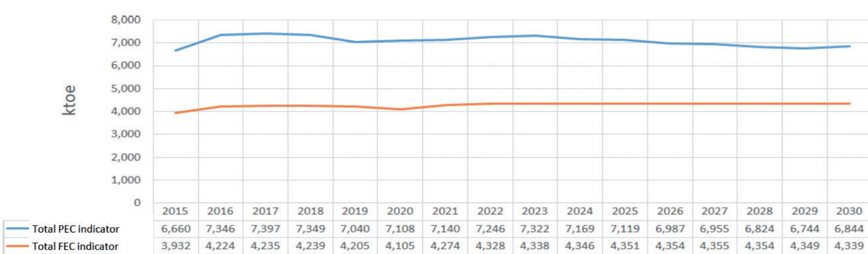
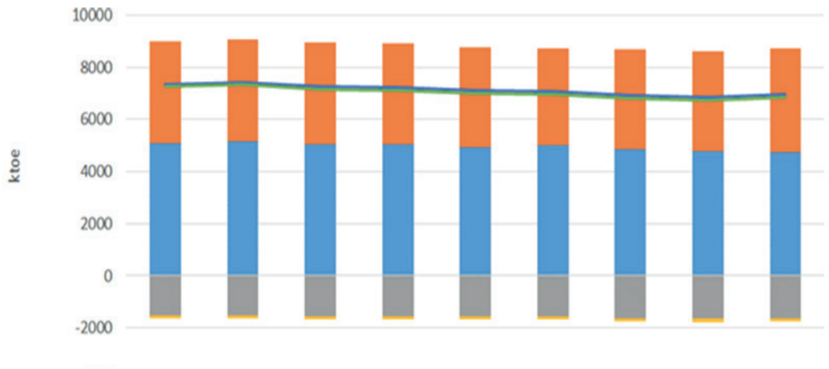


Figure 16. Target trajectories of PEC and FEC indicators in Bosnia and Herzegovina, 2022-2030 [2]

Primary energy consumption (PEC) is the sum of total produced, imported energy and stored energy, minus the amount of energy exported and energy consumed in the energy sector's own processes. In this regard, this plan envisages the reduction of the PEC in a manner that all of its elements are changed. The biggest change is predicted by the decrease in energy production, while no significant changes are predicted in its import and export. This ultimately results in an overall reduction in PEC, which is mainly accompanied by a reduction in energy production. The trajectories of changes in these parameters are given in the following Figure.



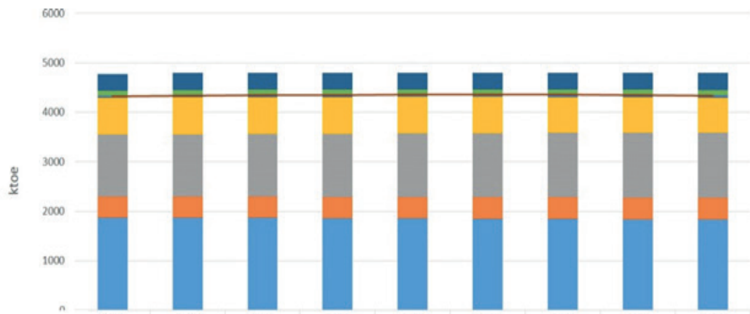
	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total inventory	-127.8	-127.8	-127.8	-127.8	-127.8	-127.8	-127.8	-127.8	-127.8
Total exports	-1,513.5	-1,513.5	-1,536.9	-1,556.2	-1,550.1	-1,544.0	-1,623.3	-1,642.8	-1,633.2
Total import	3,907.7	3,902.2	3,901.7	3,860.4	3,842.6	3,727.6	3,841.8	3,831.9	3,979.0
Total production	5,088.9	5,170.4	5,040.9	5,051.5	4,931.4	5,008.1	4,842.7	4,791.9	4,734.7
TPES	7,355.3	7,431.2	7,277.9	7,227.9	7,096.2	7,063.8	6,933.5	6,853.2	6,952.7
Total PEC-Indicator	7,246	7,322	7,169	7,119	6,987	6,955	6,824	6,744	6,844

Figure 17. Target trajectories of PEC towards production, import, export and energy stocks in Bosnia and Herzegovina 2022-2030 [2]

In the coming period, a significant increase in the need for energy in the final consumption sectors is expected, caused primarily by the growth of consumption and the intensification of activities. This increase is compensated by the effects of energy efficiency measures in the final consumption sectors, so that ultimately the total growth of FEC is not significant.

Figure 18 shows the target trajectories of final energy consumption by sector.

In the ambitious decarbonisation scenario in Bosnia and Herzegovina by 2030, electricity plays a crucial role in final energy consumption. Electricity is considered a clean form of energy when produced from renewable sources or used to power electric vehicles. According to the "Policy" scenario, in 2030, the share of coal in energy exports in Bosnia and Herzegovina is set at 23.26%. In contrast to the "Baseline" scenario, which predicts projections based on existing policies and measures, where this share was 23.21%, there is a constant share in the use of electricity in final energy consumption in Bosnia and Herzegovina, although the overall final energy consumption across all sources should be considered in decline.



	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total FEC/Consumption of energy plants	333.0	343.2	342.4	337.9	333.3	329.7	337.7	336.8	343.6
Total FEC/Final non-energy consumption	109.3	109.3	109.2	109.2	109.1	109.1	109.1	109.0	109.0
TotalFEC/Agriculture and Forestry	38.2	39.1	39.9	40.8	41.6	42.5	43.3	44.2	45.0
Total FEC/Industry	741.2	745.0	746.6	746.2	743.4	738.2	730.2	719.4	705.3
Total FEC/Transport	1249.5	1256.8	1264.1	1270.2	1278.1	1286.1	1294.1	1302.2	1309.1
Total FEC/Public,Commercial and Services	424.7	427.6	430.6	433.5	436.5	439.4	442.3	445.2	448.0
Total FEC/Residential	1874.0	1869.6	1864.9	1859.9	1854.7	1849.3	1843.6	1837.8	1831.6
TotalFEC -Indicator	4,328	4,338	4,346	4,351	4,354	4,355	4,354	4,349	4,339

Figure 18. Trajectories of final energy consumption by sector in Bosnia and Herzegovina 2022-2030 [2]

2.9.1.3. Share of renewable sources in gross final energy consumption

The total share of renewable energy sources (RES) consists of individual sectoral shares RES-E, RES-T and RES- H&C with all their specificities, which must be taken into account when determining the total share.

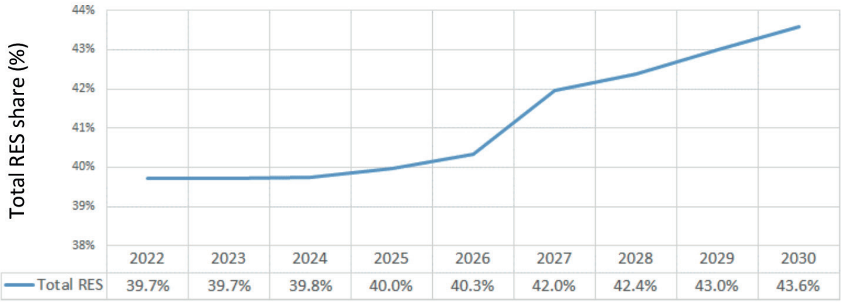


Figure 19. Trajectory of the RES share in gross final energy consumption in Bosnia and Herzegovina, 2022-2030 [2]

The goal of the share of RES in the total gross final consumption of energy in Bosnia and Herzegovina in 2030 is:

Total Share of RES in 2030	43.6 %

The trajectory of the share of RES in gross final energy consumption in Bosnia and Herzegovina by 2030 is shown in the Figure 19.

Target sectoral and total shares and actual consumption of energy from renewable sources in Bosnia and Herzegovina in 2030 (Article 22(1)(a) of Directive 2009/28/EC) are shown in the following table:

Table 21. Sectoral (electricity, heating and cooling, and transport) and total share of energy from renewable sources in Bosnia and Herzegovina in 2030 [2]

	2030
RES-H&C	60.8 %
RES-E	70.1 %
RES-T	8.4 %
Total RES	43.6 %

The budget table for the contribution of renewable energy for each sector of final energy consumption is shown as follows, (ktoe).

Table 22. Target values of energy consumption from RES in Bosnia and Herzegovina in 2030 [2]

ktoe	2030
(A) Gross final energy consumption from RES for heating and cooling	1,313.0
(B) Gross final consumption of electricity from RES	702.0
(C) Energy consumption from RES in transport	109.9
(D) Gross final consumption of energy from RES	2,015.1
(E) Transfer of energy from RES to other countries	0
(F) Transfer of energy from RES from other countries	0
(G) Adjusted gross final energy consumption from RES (D)-(E)+(F)	2,015.1

The gross final consumption of electricity is determined as:

- Gross production of electricity from all energy sources (actual production, without normalisation for hydro and wind), excluding production of electricity in pumped storage units from water previously pumped uphill,
- Plus the total import of electricity,
- Minus the total export of electricity.

The target value of the RES share in electricity consumption in Bosnia and Herzegovina in 2030, which is foreseen by this plan, is as follows:

The RES share in electricity consumption in 2030	70.1 %

Projection of this share for the period 2022-2030 is shown in the following figure:

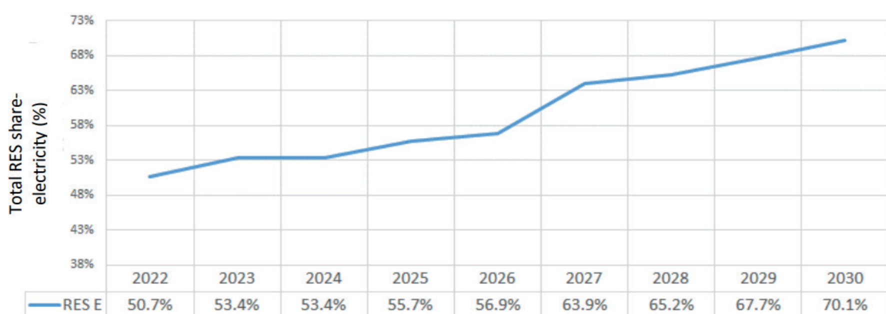


Figure 20. The trajectory of the RES share in electricity consumption in Bosnia and Herzegovina 2022-2030 [2]

The structure of the presented share is reflected in the ratio of Gross final consumption of energy from renewable sources in electricity consumption, and Gross final consumption of electricity, whose values for the period 2022-2030 are shown in the following Figure:

Figure 21. Trajectory of Gross final consumption of electricity from renewable sources and Gross final consumption of electricity in Bosnia and Herzegovina for the period 2022-2030 [2]

2.9.2. Plans for the electricity generation from RES

The plan envisages the development of capacities for the production of electricity from RES using different technologies, such as hydroelectric power plants, wind power plants, solar power plants, and plants for the production of electricity from biomass, including cogeneration (CHP) plants. The following table shows the target values of capacity and electricity production from RES by these technologies.

Table 23. Total actual contribution (installed capacity, gross electricity production) of each renewable energy technology in electricity production in Bosnia and Herzegovina in 2030 [2]

	2030	
	MW	GWh
Hydropower	2.526,8	6,563.3
< 1 MW	206.8	651.3
1 MW – 10 MW	0	0
> 1 MW	1,900.0	5,817.9
pumped hydro power plants	420	94.1
combined power plants	0	0
Geothermal energy	0	0

	2030	
	MW	GWh
Solar energy	1,492.0	1,638.8
photovoltaic power plants	1,492.0	1,638.8
concentrated solar energy	0	0
Wave and tidal energy	0	0
Wind energy	600	1,261.2
onshore power plants	600.0	1,261.2
coastal power plants	0	0
Biomass	25	43.15
solid biomass	25	43.15
biogas	0	0
liquid biofuels	0	0
Total	4.643,8	9,506.5
of which CHP	25	43.15

In Bosnia and Herzegovina, priority for the development of capacity for the production of electricity from RES is given to certain technologies. The trajectory of capacity and production of electricity from renewable sources by priority technologies are shown in the following Figure:

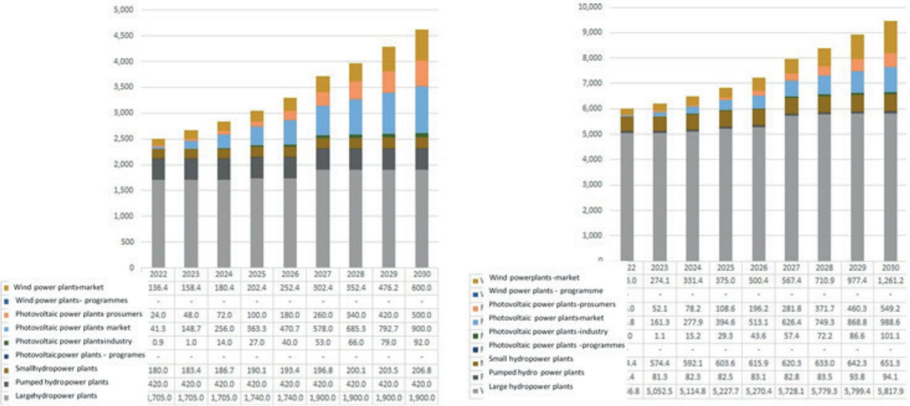
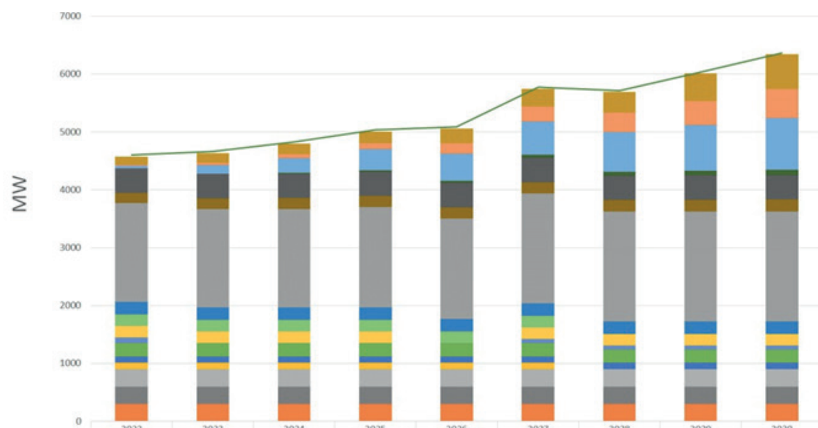


Figure 22. The trajectory of priority capacities for the production of electricity from renewable sources by different technologies in Bosnia and Herzegovina for the period 2022-2030 [2]

The plan envisages the construction of new large hydro plants, namely the introduction of a new 35 MW into operation in 2025, and an additional 160 MW from 2027 onwards. When it comes to small hydropower plants, a steady increase in capacity is foreseen until 2030, when a total of 26.8 MW should be introduced compared to 2021.

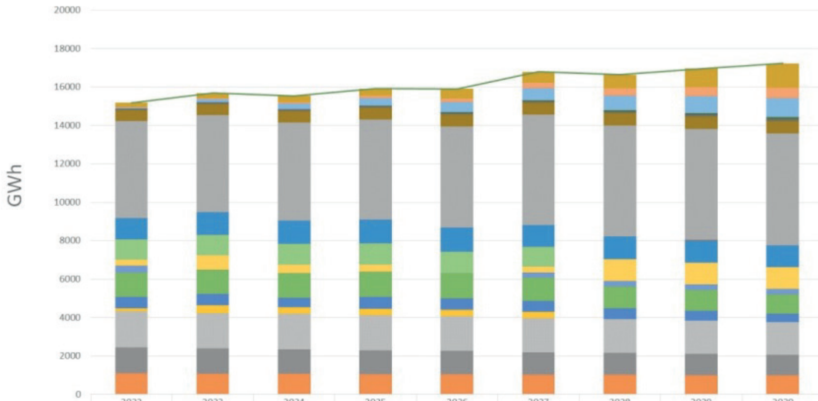
On the other hand, a significant increase in the capacity of photovoltaic power plants is predicted. By 2030, it is planned to introduce a new 850 MW of large PVE, 92 MW of new capacity of industrial PVE exclusively for meeting own electricity consumption, and through the prosumer programme in households a new 500 MW. Also, the construction of wind power plants a total capacity of 600 MW is planned in 2030.

The following figure shows the trajectories of electricity production capacity in Bosnia and Herzegovina for the period 2022-2030.



	2022	2023	2024	2025	2026	2027	2028	2029	2030
Wind power plants-market	136.40	158.40	180.40	202.40	252.40	302.40	352.40	476.20	600.00
Photovoltaic power plants-prosumers	24.00	48.00	72.00	100.00	180.00	260.00	340.00	420.00	500.00
Photovoltaic power plants-market	41.32	148.66	255.99	363.33	470.66	578.00	685.33	792.67	900.00
Photovoltaic power plants-industry	0.88	1.00	14.00	27.00	40.00	53.00	66.00	79.00	92.00
Pumped hydro power plants	420.00	420.00	420.00	420.00	420.00	420.00	420.00	420.00	420.00
Small hydropower plants	180.00	183.35	186.70	190.05	193.40	196.75	200.10	203.45	206.80
Large hydropower plants	1,705.00	1,705.00	1,705.00	1,740.00	1,740.00	1,900.00	1,900.00	1,900.00	1,900.00
TE TZ6 215 MW	215.00	215.00	215.00	215.00	215.00	215.00	215.00	215.00	215.00
TE TZ5 200 MW	200.00	200.00	200.00	200.00	200.00	200.00	-	-	-
TE TZ 4 200 MW	200.00	200.00	200.00	200.00	-	200.00	200.00	200.00	200.00
TE TZ3 100 MW	100.00	-	-	-	-	70.00	70.00	70.00	70.00
TE KK7 230 MW	230.00	230.00	230.00	230.00	230.00	230.00	230.00	230.00	230.00
TE KK6 110 MW	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
TE KK5 110 MW	110.00	110.00	110.00	110.00	110.00	110.00	-	-	-
TE Stanari 300 MW	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00
TE Ugljevik 300 MW	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00
TE Gacko 300 MW	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00
Gas power plant	-	-	-	-	-	-	-	-	-
Total	4,607.2	4,662.2	4,830.1	5,037.1	5,089.0	5,770.9	5,712.9	6,038.6	6,364.3

Figure 23. Trajectories of capacity for electricity production by plant types in B&H 2022-2030 [2]



	2022	2023	2024	2025	2026	2027	2028	2029	2030
Vjetroelektrane - tržište	236.0	274.1	331.4	375.0	500.4	567.4	710.9	977.4	1,261.2
Fotonaponske elektrane - prosumeri	26.0	52.1	78.2	108.6	196.2	281.8	371.7	460.3	549.2
Fotonaponske elektrane - tržište	44.8	161.3	277.9	394.6	513.1	626.4	749.3	868.8	988.6
Fotonaponske elektrane - industrija	1.0	1.1	15.2	29.3	43.6	57.4	72.2	86.6	101.1
Pumpne hidroelektrane	81.4	81.3	82.3	82.5	83.1	82.8	83.5	93.8	94.1
Male hidrolektrane	564.4	574.4	592.1	603.6	615.9	620.3	633.0	642.3	651.3
Velike hidroelektrane	5,056.8	5,052.5	5,114.8	5,227.7	5,270.4	5,728.1	5,779.3	5,799.4	5,817.9
Korištenje nafte i naftnih derivata	2.9	2.8	2.7	2.5	2.4	2.2	2.1	1.9	1.8
TE TZ6 215 MW	1,109.5	1,196.0	1,203.3	1,234.7	1,244.8	1,146.3	1,195.8	1,162.5	1,128.6
TE TZ5 200 MW	1,060.9	1,060.0	1,097.1	1,093.6	1,107.7	1,033.6	-	-	-
TE TZ 4 200 MW	294.9	734.9	445.7	372.5	-	299.8	1,136.7	1,140.7	1,144.3
TE TZ3 100 MW	366.9	-	-	-	-	273.1	275.6	276.5	277.4
TE KK7 230 MW	1,266.3	1,265.2	1,280.8	1,305.2	1,315.9	1,190.9	1,140.8	1,083.9	1,026.2
TE KK6 110 MW	588.2	587.7	493.1	629.2	605.4	586.2	578.5	535.2	433.1
TE KK5 110 MW	166.4	415.6	332.2	337.8	341.3	339.7	-	-	-
TE Stanari 300 MW	1,878.4	1,848.6	1,842.8	1,817.0	1,803.0	1,765.8	1,752.6	1,729.6	1,706.0
TE Ugljevik 300 MW	1,347.4	1,304.9	1,279.2	1,239.3	1,207.3	1,159.6	1,127.6	1,089.0	1,049.8
TE Gacko 300 MW	1,093.1	1,076.3	1,073.5	1,059.1	1,051.5	1,030.4	1,023.3	1,010.5	997.3
Gasna elektrana	-	-	-	-	-	-	-	-	-
Total	15,185.4	15,688.7	15,542.4	15,912.1	15,902.0	16,791.8	16,632.9	16,958.5	17,227.9

Figure 24. Trajectories of the amount of electricity produced by type of plant in B&H 2022-2030 [2]

In order to satisfy domestic needs for electricity, and on the other hand to meet climate criteria, this plan defines the trajectories of the amount of electricity produced. These trajectories are shown by different technologies in Figure 24.

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Dionysios Stamatiadis

1. Greece Electricity Outlook

Regarded as a cornerstone of Greece's industry, the electricity sector has experienced some significant changes recently.

Figure 1 illustrates the anatomy of Greece's power system, grounded by a 400 kV network that spans across the country's continental part. Linking to key load and generation centers, including interconnected islands, is a 150 kV sub-transmission network. Plans are in the pipeline for two DC lines to link the southern islands of Crete and Kos. Greece's electrical grid also extends beyond its borders, connecting to neighboring countries via:

- Two 400 kV circuits with North Macedonia
- A 400 kV and a 150 kV circuit with Albania
- A 400 kV circuit with Bulgaria, with an additional 400 kV interconnection under construction
- A 400 kV circuit with Türkiye
- A 400 kV DC interconnection with Italy

The total installed generation capacity is 19.3 GW while the peak demand reaches 7.5. GW.

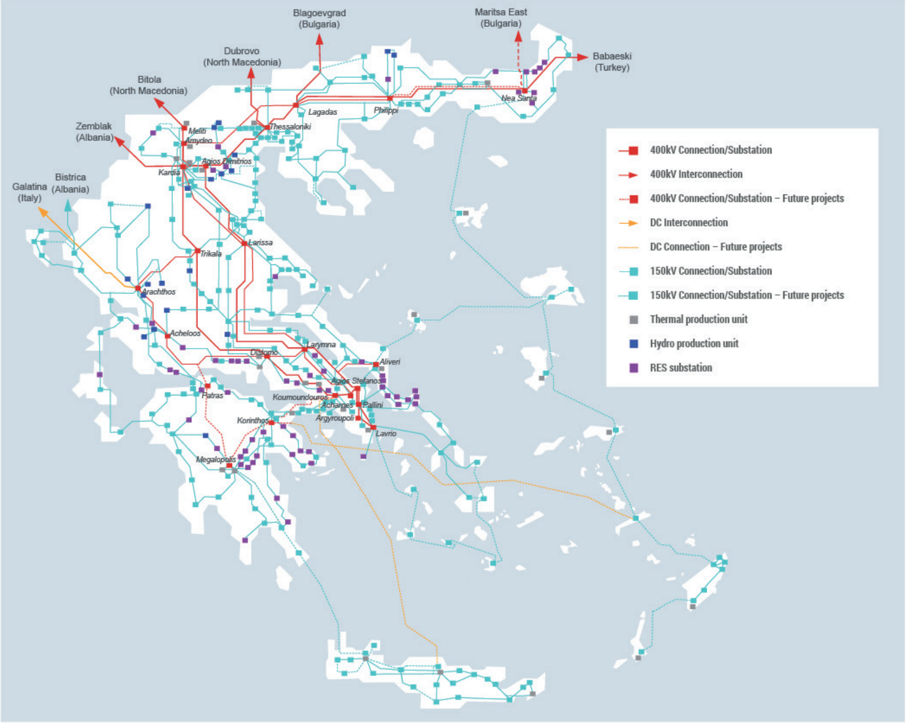


Figure 1. Hellenic power system

In 2020, gross electricity production marginally declined to 48.2 TWh from 48.6 TWh in 2019, reflecting the ripple effects of the Covid-19 pandemic. Concurrently, Greece has steadfastly pursued the decarbonization of its electricity production. The capacity share of lignite energy technologies decreased to 12% in January 2022. However, overreliance on imported natural gas has led to an extension of the lignite phase-out timeline from 2025 to 2028.

Renewable Energy Sources (RES) have seen substantial growth in installed capacity, exceeding 8.5 GW and holding 45% of the capacity share (excluding hydro). A clear tilt towards green energy was noticeable in February 2021 when RES contributed over 54% to the energy mix. For half of 2021, RES accounted for more than 40% of the energy mix, even including the non-interconnected system, underlining a determined decarbonization drive. Despite these strides, the interconnected system remains dependent on power imports. The import-export power disparity in 2021 was 3655 GWh.

The Public Power Cooperation (PPC) retains a significant role in Greece's electricity production. From October 2021 to February 2022, the PPC's market share in retail fluctuated between 63.4% and 64.6%, signifying a downward trend from January 2016.

The year 2021 also witnessed notable shifts in European electricity prices. The first and last quarters exhibited marked price variability across many European nations, with Malta, Italy, Slovenia, and Croatia (EU-27) displaying the greatest fluctuations. In contrast, the Nordic countries - Sweden, Finland, and Norway - experienced the least. With its power prices ranking amongst the top ten most volatile in Europe (EU-27, UK, Switzerland, Serbia, Norway, Ukraine), Greece saw record highs in the latter half of 2021. The Market Clearing Price consistently surpassed 200 €/MWh from November 2021 and hit a peak at 235 €/MWh in December 2021, with an extraordinary six-year high hourly price of 542 €/MWh.

1.1. Electricity generation

The electricity sector in Greece has experienced significant changes and challenges in recent years. As shown in Figure 2, between 2009 and 2014, the electricity generation exceeded 57 TWh, indicating a relatively stable level of production. However, from 2014 to 2020, there was a noticeable decline, with the mean electricity generation dropping to 52 TWh. Over the period of 2009 to 2020, there was an overall decrease in gross electricity generation of 18.7%, falling from 59.4 TWh to 48.3 TWh.

This decline can be attributed to various factors, including the impact of the economic crisis that began in Greece in 2009. Since then, the domestic generation of electricity has been subject to fluctuations, with a general downward trend. The year 2020 marked a significant drop in electricity generation, reaching the lowest level of the decade, primarily due to the adverse effects of the Covid-19 outbreak.

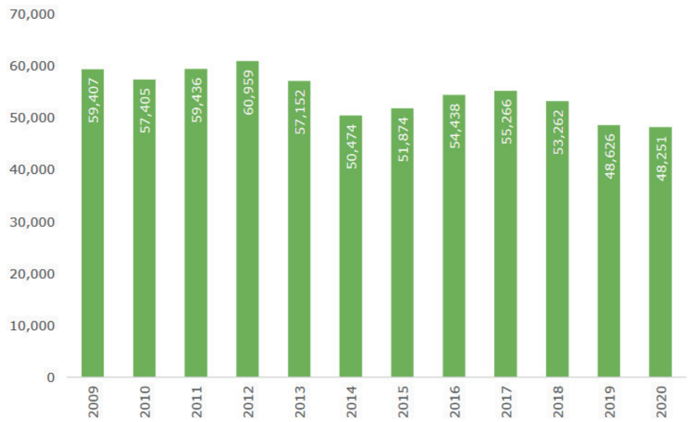


Figure 2. Gross electricity generation (GWh)

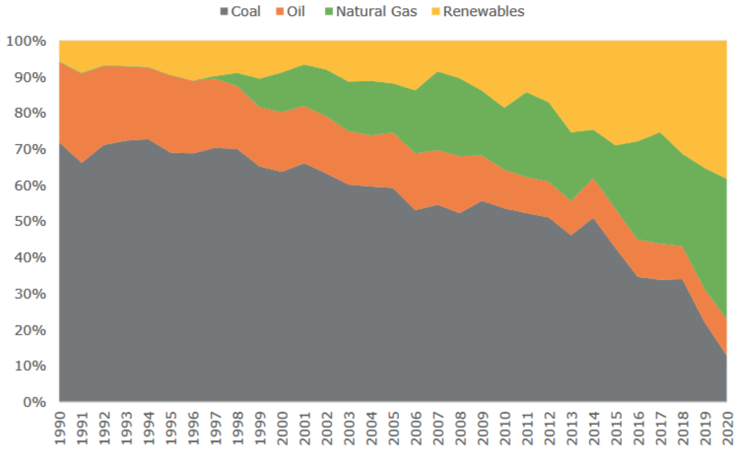


Figure 3. Gross electricity generation by fuel (%)

Regarding the energy mix, shown in Figure 3, there was a remarkable 44.4% decrease in the share of lignite in 2020, marking a substantial shift towards cleaner energy sources. For the second consecutive year, natural gas-based electricity generation exceeded that from lignite power plants, highlighting the increasing importance of natural gas in the energy landscape. In 2020, natural gas experienced a growth of 4% and 13% compared to 2019 and 2018, respectively. Renewable Energy Sources (RES) have also gained prominence in Greece's electricity generation, with the second-largest share after natural gas. In 2020, RES witnessed a 3% increase compared to 2019, while the growth was even more significant, at 7% and 13%, compared to 2018 and 2017, respectively. Together, Renewable Energy Sources and natural gas dominate the electricity mix, accounting for a cumulative share of 77%, reflecting the ongoing efforts to transition towards cleaner and more sustainable power generation in Greece.

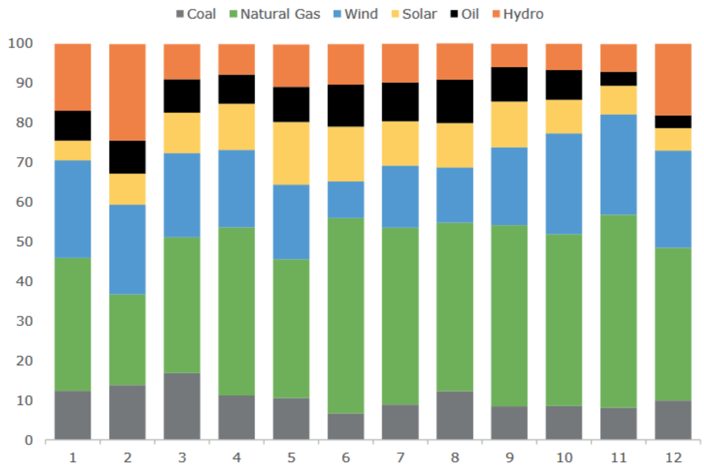


Figure 4. Gross electricity generation by fuel (%) in 2021

The same trend continued in 2021, as shown in Figure 4, with Renewable Energy Sources (RES) making significant contributions to the energy mix. The share of RES in Greece's electricity generation exhibited a wide range throughout the year, reaching a minimum of 33.2% in June and a maximum of 54.69% in February. Throughout the year, RES consistently contributed a substantial share, surpassing 40% for six months (January, February, March, May, October, and December). Fossil-based generation, on the other hand, experienced peaks during the summer months, reflecting the seasonal demand patterns. Water resources played a crucial role in the decarbonization process, with their share in electricity generation increasing during the winter months due to higher rainfall and precipitation.

Additionally, the electricity generation from oil sources primarily stemmed from the use of diesel generators in the non-interconnected system, showcasing the need for alternative and cleaner energy solutions.

The electricity imports/exports in 2023 showed notable patterns in 2021 – see Figure 5. Throughout the year, electricity imports consistently remained above 500 GWh per month, indicating a sustained reliance on imported electricity. However, the exports showed greater variability, with fluctuations in different periods. The interconnected system experienced a significant imbalance between imports and exports in 2021. March emerged as a month of particularly high electricity imports, peaking at over 863 GWh. The summer months, characterized by increased demand, witnessed the highest level of imbalance, necessitating a greater need for electricity imports to meet the rising consumption. In contrast, electricity exports reached their peak during December and January. This surge in exports can be attributed to the augmented domestic generation from wind and hydroelectric sources during this period. Throughout the year, the balance between exports and imports was positive for only three months: January, October, and December 2021. These observations highlight the ongoing challenges in achieving a consistent balance in electricity trade and emphasize the importance of diversifying the domestic generation capacity to minimize reliance on imports and enhance energy self-sufficiency.

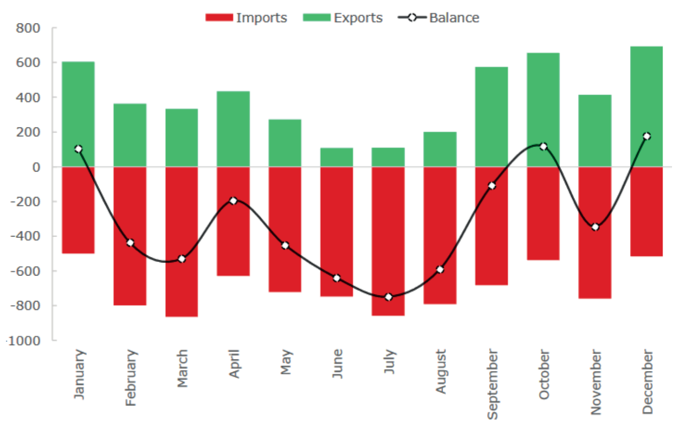


Figure 5. Monthly imports, exports and balance (GWh) in the interconnected system in 2021

1.2. Electricity demand

The onset of the pandemic crisis had a profound impact on the final energy consumption both in the EU-27 and Greece, resulting in a significant decline within a short span of one year. This contrasted with the slight increase observed in the preceding years. Notably, as shown in Figure 6, Greece experienced a higher rate of decrease in final energy consumption compared to the EU average, primarily due to the economic recession and the prolonged lockdown measures.

In 2020, final energy consumption per sector in Greece dropped to its lowest level since 2011, with the exception of households, as shown in Figure 7. Notably, the household sector witnessed an increase in final energy consumption compared to 2019, driven by the lockdowns, teleworking, and extended periods spent at home. Conversely, the transport sector experienced the most significant decline, with final energy consumption decreasing by 15% compared to the previous year. The industry sector also faced a considerable decrease in final energy consumption in 2020, reaching an all-time low level of 2,500 ktoe, representing a significant drop compared to 2011. Additionally, the final energy consumption in the other services sector, which had been steadily increasing since 2014, returned to 2011 levels, standing at 1900 ktoe in 2020.

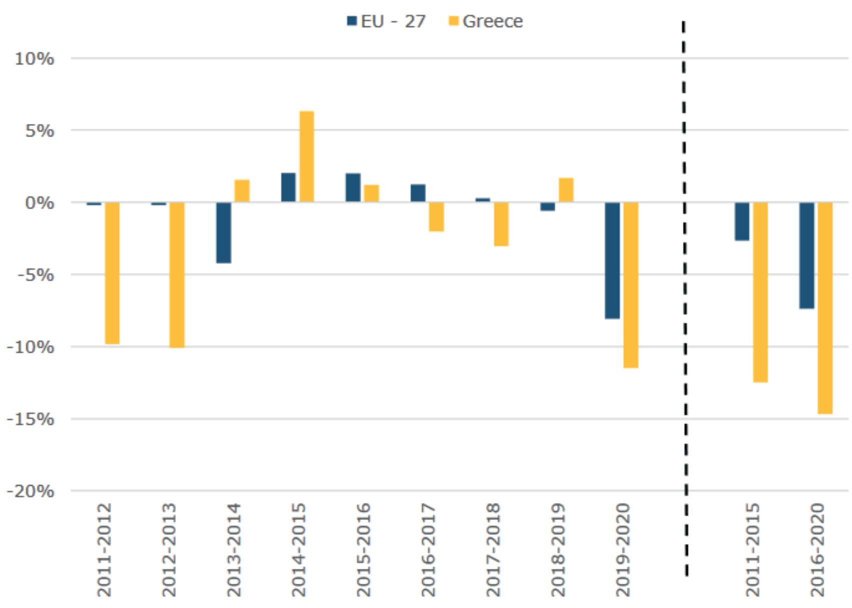


Figure 6. Final energy consumption compared to previous year (y-on-y) (%)

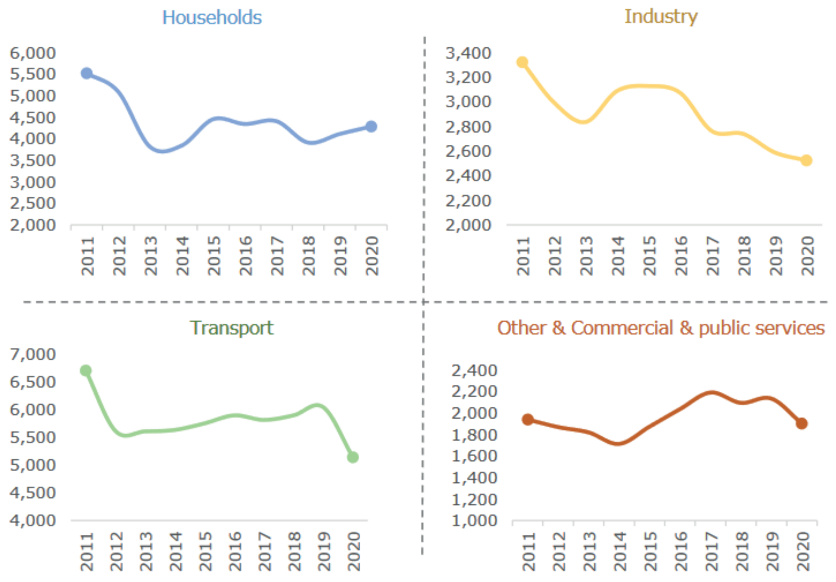


Figure 7. Final energy consumption per sector (ktoe)

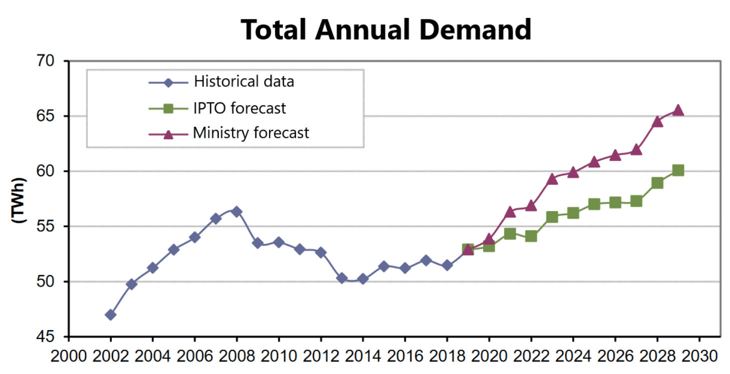


Figure 8. Historical data and forecast of total annual demand for electricity (GWh)

The future of electricity demand in Greece is projected to witness a sharp increase in the next decade, with estimations surpassing 60 TWh after 2028 as seen in Figure 8. Even the more conservative projections from the Greek Ministry of Environment and Energy, indicate a substantial rise in electricity demand in the upcoming years. The impact of the Covid-19 pandemic was evident in the total electricity demand, as it experienced a rapid decline of 7.6% within a single year, reaching 49.9 TWh in 2020.

However, there has been a notable recovery in 2021, which can be attributed to the overall economic rebound following the easing of Covid-19 restrictions. In comparison to the electricity generation of 56.3 TWh in 2008, the Ministry forecast suggests that Greece will reach identical demand levels only by 2025. IPTO forecasts that the total annual demand for electricity is projected to reach 66.7 TWh by 2031. These projections highlight the anticipated growth in electricity demand in Greece and emphasize the need for strategic planning and investments in the power sector to ensure a reliable and sustainable energy supply to meet the future needs of the country.

1.3. Installed capacity

The installed capacity in Greece is dominated by Renewable Energy Sources (RES) technologies, accounting for a significant share of 45%, as shown in Figure 9. This indicates the growing prominence of RES in the Greek energy landscape. The decommissioning of lignite-fired power plants led to a reduction in lignite installed capacity, bringing it down to 2,256 MW and reducing its share to 12%. The capacity of natural gas power plants and hydro remained steady when compared to October 2020, reflecting their consistent contribution to the electricity generation capacity. Gradually, lignite, which was once the primary domestic fossil fuel in Greece, is being replaced by RES and natural gas as part of the country's transition to cleaner and more sustainable energy sources.

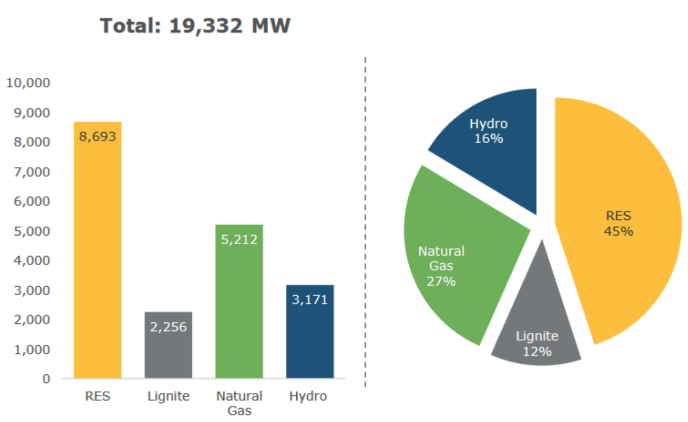


Figure 9. Installed electricity capacity per fuel

As seen in Figure 10, over the past two years, wind capacity demonstrated a substantial augmentation, increasing by 24% in 2021 to reach 4,338 MW. In 2020 and 2019, wind capacity stood at 3,810 MW and 3,283 MW, respectively. Solar capacity added nearly 849 MW to the Greek RES capacity, while hydro, biomass, and combined heat and power (CHP) stations maintained a steady capacity. Solar energy demonstrated significant momentum, with its capacity increasing by 23.7% in 2021, while wind capacity experienced a comparatively lower growth rate of 12.2%. The overall RES capacity in Greece continues to follow a significant upward trend as more and more RES projects are constructed. Since 2020, the RES capacity has increased by over 2.2 GW, highlighting the ongoing efforts to expand renewable energy infrastructure and accelerate the transition towards a greener and more sustainable energy system.

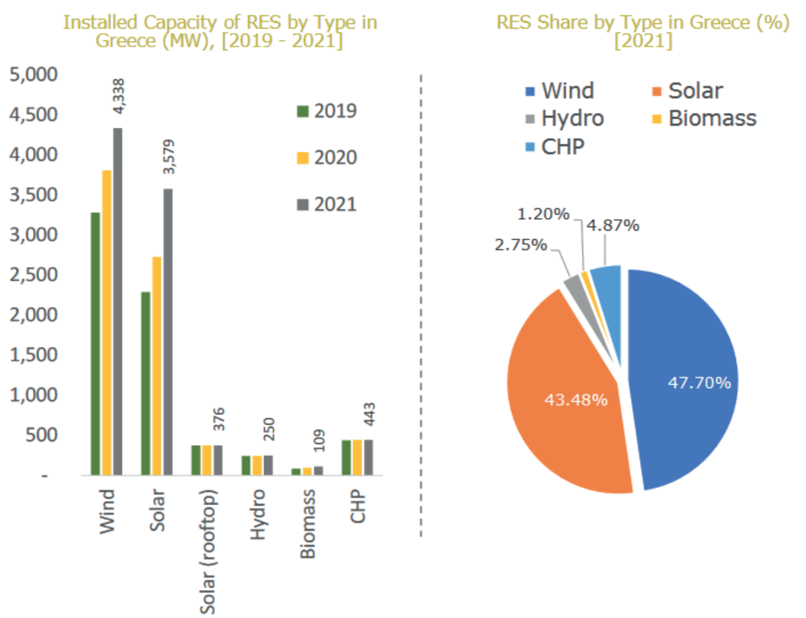


Figure 10. Installed capacity of RES by type (MW)

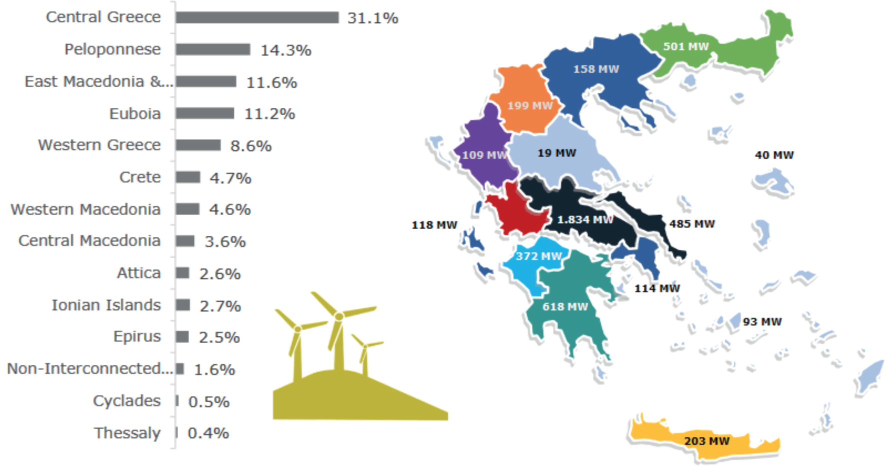


Figure 11. Installed wind capacity by region

Wind energy remains the dominant form of RES in Greece, with over 30% of its capacity concentrated in Central Greece, reaching an impressive 1.5 GW. In 2021, additional wind projects were successfully developed, leading to an increase in the installed wind capacity to 4.4 GW, surpassing the target set for 2022 of 4.2 GW. The interconnection of Crete with the mainland resulted in the integration of an additional 203 MW of wind capacity, representing 4.7% of the total installed capacity in Greece. Central Greece accounts for 31.1% of the wind capacity, while a significant amount is also installed in the Peloponnese, contributing to 14.3% of the total. When considering the wind projects in Central Greece, the Peloponnese, and Euboea, they collectively cover nearly 60% of the total installed wind capacity in Greece.

1.4. Energy transition

Greece is actively working to increase the share of its energy that comes from renewable sources. It has a goal of reducing total greenhouse gas emissions by 55% by 2030 and reaching net-zero emissions by 2050. To help achieve these targets, it is planning to end lignite-fired power generation by 2028 and has been making significant progress in increasing the proportion of energy it derives from renewable sources, which accounted for 20% of its total final energy consumption in 2021.

Greece is also undertaking several major electricity interconnector projects that are either in progress or in the planning stages, which will help to facilitate the integration of renewable energy. These projects include the Cyclades interconnection, the Adriane Interconnector that will link Crete with the mainland, the proposed Euro Asia Interconnector which would connect the grids of Greece, Cyprus, and Israel, and two interconnector projects that would link excess renewable energy from Egypt to Greece2.

In recent years, renewable energy sources (RES) and natural gas have been replacing lignite in Greece's electricity generation mix at a higher rate. For the first time in Greece's history, annual CO2 emissions from lignite power plants were lower than those from natural gas plants. The carbon intensity of Greece's electricity sector is decreasing significantly due to the increased use of renewables and reduced reliance on fossil fuels. The electromobility market in Greece is growing rapidly and is supported by subsidies and policies, surpassing previous estimations.

The Greek government has set ambitious targets in the latest National Plan for Energy and Climate (NPEC). The strategic targets associated with the development of the power sector are:

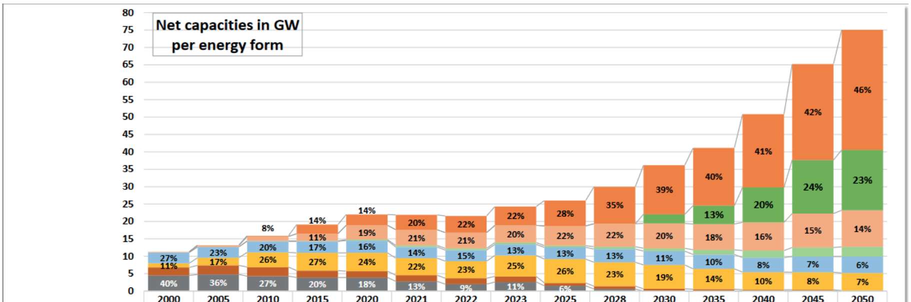
1. Rapid growth of Renewable Energy Sources (RES): Accelerating PV and wind development, including offshore wind, to add over 12GW by 2030. Additionally, tapping into the country's untapped hydro potential.
2. Energy storage: In tandem with high RES penetration, prioritize the development of storage technologies such as batteries and pumped storage to ensure system balance and stability.
3. Energy efficiency: Enhancing energy efficiency in buildings through insulation improvements, appliance upgrades, and heat pump installations. Encourage smart energy management practices and promote behaviour changes that reduce energy consumption and demand, thereby creating significant added value.
4. Electrification of light transport: Electrify light and medium vehicles while concurrently establishing robust charging infrastructure and grid integration capabilities. Emphasize investments in vehicles and

batteries, while also establishing a regional role in the Balkans by creating a battery recycling economy.

5. Establishing a green hydrogen economy: Utilize green hydrogen in various sectors, including transportation (heavy vehicles, shipping, aviation), industry, and power generation. Leverage existing mobility advancements and combine them with competitive RES to maximize the country's value.
6. Development of synthetic, green fuels (RFNBO): Foster the emergence of a new industry focused on synthetic, green fuels for transportation purposes (heavy vehicles, shipping, aviation). Prioritize the immediate establishment of this sector.
7. Innovation and systemic solutions for carbon capture and storage (CCUS): Address the energy transition of the country's industrial sectors (mainly cement, refining, fertilizers) through innovation and systemic approaches to carbon capture and storage. Develop a national plan and coordination strategy, considering the limited scale of local companies. Collaborate with European and American states that are coordinating similar projects.

1.5. Renewable energy sources

Figure 12 provides an overview of the NPEC (National Power and Energy Council) targets for Renewable Energy Sources (RES) until 2050, outlining key milestones and projections. A significant objective is the complete elimination of lignite from the energy mix. Offshore wind power is set to experience substantial growth, with a target of 2.7 GW by 2030 and an ambitious 17.3 GW by 2050. In the RES landscape, PV solar is projected to dominate, aiming for a capacity of 14.1 GW by 2030 and an impressive 34.5 GW by 2050. While onshore wind currently holds the largest share of RES in 2023, it is expected to maintain around 20% by 2030 and decrease to 14% by 2050, despite capacity increases to 7.1 GW and 10.5 GW in 2030 and 2050, respectively. Furthermore, a gradual reduction of natural gas power is envisaged, with a target of reaching only 7% of the energy mix by 2050. These targets reflect a comprehensive plan to transform the energy sector, prioritize cleaner and more sustainable sources, and steer towards a greener future.



	2000	2005	2010	2015	2020	2021	2022	2023	2025	2028	2030	2035	2040	2045	2050
Solar	0.0	0.0	0.2	2.6	3.1	4.3	4.8	5.4	7.3	10.6	14.1	16.5	21.0	27.5	34.5
Wind offshore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	5.3	10.0	15.4	17.3
Wind onshore	0.2	0.5	1.3	2.1	4.1	4.5	4.6	4.9	5.6	6.6	7.1	7.4	8.1	9.8	10.5
Other RES	0.0	0.0	0.1	0.1	0.3	0.5	0.5	0.5	0.5	0.7	0.8	1.4	2.0	2.6	2.8
Hydro	3.1	3.1	3.2	3.3	3.5	3.2	3.2	3.2	3.4	3.8	4.0	4.1	4.2	4.5	4.7
Gas fired	1.2	2.2	4.2	5.1	5.3	4.9	4.9	6.0	6.9	6.9	6.9	5.8	5.1	5.1	5.1
Oil fired	2.3	2.6	2.6	2.0	1.8	1.8	1.7	1.6	0.8	0.8	0.7	0.6	0.4	0.4	0.2
Solids fired	4.5	4.8	4.3	3.9	3.9	2.8	2.0	2.6	1.5	0.6	0.0	0.0	0.0	0.0	0.0
Total Net-Capacity (GW)	11.3	13.2	15.9	19.1	22.0	21.9	21.6	24.3	26.0	30.0	36.1	41.1	50.8	65.2	75.0

Figure 12. RES targets (GW) set in national plan for energy and climate

1.6. Energy storage

June 2023 marked the first tender for subsidized energy storage projects of 400 MW; a second will follow later in the year. These initiatives will not only secure investment but also receive annual operational support for their first decade of operation. These tenders form part of Greece's EU-approved support package for 900 MW storage projects, which boasts a budget of 341 million euros.

Growing interest in the electricity market is pivoting towards storage solutions, primarily due to these tenders. This trend mirrors past enthusiasm for wind farms and, more recently, photovoltaic projects. Investor interest has far surpassed the objectives outlined in the updated NPEC. By early April, the Regulatory Authority for Energy (RAE) greenlit licenses for energy storage systems boasting a total capacity of 26.64 GW. This approval is significant, given that the NPEC revised target anticipates a capacity of 8.1 GW by 2030, comprising 5.6 GW from batteries and 2.5 GW from pumped storage projects.

Projects with a total capacity of 5.3 GW have already submitted connection requests to the Independent Power Transmission Operator (IPTO), positioning themselves as frontrunners in the race for investment and operational support. The NPEC objectives equate to investments worth 5 billion euros, a figure that pales in comparison to the value of the licensed investments, which are estimated to exceed 16 billion euros.

1.7. Electromobility

The electromobility market in Greece is experiencing rapid growth, surpassing the estimations of the NECP. The penetration of electric vehicles in Greece has exceeded expectations, with BEV and PHEV new registrations reaching 7,067 in 2021, representing 6% of total registrations. This far exceeds the NECP target of 2.8%. In 2020, there were 2,398 new electric vehicle registrations, surpassing the NECP target of 1,265 for that year.

The number of charging infrastructures, both publicly accessible and private, has seen a significant increase. In 2021, there were 1,344 charging points, marking a sixfold increase compared to 2020. Public charging is expected to be the largest market segment until 2030, as it is the leading factor driving energy demand in the electromobility sector in Greece. This growth is supported by various subsidies and policies aimed at promoting electric vehicle adoption in the country.

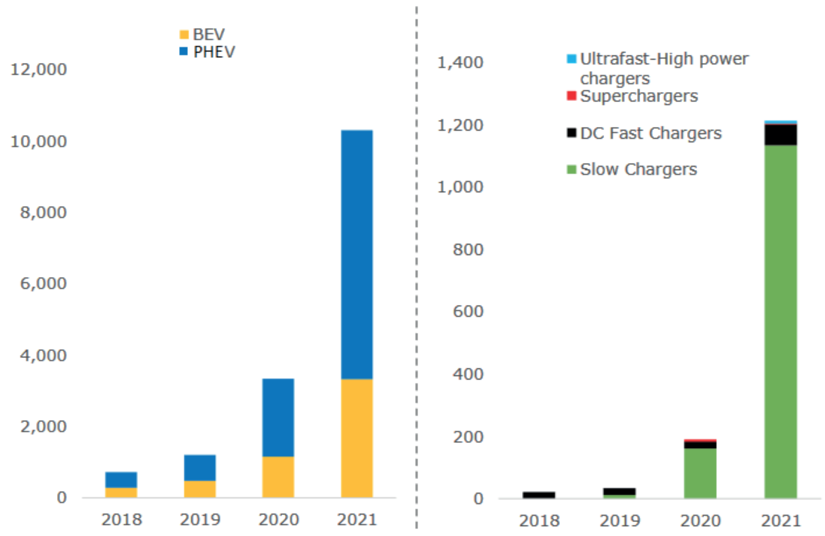


Figure 13. Number of new EV passenger cars and publicly accessible chargers

1.8. Energy efficiency

Energy efficiency serves as a crucial foundation for Greece's shift towards sustainable energy. Its impact is significant, as it aids in minimizing final energy consumption, curbing energy demand, and reducing reliance on traditional power sources. Enacting innovative fiscal strategies and initiatives, such as the newly introduced "Exoikonomo" program, provides a potent solution to combat energy poverty. The recent efficiency program benefits a total of 50,000 participant households, marking a 38% increase over its predecessor. The entire program, involving various interventions, is projected to cost roughly 630 million Euros. However, the benefits are notable, with expected energy savings circling around 2 TWh.

Between 2030 and 2050, there are ambitious targets set for the reduction of final energy consumption in the residential sector. These targets aim to substantially decrease the final energy consumption by buildings compared to 2015 levels. By 2030, the aim is an 8% reduction in consumption. This goal hinges on the significant reduction of diesel use, a reduction in the use of conventional biomass, NG burners comprising 47% of the total energy share, and aerothermal heat pumps representing 11% of the total.

Progressing into the next decade, by 2040, the goal amplifies to a 20-28% reduction in energy consumption. This target aspires to completely eliminate the use of diesel. Also, it includes growing the share of aerothermal heat pumps by 12%-21% and decreasing NG and synthetic gas burners to 20% of the total energy use. Furthermore, an increasing reliance on solar thermal energy for domestic hot water is projected, reaching between 83%-86%.

Finally, by 2050, the reduction target ranges from 28% to 40%. The strategy includes a further expansion in the usage of aerothermal heat pumps, making up between 12%-50% of the total energy share, and solar thermal for domestic hot water, representing between 83%-92%. Additionally, it comprises the reduction of NG and synthetic gas burners to between 14%-64% of total energy use. Remarkably, the objective includes reaching zero use of electric water heaters, marking a significant shift in energy consumption patterns in the residential sector.

1.9. Hydrogen

Greece is setting the stage for a "green" hydrogen economy, as highlighted in the revised NPEC. The ambitious objectives include achieving 1.2 GW of electrolysis capacity to produce 205,000 tons of green hydrogen by 2030. This capacity is projected to double by 2035, reaching 2.4 GW, and rise exponentially to 14.7 GW by 2050, when it will generate 2.3 Mt of hydrogen.

With the National Strategy for Hydrogen estimating that the hydrogen supply chain turnover will amount to 10 billion euros per year by 2050, measures have been put in place to support this nascent sector. To overcome the high investment cost due to the immaturity of the technology, the government plans to introduce fast-track licensing procedures for hydrogen production projects and provide state aid until 2030.

Initial deployment will focus on refineries, powering maritime and aviation transport. Urban transportation modernization is another key component, with a substantial increase in hydrogen buses, intercity buses, and urban delivery vehicles planned. The strategy also includes upgrading heavy-duty waste collection vehicles, passenger cars, trains, and passenger-ferry ships to hydrogen power. Finally, the plans include the application of hydrogen into hard-to-abate industries such as cement and steel production.

Greece's efforts in this sector have been recognized at the European level, as evidenced by the European Commission's approval of two Greek projects worth €5.4 billion in total. The country has also secured aid of up to 800 million euros, a testament to the strategic role it is poised to play in the energy sector and its active involvement in the hydrogen industry.

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Archil Kokhtashvili, Giorgi Amuzashvili, Giorgi Arziani, Teona Elizarashvili

1. Georgia Electricity Outlook

1.1. Introduction

This paper is expressing the Georgia (GE) power system potential, the current situation, the fleet of generation, transmission system. It reflects the challenges of power system, such are operational challenges, generation adequacy and generation expansion challenges, challenges of frequency control and flexibility, dependence on hydrology, situation of operation with the neighboring power system. The paper also tells regarding the existing and ongoing important projects which responds to the existing challenges of GE power system. Paper consists of 4 sections. Section 1 is about how the GE system developed after the independence of the country. Section 2 expresses the challenges, Section 3 is about the projects to overcome these challenges and Section 4 summary of the paper.

Hoping that the readers, after the discussion of below paper, will become more familiar to the GE power system and will like the information.

1.2. GE power system energy potential

Georgia is rich in natural renewable energy resources. It's estimated the economic potential of hydro is about 50 TWh, the wind about 4.0 GW and 14 TWh, solar about 4.5 GW 8 TWh.

The utilization level of this potential is quite low. For hydro, it's about 20%, regarding wind and solar less than 1% for each one.

In case of utilization of this RE economical potential, Georgian energy system (including power system, transport, residential) could move to fully green electrified system. However, some steps to accelerate renewable integration is needed and there are some strong motions to drive this process.

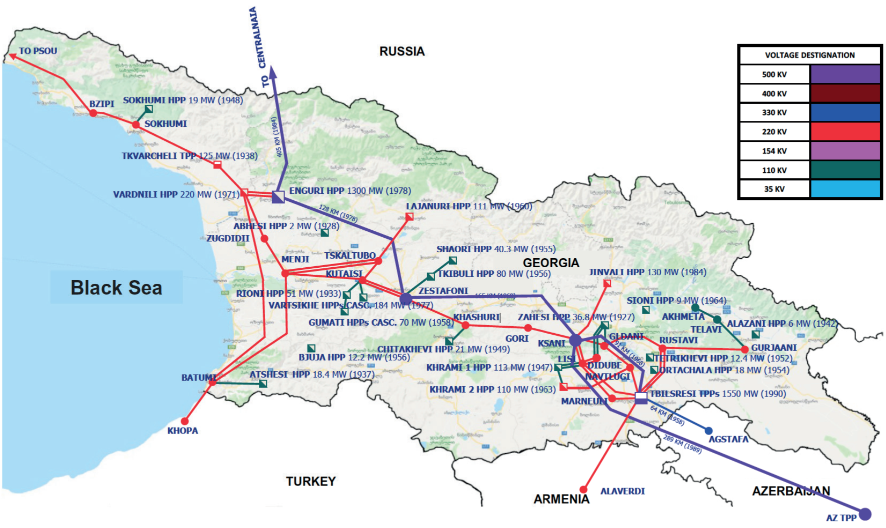


Figure 1. Georgian transmission system for 1990

1.3. The power system of Georgia, after the independence and before 2003

The heavy legacy of Soviet Georgia

The electricity transmission system of Georgia was planned for the stable operation with the giant united system of USSR and Eastern Europe. Sizes of big units and power stations were fitted for this system as well.

Enguri cascade – 1500 MW - the biggest Hydro Power Plant (HPP) is situated in Western Georgia and was designed not for resident power system but for the peak sheaving of South Russia. For supply of Tbilisi-Rustavi consumption centers 2000 MW Thermal Power Plant (TPP) was built. Georgia doesn't own enough sources of oil and gas, however for the operation of this TPP gas and oil was imported from Russia and Azerbaijan, almost without price, as all these countries treated as one state.

Soon, after the recovery of independence of Georgia in 1991, civil war began and the electricity system had to withstand for hard times. Many equipment's, including conductors of the transmission lines had been stolen. Because of absence of fuel, TPPs were unable to operate, HPPs had to cover the full electricity consumption of the country. Industrial consumption decreased but civil consumption increased. Beside the scheduled power supply restrictions, around 4-6 hour/day, real time electricity supply was not enough and recently our system was operating at 45 Hz frequency. It in turn caused additional damages of electrical equipment. Most disappointing was that the building of Khudoni HPP with 700 MW installed capacity (the biggest storage HPP after Enguri) was stopped and even nowadays this HPP is not built. Because of difficult operational situation, the 300 MW TPP units N9 and N10 at Garabani where hardly damaged. N10 TPP unit is still is not able to operate.

The situation, in electricity supply, gradually improved after 2003, it was caused mainly by improvement of metering, tax deductions and overall criminogenic satiation in the country.

1.4. Transmission network reinforcement from 2003 up to now

500 kV Overhead Lines (OHL) Zestafoni-Akhaltsikhe "Zekari" and Akhaltsikhe-Gardabani "Vardzia" commissioned, which closed 500 kV ring from Zestafoni around Tbilisi and increased the stability of power system. 500/400 kV HVDC at Akhaltsikhe and 400 kV OHL Akhaltsikhe-Borshkha (Meskheti) commissioned. These elements make possible 700 MW power exchange between the power systems of Caucasus and Türkiye. The stollen 2-Circuit 220 kV OHL Tskaltubo-Menji "Senaki 1,2" had been restored.

This element increased the reliability of 220 kV western grid. All 220/110 kV substations had been refurbished. 500 kV substation Marneuli commissioned. Existing OHL "Asureti" connected in this substation from substation Ksani. So new "smaller" 500 kV ring closed around Tbilisi. In substation Marneuli existing OHL Akhaltsikhe-Gardabani looped as well and new sections Akhaltsikhe-Marneuli "Vardzia" and "Marneuli-Gardabani" Gachiani had been established. Substation Marneuli solves to tasks: 1 - reserves existing 500/220 autotransformers of Garabani and Marneuli, 2 – prepares support for north south connection Russia – Georgia – Armenia -Iran.

500/220 kV substation Jvari commissioned, for the back-up of 500/220 kV substation of Enguri and 220 kV western grid. 220/110 kV substation Khorga and 2-Circuit 220 kV OHL Menji-Khorga commissioned, for the feeding of free industrial zone and future port Anaklia. 500/220 kV substation Jvari commissioned, for the back-up of 500/220 kV substation of Enguri and 220 kV western grid. New circuits built for Ajameti -2 circiut and Sataflia – 1 Circuit OHLs, bilt OHL Batumi 1,2 for the evacuation of Shuakhevi HPP energy. 220/110 kV substation built near Tbilisi. 500 kV OHL Sno (Ksani-Stepantsminda) commissioned, from central part of Georgia to the border of Russia. New 500 kV OHL Gardabani – Samukh had been built and existing 330 kV OHL Gardabani-Agstapha had been upgraded to 2-Circuits.

Figure 2. Georgian transmission system 2003-2023

Bottlenecks of transmission network of Georgia are:

- Non reserved cross-border lines (with Russia (RU), Armenia (AM), Türkiye (TR))
- Radial/inadequately backed-up Network of West Georgia (Enguri-Zestafoni-Akhaltsike)
- 220 kV grid of Shida Kartli, backed-up inadequately
- Dead end transmission lines
- Generation of which shutdown time not completed G-1 criterion

1.5. Generation expansion from 2003 up to 2023

From 2003 up to now, several new HPPs had been commissioned with total capacity 725 MWs. From which the biggest ones are: Shuakhevi HPP – 175 MW (2017); Dariali HPP -108 MW (2016); Paravani HPP – 86 MW (2014); Kirnati and Khelvachauri HPPs – 100 MW (2017, 2018); Mestiatshala 1,2 HPPs – 50 MW (2019); Mtkvari HPP – 50 MW (2020). Beside HPPs, three TPPs were built with total capacity 610 MW, in order to satisfy winter demand, when HPP generation is low, because of dry period: GPower GT - 110 MW; Gardabani 1 CCGT – 250 MW (2015); Gardabani 2 CCGT – 250 MW (2020). In addition, 21 MW of Wind Farm had been commissioned in 2016. It is the first wind farm in the Caucasus region.

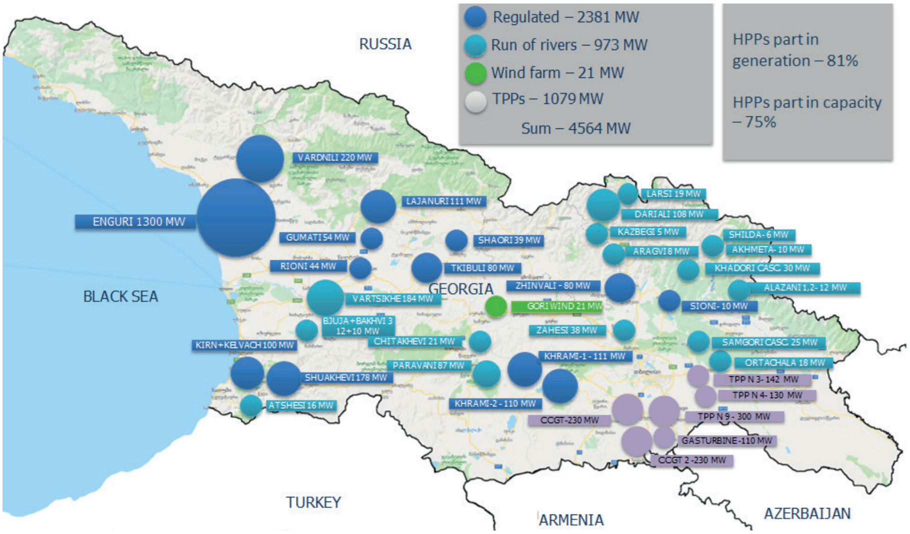


Figure 3. Existing power plants of Georgia

B3) Grid losses

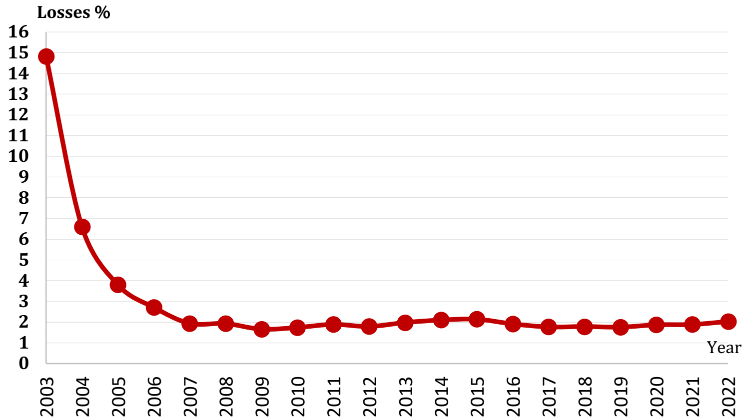


Figure 4. Statistics of the losses

Figure 4-1 shows the statistics annual electricity losses in percentage. It seems that for 2003 annual energy losses was up to 15%. Then in coming years, it gradually decreased mainly because of metering system improvement and refurbishment of transmission equipment. from 2012 to 2022, beside the 4.5% average annual electricity consumption gross, the energy losses remain close to 2%. It's because the transmission grid expansion very well follows the electricity demand growth.

1.6. Operational challenges.

In case of outage of each of above mentioned non reserved cross-border lines when the power flow on them is more than 100 MW, because of low inertia of GE power system, will cause frequency deviation and load/generation tripping with underfrequency/overfrequency relays. The same situation is when there is an outage of >100 MW units. In order to avoid the risks regarding the big frequency excursion from the nominal value, the RAS system almost immediately balances the power system by the tripping same amount but opposite of disturbance. In case of outage of Enguri – Zestafoni 500 kV OHL or Zestafoni-Akhaltsikhe 500 kV OHL, when the lines are loaded with more than 500 MW, as this line are not sufficiently reserved with the rest part of the grid, the RAS system trips a portion of load in Eastern Georgia, including Tbilisi area and a portion of Generation in Wester Georgia including Enguri units, in order to maintain the unity of power system.

Based on above mentioned, in GE power system there are contingencies, when the N-1 condition is not maintained naturally with the redundancy of network elements. The number of such contingencies might increase when some of 500 OHLs are in maintenance. If not the RAS, in GE system, the best operational mode would be corresponded to the Alarm Mode. However, by the RAS actions, the Normal Mode of operation is artificially maintained, by the temporarily restrictions of load and generations.

Several projects are considered in 10-year network development plan of Georgia which will resolve above mentioned problems, integrate new HPPs into the grid and reinforce transitability of Georgian system, N-1 criteria will be maintained naturally, without the RAS interaction.

1.7. Generation adequacy challenges

Currently, Georgian power system has installed capacity of 4'700 MW and an annual output of 14'800 GWh. Electricity consumption in Georgia is seasonal: the maximum consumption is in winter, indicating that during this period electricity is mainly used for domestic purposes. Demand is being filled by electricity generated by hydropower plants, thermal power plants and as well by imported electricity. However, the ratio of electricity generated by hydropower plants and thermal power plants is 80/20. Accordingly, water is the main source of electricity generation in Georgia. However, in the rivers, the water flow is also seasonal: in summer they have abundant water, and in winter the water level drops down significantly. That is why there is an electricity shortage. As the maximum utilization of existing abundant hydro resources is one of Georgia's priority areas, alternative energy sources (wind and solar) are also being worked on. The long-term policy objective of the energy sector is to attract investment for building the new power plants. Part of this policy is to fully meet the country's demand for its own resources step by step: first by replacing imports and then by replacing the thermal power plant.

For the last decade the consumption is increasing in average 4.5% annually, when the increasing of hydro generation is 2.3% annually. The increasing of hydro generation deficit is covered with the increased electricity import or increased generation of thermal power plants. As GE does not have significant fuel sources, the thermal generation is import as well.

Despite big HPP and wind projects in the pipeline, their development decelerated because (1) of NGO resistance and (2) cancelation of PPA support schemes. After the end of 2022, the CfD support scheme for renewable energy sources had been established, hoping to accelerate the renewable projects.

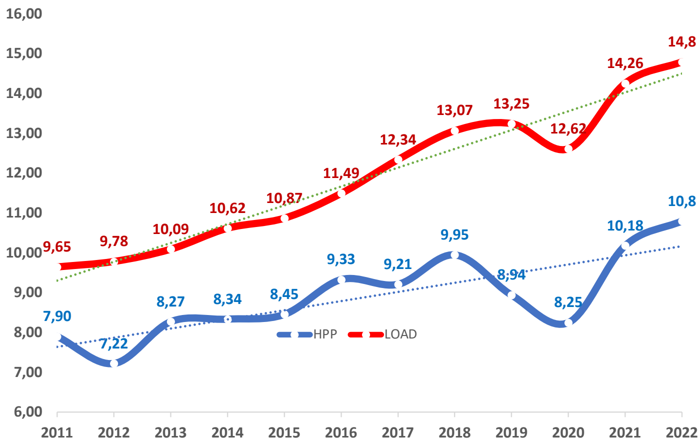


Figure 5. Annual generation and consumption (TWh)

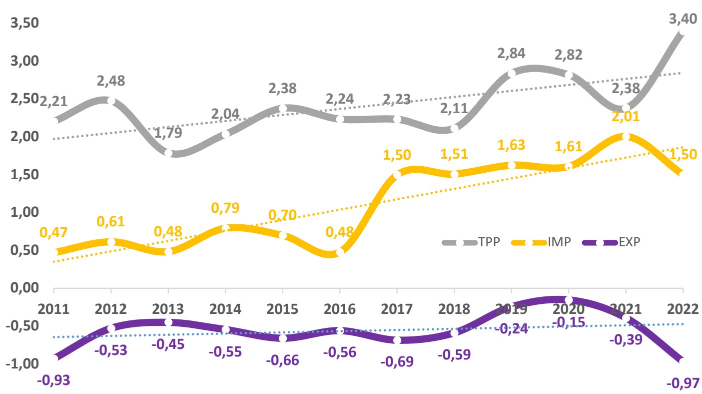


Figure 6. Export, Import and TPP generation (TWh)

1.8. Frequency control reserve deficit and flexibility challenges

As mentioned, the big units have 250 MW capacity and in some times GE system imports 350 MW by unreserved line, when in minimum consumption modes the system load is close to 1000-1200 MW, it means that in case of tripping of importing line or tripping of big generator in island mode, the GE power system may lose about 25% of its generation. Therefore the significant lack of inertia takes place.

The speed governors at many generating units are not in appropriate technical conditions or out of service. Because of this, even in conditions where load is variation is in +-50 MW range, the frequency variation in isolate mode is +-0.8 Hz range and can lead to the activation of frequency load shedding or generation shedding.

Another issue is that in some years the reservoir of the biggest HPP of Georgia, Enguri, works in intensive discharging mode. It has maximum generation in June-August and in November-March period, the reservoir is close to minimum critical level. In such period Enguri HPP acts like run-of-river hydro power plant and is unable to give more than 50 MW reserve. Other reservoir HPPs try to cover the daily load profile, they are also unable to give reserves. Regarding the TPPs in such period in daily peaks they operate close to their installed capacity, when in night periods they operate close to their technical minimums, as old steam turbines are too inflexible and can operate only close to their rated capacities.

Based on above mentioned, GE power system faces the lack of inertia, lack of primary control reserve and lack of secondary and tertiary control reserves together with the system flexibility. It causes risks to the system security of supply and makes limits to the integration of variable renewable sources (Wind and Solar).

For nowadays, in case of loss the synchronous parallel operation with neighboring system, the loss of >100 MW import/export, or loss of >100 MW generation/consumption in the island mode, the frequency deviates more than 0.8-1.0 Hz. In order to maintain the power system unity and stability and also the frequency in the normal ranges, the two levels of Remedy Action System work: (1) Automatics of SEL (US) production which trips almost immediately the same amount of power consumption in case of generation/import lost or vice versa same amount of generation in case of load/export lost. This automatic system does not allow the frequency vary in big range. (2) Underfrequency/Overfrequency load/generation shedding relays acts as the last line of defense, in case of SEL's RAS system will not work.

As for elimination small inertia challenge, in the other words to be able to overcome the loss of biggest 250 MW generation units, without frequency deviation more than 0.8-1.0 Hz, GE system needs to have approximately 8000 MW installed capacity, with perfectly operating of the speed governors of generators. It can happen only in optimist development scenario after 10 years from today. It's not reasonable to wait for the power system expansion, some faster actions are needed. And this action is installation of grid scale Battery Energy Storage System (BESS).

For the overcoming of these challenges and for the increasing of Variable Renewable Energy (VRE) integration limits, with financial support of Asian Development Bank (ADB), the grid scale BESS project is ongoing. The study should be finished at the end of this year and in case of timely confirmation with the ministries and regulatory commission, the project should start the operation by the year 2027.

1.9. Challenges of occupied region and crypto consumption

Occupied Region Abkhazia. Despite the occupation the electrical grid of Abkhazia remains the unseparated part of united GE power system. The governmental controlled part of GE and the occupied region Abkhazia shares the biggest reservoir HPP of the Caucasus region Enguri 1300 MW and Vardnili cascade 220 MW. The reservoir is under the governmental controlled part and the machinery at the occupied part.

Rest part of GE and Abkhazia region shares the Enguri-Vardnili generation. The electricity consumption of Abkhazia region is increasing, due to low rate of payment for the electricity price and low rate of accounting (metering).

Not only the heating consumption is uncontrollable increases but also increases the number of the cryptocurrency factories (miners). In order not to allow to consume too much energy by Abkhazia region, GE is implementing the intensive discharging of Enguri and Vardnili HPPs, what means the maximum generation during low consumption of Abkhazia (Spring-Summer). This causes also that there is a very low level at Enguri reservoir from November to March and it acts like RoR. In this period GE power system is out of power reserves.

Crypto Miners as a source of load forecast uncertainty. Because of relatively low electricity price there is a significant share of cryptocurrency miners in total electricity consumption of GE. As the price of the cryptocurrency is nearly impossible to forecast, the load forecast of GE is quite challenging. Because of this, the total consumption of Georgia depends more to cryptocurrency price, rather than GDP, population or tourm.

1.10. Hydrology

As mentioned above, about 80% of electricity consumption is covered by the generation of HPPs, however it has quite low correlation with consumption, as the biggest water inflow for HPPs there are in May and June months where there is a comfortable temperature, not cooling and heating devices are in service and therefore the electricity consumption is minimal. The opposite situation is in winter when because of low temperatures the heating equipment are loaded fully but the water inflow and respectively HPP generation is minimal. Because of HPP generation surplus, GE power system implements the electricity exports in Summer – Spring seasons and imports in Autumn – Winter seasons.

In case of increasing of HPP capacities in energy mix, the same situation will remain. Hence, for the seasonal balancing of GE power system, production of green hydrogen could be solution. When the green hydrogen could be produced in Spring-Summer seasons and consumed in Autumn-Winter season.

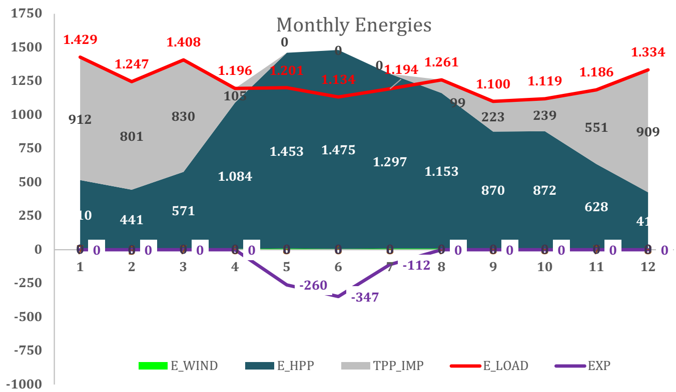


Figure 7. Monthly energy balances (GWh)

KfW supported project regarding the green hydrogen strategy is ongoing. Due to the big share of HPPs in the energy mix, it makes "green" the Georgian electricity generation, but it makes too depended on the hydrology regimes. For instance, with nearly same capacity of the HPPs, the hydro generation was 8.25 TWh in 2020 and 10.20 TWh in 2021. Year by year the hydrogeneration may have about 25% variation.

The hydrogeneration forecast itself is quite challenging. For short – term planning, Georgian State Electrosystem (GSE) uses receives the data from National Environmental Agency (NEA) but at the same time uses an inhouse software, considering the weather forecasts for the forecasting of water inflows. GSE together with NEA participates in several projects for the forecast improving, including the installation of measurement masts in rivers.

1.11. Neighboring systems with different synchronous zones and markets

Different Synchronous Zones. TR operates in the synchronous zone of the Continental Europe and with Türkiye GE has HVDC B2B and 400 kV interconnection line. GE system can operate only with one rest neighbors. AZ and RU operate in the IPS/UPS synchronous zone and GE system works directly with RU power system by 500 kV interconnection line or through AZ. GE, AZ and RU cannot operate with all interconnections ON, because of some operational, loop flow and market issues. In rare situations, GE can operate with AM system by weak 220 kV OHL and AM operates synchronously with IR power system. Therefore, when GE operates with UPS/IPS synchronous zone, it can't be synchronized with AM/IR synchronous zone. (as it's known from the stability course, the large power systems, such are RU and IR, can't be synchronized with the weak interconnections or systems such are GE and AM). Based on mentioned, GE power system is able to be connected synchronously only with one neighboring system can't have benefits from well interconnected operation.

All the neighboring power systems have their particular energy markets, and GE system is not a part of each of them. Hence, it's impossible to have a short-term balancing from these markets or provision of some services to these markets. As there is not possibility to give some flexibility services from the neighboring systems, GE power system should increase it's reserve provision capabilities.

All of the neighbors have different planning and operational philosophy. GE have a separate agreement with neighbors regarding the data exchange and regarding the emergency support.

GE tries to increase the cooperation with all the neighbors, reinforce the grids and also, for the joining of ENTSO-e internal energy market GE-RO HVDC interconnection Black Sea Submarine Cable project feasibility study is ongoing. This project is reflected in TYNDP of ENTSO-e.

Figure 8. Synchronous zones around GE

For the long-term perspective, GE is interested to switch from IPS/UPS synchronous zone to the CE one and to join the Internal European Market of electricity.

1.12. Challenges for the building of generation and transmission infrastructure

The challenges regarding the building of important generation and transmission elements began after the independence. Most disappointing was that the building of Khudoni HPP with 700 MW installed capacity (the biggest storage HPP after Enguri) was stopped in 1992, because of The "green movement" actions. Even nowadays this HPP is not built.

This HPP should be a part of Enguri cascade and not only could to add to the system flexible capacity and significant electricity generation but also was able to increase the generation of Enguri and Vardnili HPPs. After this several years was unsuccessful tries to build a big reservoir HPP. By 2019 because of resistance of locals, 60 MW storage HPP project Kheledula had been stopped. In 2019, the construction of 280 MW reservoir Nenskra HPP had been stopped due to the resistance of locals and so called "green NGO"s. Also about 200 MW RoR hydro projects were stopped because of same resistance by 2020.

By 2021 started the construction of 433 MW Namakhvani reservoir HPP project , but the people calling themselves the defenders of local gourde, raised the local people and also some people living in close cities and spread disinformation that the arch dam can be broke and the released water wave can flood one of the biggest cities of GE Kutaisi. Finally, the construction of Namakhvani HPP had been stopped.

The interesting is that so called green NGOs striking against the HPP claiming that the reservoirs are changing the climate however they say nothing against building of the Thermal Power Plants even against coal power plants.

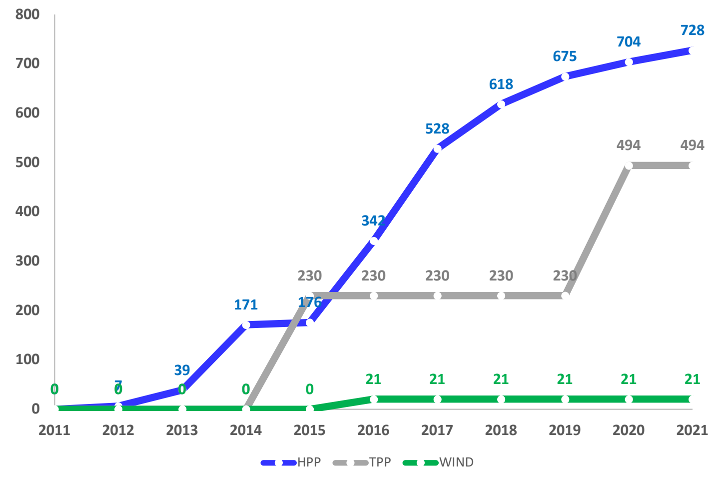


Figure 9. New capacities of generation types

As the result, the electricity import ant TPP generation (GE does not have significant fuel sources, so the gas burned in TPPs are imported one) increases, due the rapid increasing of consumption and slow expansion of internal renewable generation.

There were some challenges regarding the building of system importance transmission lines. As some people managed to register the lands on the path of the projected OHLs and required much compensation from the Transmission System Operator (TSO). In case of expropriation, TSO had dispute in such case for the several years because of several hundred matters.

In total, so called green NGOs "managed" to stop around 1700 MW of HPP projects. Also, some "land owners" managed to delay the critical importance transmission infrastructure for several years.

In order to make the diversification of electricity imports supply GSE is building and reinforcing the cross-border transmission infrastructure.

Somehow to meet increased regulating reserve needs of the GE system, the BESS project is ongoing, also there was introduced special amendments in legislation in order to avoid the delays of transmission projects due the inadequate requirements of land owners.

The government, in order to accelerate the renewable energy development, introduced the CfD support mechanism at the end of 2023, which should help the generation developers to implement the projects somehow with guaranteed tariffs.

As from side of TSO, GSE creates hub substations for the collection of electricity generation from the RE sources, also builds transmission lines connecting to the back-bone of transmission system.

The State involvement in big reservoir HPP projects is considered as well, because they have the strategic importance for the energy sector of GE.

1.13. Remedy action scheme (Emergency controls system)

The modern power systems are automated and their operation without automatic control devices is impossible. From these, one of the most important are devices building Emergency Control System.

For improving operating stability of the national power system and enhancing power exchange with neighboring countries, Emergency Control System (ECS) has been installed. The ECS aims at ensuring reliable and uninterrupted power supply to the customers, and localization of contingencies to avoid their propagation and growth into the system wide emergency. In addition, ECS targets maximum use of the national energy resources and power re-export potential, provided that under single N-1 regime full collapse of the regional network should be avoided.

The ECS devices maintain static, dynamic and resultant stability of the power system. They respond in both cases, when the network is operating in steady mode, or when one of the transmission lines is under maintenance outage.

Under the single contingency (N-1), in case of active power excess in the system, ECS will initiate rapid automatic reduction of the active power generation in Enguri HPP, while in case of active power shortage, will shed the load (in the country) and, if needed, the export (re-export) by remote control commands sent via fiber optic communication

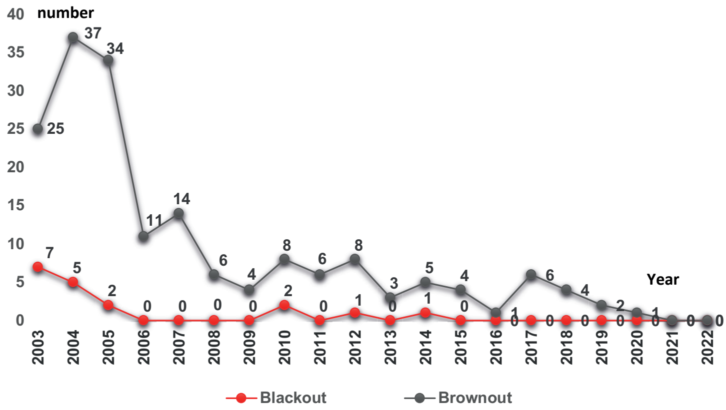


Figure 10. Number of significant emergencies

The first phase of ESC system was installed in 2011. It seems that in following years the number of blackouts and brownouts gradually decreased.

1.14. Projects for increasing of power system stability, flexibility and VRE integration

BESS project, with the financial support of ADB, the consortium of the consultant companies Mercados Aires International, Integration and PMCG, BESS development program started. The main tasks of the project are to identify the size and localization of battery, to build the capacity of Georgian energy sector entities, to specify the standards and technical specifications, to propose recommendations of legislation and policy amendments to take into account the BESS technology which is new for GE.

The purposes of the BESS project are:

- To eliminate the low inertia problem and fast FCR deficit with very fast ramp response
- To reduce the unserved energy
- To increase the VRE integration limits
- To reduce the curtailed energy

- To eliminate the aFRR and mFRR reserve deficit and to increase the system flexibility
- To provide the black start service to supply the critical importance consumers around GE capital (act like UPS for Tbilisi area)
- To provide the voltage control service around Tbilisi area
- To increase the power system dependence on other systems
- To make the peak sheaving and energy arbitrage

Figure 11. BESS for Georgia

The preliminary location is substation Ksani, which is located in the central part of GE electricity grid. It will allow to easily exchange the energy as with east as with west part of the electricity grid. The approximately sizes for the first phase of installation is 200-250 MW capacity, 1-4 hour duration.

The current energy sector can be assessed as a transitional sector. whose technical capabilities as well as the legal framework are being modernized. The point is that Georgia's energy system was planned as part of a larger unified energy system, so as not to jeopardize the sustainability of this large unified system. Energy legislation and standards were tailored to this system.

Figure 12. Existing and planned Georgian transmission system 2023-2033

Strengthening and developing technical capabilities is aimed at ensuring security of supply and energy independence. In particular, power plants are being built in this direction, including hydropower plants, wind and solar power plants, so that at any time it is possible to meet the country's electricity consumption with its own sources (this does not exclude the possibility of disconnecting a number of thermal power plants in a given period). In the same direction, the construction of transmission infrastructure is being carried out in order to ensure high reliability of electricity supply from generation sources (including imports) to consumption centers (including exports).

So Georgian power system development has following goals:

- To increase the security of supply and the flexibility
- To utilize the transit potential of the country, from east to west (AZ-GE-TR) and North to South (RU-GE-AM-IR)
- To integrate RES and consumption centers to the grid

1.15. Georgia-Romania Black Sea submarine cable interconnection project

One of the projects, which is currently being evaluated for inclusion in TYNDP of GE, is the electric and digital interconnection between Georgia and Romania (GE-RO Interconnection Project). This Interconnection Project, which the World Bank's preliminary economic analysis confirmed to be viable, would create significant economic benefits for Southern Caucasus (SC) countries and Romania. In particular, the electric cable would allow SC countries to benefit from expanded export opportunities to Romania and broader South-Eastern Europe (SEE) considering the hourly energy market prices and import electricity during winter time periods at competitive rates, thus reducing dependency on existing expensive imports and thermal generation.

The Interconnection Project would also contribute to integration of larger solar PV and wind capacity in Romania considering the new European Green Deal by allowing to provide competitively priced reserves for those intermittent sources of electricity. The Interconnection Project would also allow Armenia to export RE based electricity coming from hydro and increasingly solar PV considering ambitious ongoing program for scaling up solar PV. Azerbaijan would be able to offer gas-based thermal electricity, which would allow to displace coal-based generation in SEE therefore contributing to decarbonization of the power sector in SEE.

An optic fiber cable (OFC), which would be part of the Interconnection Project, would enable to increase broadband data traffic and help reduce the prices for Georgia and overall SC as well as generate revenues from transit traffic to Middle East, Central Asia, and South Asia. This would also contribute to further development of the IT industry considering progress made in some of the countries where IT industry has been expanding very rapidly during last ten years. Due to the unique scale of the Project, the OFC might be deployed as a part of a hybrid power-telecom cable or a parallel cable, depending on the technical and economic feasibility.

Romanian TSO as well as neighboring TSOs of Armenia and Azerbaijan have been duly informed about the developments of the given project and they will be in constant cooperation with GSE and the Consultant, as well as higher political and regulatory bodies in a specific working format headed by relevant Deputy Ministers in order to assist the Feasibility Study process.

Following consultations with GSE's counterpart of this project Transelectrica, GSE submitted the application of the Georgia-Romania Black Sea (submarine) interconnection cable project to the ENTSO-E 10-year Network Development Plan (TYNDP) projects platform on October 15, 2021 for the purpose of including the given project into ENTSO-E 10-year Network Development Plan of 2022. As a result, on the given stage the project application has been selected in the list of projects to be potentially included in the ENTSO-E TYNDP 2022 list.

Figure 13. GE-RO Black Sea submarine cable

Main preliminary parameters of GE-RO submarine cable

1. Structure:
   a) 500 kV double circuit OHL SS „Jvari" - SS „Anaklia" (other internal grid reinforcements are under study)
   b) 2X500MW or 3x500 MW converter station in „Anaklia"
   c) Submarine cable Anaklia - Constanta Sud ±500kV
   d) 2X500MW or 3x500 MW converter station in Romania (Constanta Sud)
2. Voltage level of cable: 500 kV
3. Capacity of cable: 1000-1500 MW

4. Length of the interconnector: 1195 km (OHL - 95 km in Georgia and Romania and submarine cable - 1100 km)
5. The submarine cable will also be equipped with fiber-optic cable, which will provide high quality internet connection between Romania and Georgia.
6. Estimated date of commencement of commercial operation of interconnector: year 2030+
7. Approximate cost of the Project: Euro 2.1 Bln

1.16. Distributed energy resources and microgrids development in Georgia

Georgia faces a significant challenge of partial electrification in its mountainous regions. The mountainous terrain characterized by harsh climate conditions hinders the electrification of these areas. Inherent natural risks such as avalanches, landslides and snowfall impede the necessary investment for rehabilitating the aging transmission infrastructure and constructing new power lines.

Partial electrification in these mountainous regions directly affects the communities and small factories in rural areas, which heavily rely on a reliable power supply for their daily operations. The lack of adequate electricity access poses various challenges, including limited economic growth opportunities, reduced quality of life, and hindered social development.

To tackle this issue, one promising solution is the utilization of Distributed Energy Resources (DER) and the establishment of microgrids. DER, such as solar panels, wind turbines, and small-scale hydropower systems, can be strategically deployed throughout the mountainous regions to provide localized power generation. This reduces dependence on long-distance transmission lines and minimizes risks associated with the challenging terrain. Microgrids, which are smaller-scale localized power networks, can be implemented to ensure reliable electricity access without the need for extensive transmission infrastructure upgrades.

Recognizing Georgia's electrification challenges, commitment to reducing greenhouse gas emissions, and leveraging local renewable energy resources, the government has initiated the development of off-grid mini-grid concepts for rural electrification. The first pilot mini-grid project (shown in Figure 1) was developed in a mountainous village that is isolated from the main electrical grid. The system consists of a small hydro power plant, solar PV panels, battery energy storage system (BESS), and the local load. The village's electricity demand is initially met by the small hydropower plant, but during peak periods and increased migration, additional diversified electricity sources are necessary. To maintain the mini-grid concept as greenhouse gas emissions neutral, the pilot project integrates 40 kW solar PV panels with a 100 kW/250 kWh lithium-ion phosphate BESS instead of a traditional diesel genset. This configuration increases overall system flexibility and allows robust frequency and voltage control in both normal and emergency scenarios.

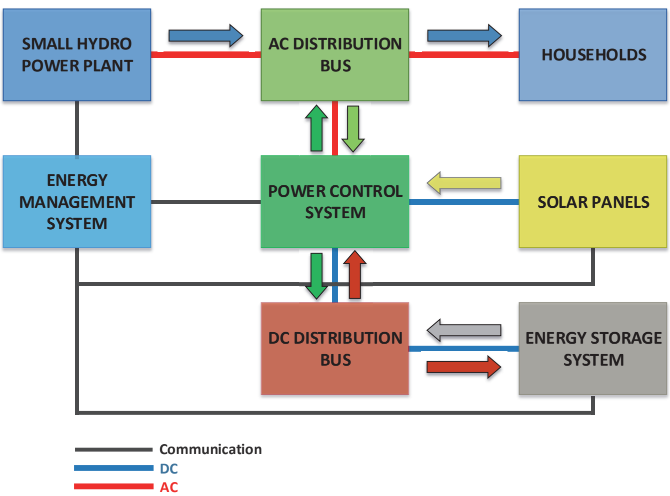


Figure 14. Mini-grid diagram

Implementing DER and microgrid systems in the mountainous regions of Georgia brings several advantages. Firstly, it ensures a more resilient and decentralized power supply, enabling the affected areas to maintain essential services during disruptions or outages. Secondly, the use of renewable energy sources promotes sustainability and reduces reliance on fossil fuels and lumber, aligning with Georgia's energy transition goals.

Furthermore, constructing microgrids creates opportunities for local community engagement and empowerment. Community-owned or cooperative models can be incorporated, allowing residents and businesses to actively participate in energy production and consumption management. This not only fosters a sense of ownership but also generates economic opportunities through job creation and local investments.

In conclusion, leveraging Distributed Energy Resources and implementing microgrid solutions can help achieve full electrification. These decentralized systems offer a cost-effective and resilient approach, ensuring reliable electricity for communities and small factories in remote areas. Furthermore, the utilization of renewable energy sources contributes to sustainability goals while empowering local communities and driving economic development. By embracing these solutions, Georgia can bridge the electrification gap and create a brighter future for its rural populations.

1.17. Green hydrogen strategy

With the support of the KfW, consultant company GOPA works for creating the Hydrogen development strategy for Georgia. If's comprising also to study the potential of Green Hydrogen producing and then ways to utilize it.

1.18. 400 MW CCGT project

While the renewable energy sources will be integrated, in order to eliminate the generation deficit, building of new CCGT decided. The construction of a new CCGT-3 thermal power plant is also important to ensure security and stability of supply. It also ensures a reduction in dependence on electricity imports, especially during the fall-winter deficit seasons when hydro generation output is minimal. It will be able to generate as much electricity as the consumption of Tbilisi. It will be the most economical power plant in the electric energy system of Georgia, which will consume almost 2 times less gas than the old power blocks.

The mentioned object will be the most maneuverable thermal power plant, which will be able to provide quick-acting reserves which in the autumn-winter months, when the capacities of the regulating hydroelectric power stations are reduced, provide the system with additional flexibility and stability. Also, thanks to its high flexibility, it will make it possible to balance the variable generation of solar and wind power plants and thus increase the integration of renewable energy sources. This CCGT will provide also the black start and voltage control services.

Thus, the said thermal power plant will increase the security and sustainability of supply, reduce dependence on electricity imports, increase the economy of the system and ensure the integration of renewable energy sources into the system.

1.19. Summary of the challenges and their solutions

GE power system had quite difficult legacy from USSR, it was not planned as an independent system and had hard times during and after the civil war. Most of the challenges come from this legacy. These are low system flexibility and deficit of power reserves inertia constant, not fully redundant power grid, different synchronous zones and power markets around, slow level of RES development too high dependence on hydrology and high share of crypto miners in electricity consumption

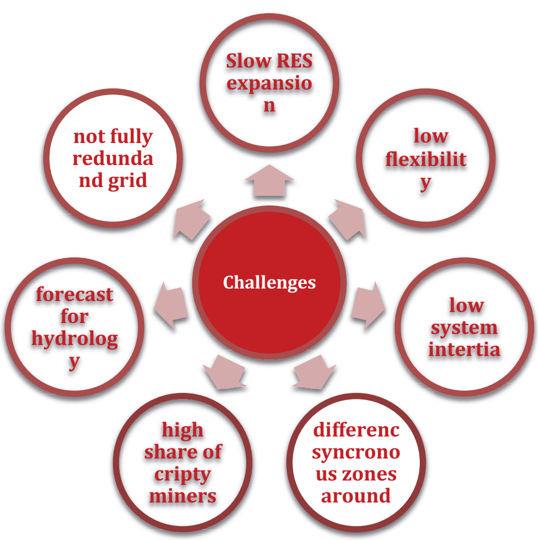


Figure 15. Challenges of GE power system

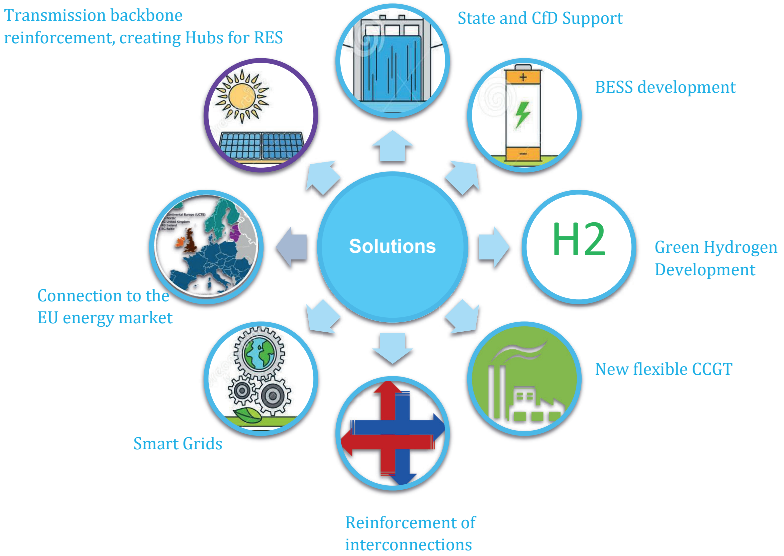
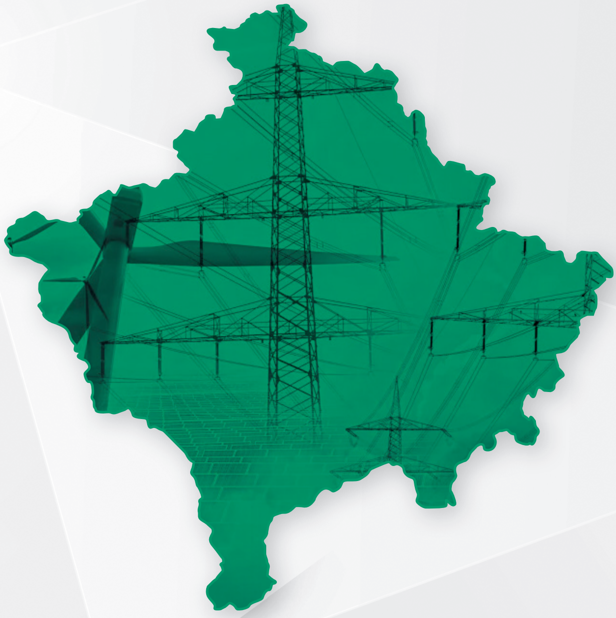


Figure 16. Activities and projects for solving the GE system challenges

At the same time there are significant projects and activities to solve these challenges: (1) Expansion of the transmission network, internal security of supply (implementation of N-1 criteria) for RES integration maximization. (2) State involvement for big HPP projects and CfD support mechanism for RES maximization. (3) Implementation of BESS project for elimination of flexibility/reserve/inertia/frequency control/VRE integration limits/power system security. (4) Green Hydrogen Development to be able to increase the RES share in power system. (5) Construction of high flexible and efficient CCGT for increasing of system security and facilitate VRE integration. (6) Reinforcement of cross border interconnectors and cooperation for the utilization of transit potential between north and south (RU-GE-AM-IR), from east to west (AZ-GE-TR), from Caucasus to CE (AZ-GE-RO). (7) Development of smart grids including RAS system and (8) Affords for connection and EU energy market and CE synchronous zone.



Pranvera Dobruna Kryeziu, Gazmend Kabashi, Avni Alidemaj, Rexhep Selimi

1. Kosovo Electricity Outlook

1.1. Power system profile

This report presents Kosovo's power system profile comprehensively. The following sections of the report offer details on Kosovo's installed power capacity, new capacity to be commissioned, electricity generation, electricity consumption, coal and hydropower plants, as well as renewable energy. Furthermore, in the context of Kosovo's energy mix, examining the potential of hydrogen generation technologies and storage roadmaps could help identify suitable options based on the country's available resources, infrastructure, and energy goals. It is important to consider the cost-effectiveness, environmental impact, and technological readiness of these options, along with potential collaborations or partnerships with other countries or organizations involved in hydrogen research and development. Finally, Kosovo's 2022-2031 Energy Strategy has been explained as a frame.

In 2022, Kosovo's electricity consumption was 6.68 billion kWh, and electricity generation was 6.44 billion kWh. During 2022, our electricity generation was obtained at 90.1% from coal, 5.6% by wind, 1.7% by hydro, and 2.6% from other sources.

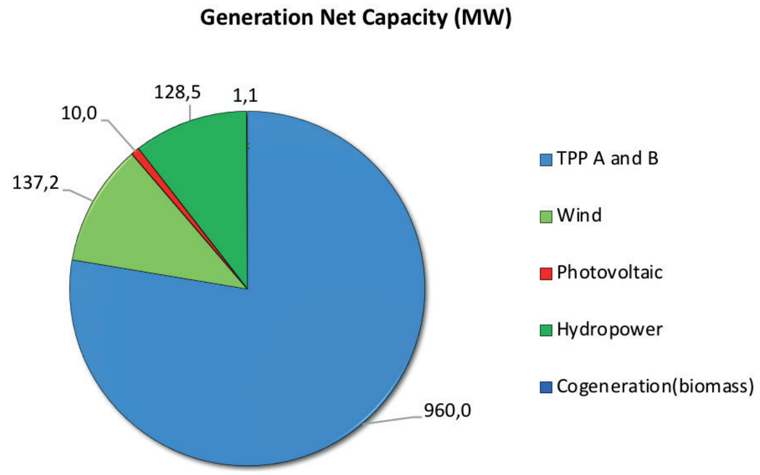


Figure 1. Generation capacities as per the type

The total number of power plant units in Kosovo was:

- 2 x coal power plants,
- 4 x hydropower plants,
- 4 x wind power,
- 6 x solar power,
- 19 x small hydropower
- 1 x geothermal power,
- few Self-Consumption generators

1.2. The Kosovo power grid infrastructure

The Kosovo power grid infrastructure is operated by one TSO – Kosovo Transmission, System and Market Operator (KOSTT) as well as one

DSO – Kosovo Electricity Distribution System (KEDS). The electricity infrastructure in Kosovo has grown historically.

1.2.1. Current electricity infrastructure

The Kosovo electricity infrastructure has an overall length of 29,553 km.

Table 1 presents the overall system lengths per voltage level and type. The transmission grid operated by KOSTT, uses 110 kV, 220 kV, and 400 kV; voltage levels, while 35 kV and below is the distribution-level voltage operated by KEDS. Today's transport grid in Kosovo is based on overhead lines.

Table 1. System lengths of Kosovo power grid per voltage level and type in the year 2022
The table contains transmission and distribution systems together [2], [3]

System lengths					
Voltage Level	Overhead Lines		Cable		Sum
	km	Share in %	km	Share in %	km
400 kV	280	0.9	0	0.0	280
220 kV	238	0.9	0	0.0	238
110 kV	897	3.0	15	0.0	912
Medium Voltages	6,278	21.2	1,496	5.1	7,774
Low Voltages	17,716	60.0	2,633	8.9	20,349
Total	**25,409**	**86.0**	**4,144**	**14.0**	**29,553**

1.3. Installed Electricity Capacity

The installed electricity capacity in 2022 was around 1230 MW, it is planned to increase to 2550 MW in 2032. While the share of renewable energy sources, was 22.0% of the installed capacity in 2022, it will reach 71% by 2032. Hydropower plants have reached an installed power value of 132 MW in the medium-long term. Based on Energy Strategy there is no additional hydro potential foreseen for further developments. Wind energy installed capacity until 2032 is expected to reach 600 MW and solar energy installed power is expected to reach 600 MW, while self-prosumers installed power is expected to reach 100 MW, at least [1]. The total installed power of geothermal and biomass power is expected to reach 20 MW. Forecast generation capacity by sources is shown in Figure 2. Furthermore, to enable large-scale RES penetration the 170 MW (340MWh) BESS is planned to be installed by 2028. This technology will provide auxiliary services (aFRR and mFRR) for Kosovo TSO (KOSTT) and energy arbitrage.

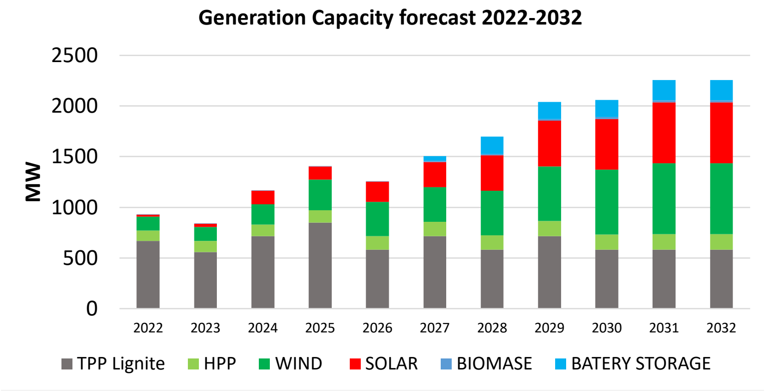


Figure 2. 10 Years Generation capacity forecast as per the technology

1.4. New capacity to be commissioned

The amount of new capacity to be commissioned during the period 2022-2032 is at the level of 1320 MW plus. Almost all of the said installed power increase consists of renewable energy sources, the majority of which are solar and wind energy. Annual new capacity for solar and wind energy averages 46.4 and 60 MW, respectively. There will be a decrease in the installed power of the lignite power plants that will be decommissioned due to the end of their lives. It is planned that beyond 2031 only TPP Kosova B will be in operation, while other units of TC Kosova A will be decommissioned or used as strategic reserves which will operate limited hours during the year, only when in the marked occurs constraints such as an energy crisis or high import prices. However, the effect of the new capacity to be commissioned on the total installed capacity is higher as capacity, but less in energy production due to the low capacity factor of wind and solar sources. The new capacity commissioned in five-year periods is shown in Figure 3.

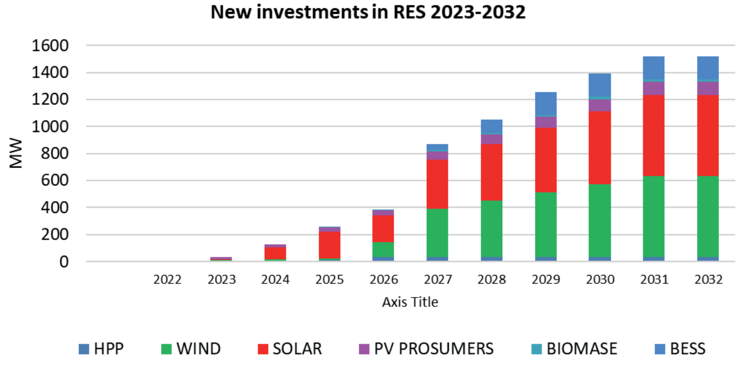


Figure 3. RES new planned capacity as per energy strategy

1.5. Electricity generation

The share of renewable electricity sources, which was 12% in electricity generation in 2022, will gradually increase to 44% by until 2032. Gradually the production of Lignite Thermal Power Plants will be reduced from an actual share of 88% to 56% in 2032. Total electricity generation decarbonization is planned to happen by 2050. To enable the decarbonization of the Kosovo Energy Sector, some crucial steps are needed: Increase of flexible capacities such, as BESS, H2 production, demand side management, new investments in transmission and distribution network, integration into the Pan-European Market, smart grid, Enhancing Cyber Security, etc.

Electrification of transport sectors such as Railways, Electrical Vehicle will play a significant role in the decarbonization of the transport sector, and avoid the high pollution in the main cities. Those activities will impact the increase in electricity demand, and the distribution network will need additional investment to create conditions for charging stations needed for fast charging of | EVs.

Figure 4 shows the forecasted electricity production by generation type, and Figure 5 the share of RES in 2032.

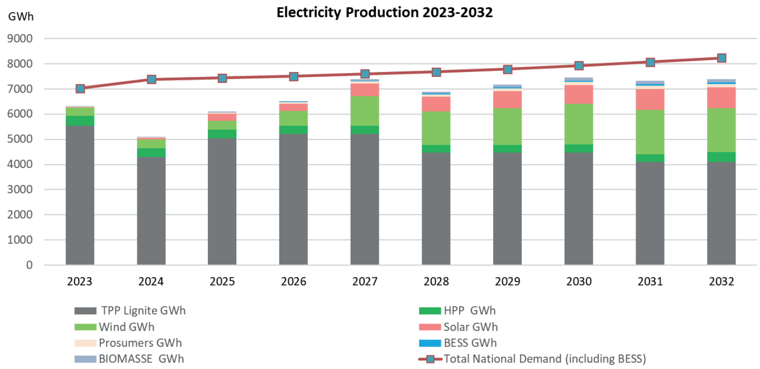


Figure 4. Electricity production compare to the demand (2023-2032)

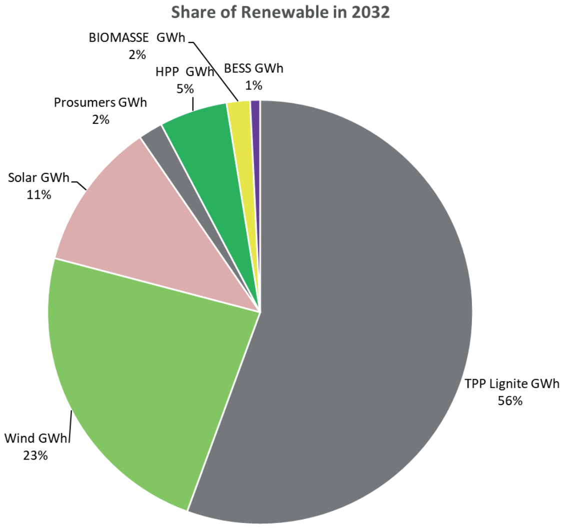


Figure 5. The share of RES production as per technology in 2032

1.6. Electricity consumption

Expressed as a percentage of the gross national demand, household electricity consumption, is currently around 53%. It is ffected by the use of electricity for heating purposes during the winter season when the demand for electricity is very high. Household consumption is projected to continuously decrease in the future, and by 2032, its share is expected to drop to 41.2%. The main factors contributing to the reduction of household demand are the increase in efficient electricity usage and the reduction of commercial and technical losses. The energy demand from the industry currently stands at 16% with a continuous upward trend, while the demand for commercial services is at 18.5% with a low growth rate. The remaining portion includes technical losses in transmission and distribution. A new category of electricity demand has been added for forecasting the security of the supply of the country: transport electrification demand. This category includes the demand for charging electric vehicle batteries, as well as the planned electrification of the railway system. The transportation demand is estimated to reach 0.8% by 2032.

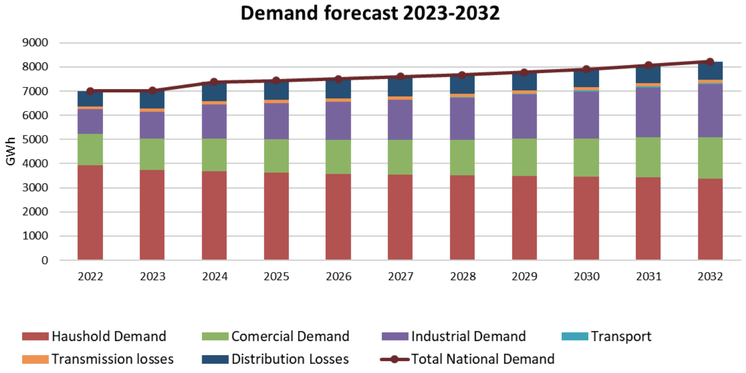


Figure 6. The share of electricity demand by the different sectors

1.6.1. Primary, final energy consumption and energy efficiency

Primary energy consumption has increased with a yearly average of 1.4% between 2008 and 2020 although showed significant fluctuations. The increase rate was moderate at the end of the decade but affected also by short-term effects (COVID-19 pandemic), thus a rapidly increasing consumption trend is expected for the following years. Final energy consumption followed a similar trend in this period with an average yearly growth rate of 2.3%, reaching 1525 kilotons of oil equivalent (ktoe) by 2020. The largest share of the final energy consumption, belongs to households, accounting for 40% of the total use in 2020. The energy demand in this sector has increased since 2008, by 148 ktoe. This segment of consumption is addressed in the Energy Strategy through measures in energy efficiency and heating.

The second largest energy-consuming sector is transport, where energy consumption increased by about 100 ktoe to 422 ktoe. The industrial sector used 302 ktoe in 2020.

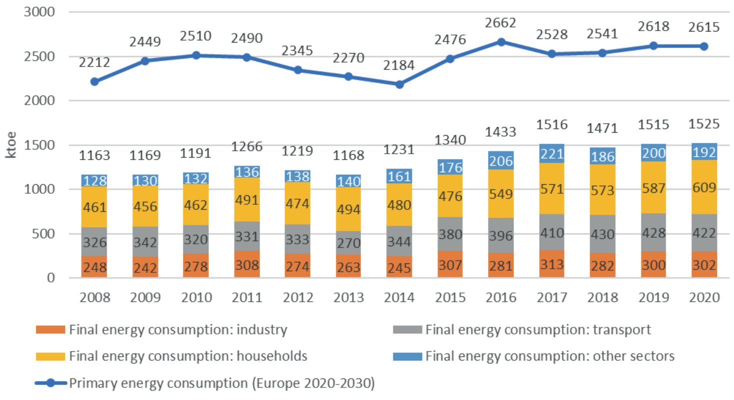


Figure 7. Primary and final energy consumption in Kosovo (Source: Energy Strategy 2022-2031)

The strategy's goal is to move toward a more efficient energy consumption pathway that results in a less energy-intensive economy. The baseline and target consumption pathways to 2031 are defined based on the "Energy Community Scenario" of the study "Projections of energy consumption and energy savings potential in Kosovo to 2030" (referred to as "EU study" and "EnC scenario"). The overall target for energy efficiency is to limit final energy consumption at the level of 1877 ktoe in 2031 as is shown in figure 8.

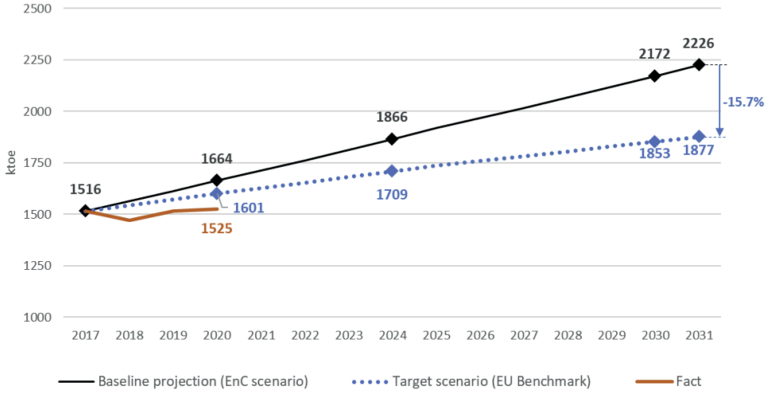


Figure 8. Final energy consumption pathways and target for 2031

1.7. Coal power plants

Kosovo Power System operates with two relatively large Thermal Power Plants based on lignite: TPP Kosova B (B1 and B2 with a total available capacity of 540 MW) and TPP Kosova A (A3, A4, and A5 with a total available capacity of 420 MW). According to the Energy Strategy 2022-2031, there are plans for the capital revitalization of Units B1 and B2, which will also result in a reduction of pollution levels to comply with European standards. As for the existing Units of Kosovo A Power Plant, the Energy Strategy 2022-2031 outlines the reconstruction of one unit which will operate as a strategic reserve with limited hours. The production of electricity by the TPP-s will be gradually reduced to achieve total decarbonization of the electricity sector by 2050.

1.8. Natural gas

Presently Kosovo has no gas transmission nor distribution gas network

1.9. Renewable energy

The share of RES in Kosovo's energy mix has increased moderately. Currently, the share of renewables represents a small fraction of the overall electricity generation output, which continues to be dominated by fossil fuels. It consists of 138 MW of Wind Power (two large wind farms), 132 MW of small HPP-s mainly runoff river, and 11 MW PV connected to the distribution network.

Diversifying the energy mix is vital for Kosovo's decarbonization efforts and maintaining the security of supply. By 2031, Kosovo's target is to have a minimum of 1472 MW RES installed capacities in wind and solar PV technology, allocated between large/small RES projects and prosumers. The use of competitive procedures, drawing from best practices in the region, represents one of the most economical and transparent approaches to increasing the deployment of renewable energy capacities in Kosovo.

1.10. BESS technology

The integration of renewable energy sources (RES) into power systems has gained significant momentum worldwide, driven by the urgent need to reduce greenhouse gas emissions and combat climate change. However, the intermittent nature of RES generation poses challenges to the stability and reliability of power grids. To ensure the smooth operation of the grid, ancillary services play a crucial role in maintaining system balance and frequency regulation. In the context of ancillary services, the Automatic Frequency Restoration Reserve (aFRR) and Manual Frequency Restoration Reserve (mFRR) services are essential for maintaining grid stability and restoring system frequency within predefined limits. In the case of aFRR, the Transmission System Operators (TSOs) play a critical role in coordinating and activating these reserves. In this context, Kosovo Power System until 2029 will install large-scale BESS with a capacity of 170 MW and 340MWh energy stored, with an aim to provide flexibility to the System Operator KOSTT. Furthermore, the BESS will provide the auxiliary products: aFRR, mFRR, and Black Start Capability, and also will be used for Energy Arbitrage. The 170 MW BESS will contain three batteries and will be connected in three different locations at the 110 kV network.

References

[1] Ministry of Economy, Energy Balance for 2022

[2] Energy Strategy 2022-2031 (Energy-Strategy-of-the-Republic-of-Kosovo-2022-2031.pdf (rks-gov.net)

[3] Transmission Network Development Plan 2023-2032, KOSTT, 2023-2032, https://kostt.com/Content/ViewFiles/Index/EN/Transmission%20Development%20Plan.pdf

[4] Distribution Network Development Plan 2023-2032, KEDS, 2023

[5] Energy Statistics February 2022 https://ask.rks-gov.net/en/kosovo-agency-of-statistics/add-news/energy-statistics-in-kosovo-february-2022

Vladimir Kostić

1. Montenegro Electricity Outlook

1.1. Power system profile[1]

According to the Energy Balance, after oil derivatives, households and businesses in Montenegro use electricity the most, with slightly more than 35% of the total final energy consumption. The total installed capacity of all power plants in Montenegro at the end of 2021 was 1051 MW.

The distribution of our installed power by resources:

- 67.08% hydropower,
- 21,41% thermal power (lignite),
- 11,23% wind power,
- 0.28% solar power.

1 Regulatory Agency for Energy and Regulated Utilities. (2022). Report on the state of the energy sector of Montenegro for the year 2021.

The total number of power plants in our country has increased to 49 (excluding power plants at households or commercial facilities that have prosumer status) at the end of December 2021. Number of active power plants:

- 2 hydro power,
- 38 small hydropower,
- 1 thermal power (lignite),
- 2 wind power,
- 6 solar power.

In 2021, electricity generation was 3655 GWh. Our electricity generation was obtained:

- 36.45 % from thermal power plant (lignite),
- 54.7% from hydropower plants,
- 8.77% from wind power plants,
- 0.08% from solar power plants.

Electricity consumption in 2021 amounted to 2982 GWh. An increase in electricity consumption by 5.79% was recorded compared to previous year.

The last document of the Energy Development Strategy in Montenegro was adopted in 2014. As the time for a new strategic document has long come, it is expected that it will be prepared in the near future.

For this reason, although outdated, data from the last official strategic document "Strategy for the Development of Energy in Montenegro until 2030" published in 2014 will be briefly presented here.

1.2. Installed electricity capacity and electricity generation[2]

Acknowledging Montenegro's determination to create a favorable investment climate for investing in renewable energy sources, and with the

2 Ministry of Economic Development and Tourism. (2014). Energy development strategy of Montenegro until 2030.

already established system of incentives for production from renewable energy sources, in all scenarios, a certain number of small hydroelectric power plants, then wind power plants, solar photovoltaic plants and plants that use various forms of biomass for the production of electricity. The strategy envisages the continuation of already started rehabilitation of existing production facilities as well as the construction of new power plants.

Revitalization of the existing conventional large power plants until 2030 will increase the installed power from the current 867 MW to 953 MW and also production from the current 2862 GWh/year to 2950 GWh/year.

- New thermal power plants - based on the available technical documentation, the most likely candidate for construction is Pljevlja II TPP with an installed capacity of 225 MW and a possible annual production of 1360 GWH (the installed capacity can be up to 300 MW),
- New hydroelectric power plants - a favorable scenario would be to obtain an additional ~ 400 MW from large HPPs (Morača HPP and Komarnica HPP)
    - Hydropower plants on the Morača River - the total installed capacity is 238 MW with an expected production of 616 GWh. According to that decision, the construction of four HPPs was foreseen: HPP Andrijevo, HPP Raslovići, HPP Milunovići and HPP Zlatica.
    - Hydroelectric plant on the Komarnica river - Montenegro has developed a technical solution for using the hydro potential of the Komarnica River, which envisages the construction of a large HPP with a total installed capacity of 172 MW and an expected annual production of 227 GWh.
    - Small hydroelectric power plant construction plan - the calculation was made with the assumption that by 2025, the average annual production from small hydropower plants would reach the level of 425 GWh (at about 132 MW of installed power).
- New wind power plants - the goal of the strategy is for annual production from wind farms to reach 348 GWh (151 MW) by 2020 and 436 GWh (190 MW) by 2030.
- Photovoltaic solar power plants - the dynamics and expected annual production of electricity from the PV plant is planned so that in 2020

it reaches the amount of 16.5 GWh (about 10 MW of peak power), and in 2030 the amount of 52 GWh (31.5 MW of peak power).

- Production of electricity from biomass - the reference scenario foresees the production of electricity from biomass of 101 GWh by 2020 and 188 GWh by 2030.

Summary:

- Electric installed power capacity and total planned production in 2030 (new and existing plants):
  - 225 MW in thermal power plants (1960 GWh/year production)
  - 410 MW in hydropower (2621 GWh/year production)
  - 31.5 MW in solar energy (52 GWh/year production)
  - 190 MW in wind energy (436 GWh/year production)
  - 121 MW in small hydropower (425 GWh/year production)
  - 10 – 40 MW in biomass (188 GWh/year production)

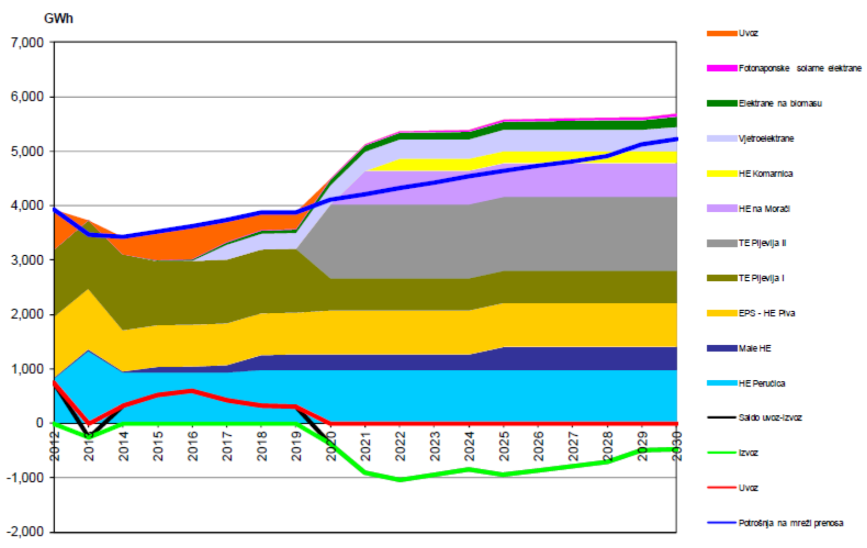


Figure 1. Electricity balance of Montenegro in the period 2011 – 2030 (GWh)[3]

3 Source: Ministry of Economic Development and Tourism. (2014). Energy development strategy of Montenegro until 2030.

1.3. Electricity consumption[4]

In the Energy Development Strategy of Montenegro until 2030, published by Montenegrin Ministry of Economy (2014), electricity consumption reaches 5.214 TWh by 2030. The share of electrical energy in final energy consumption reaches 34% by 2030. Here it is necessary to mention that in this consumption plan (2014) until 2030, the operation of the aluminum plant is assumed (84 MW), but in the meantime (2020) it has been shut down.

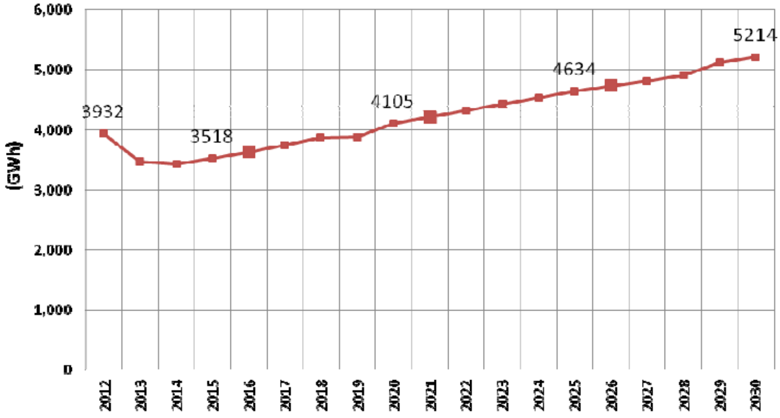


Figure 2. Total gross consumption of electricity[5]

1.4. Energy efficiency[6]

According to the Law on the Efficient Use of Energy and Energy Efficiency Action Plan for the period 2019-2021, the main objectives are:

- Implementation of the Law on Efficient Use of Energy by completing and improving the regulatory framework and improving the institutional framework;

4 Ministry of Economic Development and Tourism. (2014). Energy development strategy of Montenegro until 2030.

5 Source: Ministry of Economic Development and Tourism. (2014). Energy development strategy of Montenegro until 2030.

6 Ministry of economy. (2016). Energy efficiency action plan of Montenegro for the period 2019-2021

- Raising public awareness and increasing understanding, knowledge and capacity regarding new legal requirements and good practices in the field of energy efficiency among public sector institutions, local governments, large consumers, professional organizations and other actors;
- Improvement of the statistical and monitoring system in the field of energy efficiency, especially in the public sector and
- Implementation of energy saving measures with recognizable results.

Regarding the realization of the indicative goal of energy efficiency for the period for 2010-2018, a preliminary "bottom-up" analysis was performed, which shows that the energy savings achieved in the previous nine-year period amount to 49.76 ktoe, which represents 84.5% of the achievement of the indicative goal.

In order to achieve the indicative goal in the coming period, the energy market needs to be further liberalized, especially in terms of the provision of energy services. In this sense, it is necessary to further develop the public-private partnership in the field of energy efficiency.

Overview of planned energy efficiency measures specifically in power system sector with estimated savings:

- Improving efficiency by revitalizing HPP Piva Phase II – 10,2 ktoe saving (2020-2021)
- Improving efficiency by revitalizing HPP Perućica Phase II – 6,2 ktoe saving (2020-2021)
- Improving efficiency by incorporating energy of efficient block transformers T1-T5 - HPP Perućica 3,3 ktoe saving (2020-2021)
- Improving efficiency through the reconstruction of MHP (Crnojevića rijeka, Podgor, Šavnik, Mušovića rijeka and Lijeva rijeka)
- Development of the transmission network and improvement of its exploitation
- Development of the distribution network and improvement of its exploitation

- Development of decentralized energy production by customers - producers (prosumers)

Acknowledgement

While preparing this report, Energy Development Dtrategy of Montenegro until 2030, Energy Efficiency Action Plan and Report on the State of the Energy Sector of Montenegro for 2021 data have been used, so thanks to the former Ministry of Economy and Regulatory Agency for Energy and Regulated Utilities.

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[1] Regulatory Agency for Energy and Regulated Utilities. (2022). Report on the state of the energy sector of Montenegro for the year 2021.

[2] Ministry of Economic Development and Tourism. (2014). Energy development strategy of Montenegro until 2030.

[3] Ministry of economy. (2016). Energy efficiency action plan of Montenegro for the period 2019-2021

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