BRICS Energy Report 2022

BRICS
ENERGY RESEARCH
COOPERATION PLATFORM

BRICS 2022 CHINA

ACKNOWLEDGEMENTS

This Report was made possible thanks to the support and advice of many individuals and organizations.

The BRICS Energy Report 2022 is the outcome of the collaborative efforts of the committee of the BRICS Senior Energy Officials. The BRICS ERCP would like to acknowledge the support from the Ministry of Mines and Energy of the Federative Republic of Brazil, Russian Energy Agency by the Russian Ministry of Energy, Ministry of Power of the Government of India, Ministry of Petroleum and Natural Gas of the Government of India, Ministry of Coal of the Government of India, Ministry of New and Renewable Energy of the Government of India, Ministry of Statistics and Programme Implementation of the Government of India, National Energy Administration of the People's Republic of China, Ministry of Mineral Resources and Energy of the Republic of South Africa.

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BRICS ERCP are also graceful to Ministry of Mines and Energy of Brazil; Russian Renewable Energy Development Association；Energy officials from Bureau of Energy Efficiency and Ministry of Power, Government of India, China Renewable Energy Engineering Institute, China Electric Power Planning & Engineering Institute, South African National Energy Development Institute (SANEDI).

BRICS ERCP would like to express gratitude to China Chairmanship for leading the preparation of the Report. Overall guidance was provided by the Deputy Director General Wei Xiaowei, National Energy Administration of the People's Republic of China.

WELCOME REMARKS

Adolfo Sachsida

Minister of Mines and Energy of
the Federative Republic of Brazil

I would like to commend the Chinese Chairmanship for their leadership and coordination of BRICS in 2022.

BRICS Energy cooperation has been an important instrument in the discussion and promotion of our countries´ energy transitions. Considering the pivotal role of energy for economic development, as well as the energy growth potential within BRICS, we believe that our shared efforts will play a crucial role in providing our customers with clean, secure and affordable energy, while also promoting technological innovation and cooperation.

In this context, I am happy to say the BRICS Energy Report presents us with valuable information to explore new pathways in the energy sector, serving as a tool for exchanging experiences and investment opportunities.

Shulginov Nikolay

Minister of Energy of the Russian Federation

Development of the energy dialog within BRICS has consistently based on equality and mutual respect of interests. The Russian Federation is interested in maintaining a balance between meeting the challenges of the energy transition, the need to strengthen energy security and provide the economies and population with affordable resources.

Instability in the global energy markets caused by the negative impacts of the COVID-19 pandemic, under investment and geopolitical tensions, requires intensified international cooperation in order to ensure global energy security, socio-economic progress and the sustainable development goals.

We should respond promptly to the current challenges including through expanding mutual support and cooperation, as well as by strengthening our countries' roles in the international arena in order to find fair and efficient solutions.

Russia does support a full-scale development of the BRICS Energy Research Cooperation Platform and welcome an edition of the annual "BRICS Energy Report" that, no doubt, has become the flagship product of the BRICS ERCP research activities. Joint analytical publications by the BRICS countries help to define promising cooperation directions, as well as to reveal to the world community our views on the development of the global energy sector.

I express my gratitude to China's BRICS Chairmanship in 2022 for an integrated approach to the development of energy cooperation and proposing new initiatives that will contribute to strengthening the five-party interaction.

Shri R.K. Singh

Minister of Power and New and Renewable Energy, Government of the Republic of India

Energy is a significant part of the economic development of any country. BRICS cooperation on energy is an essential agenda of the member countries. Strengthening of collaboration and safeguarding of the common interests of the member countries through the BRICS platform is key to this cooperation. The energy sector is witnessing significant transition in pursuance of commitments to reduce greenhouse gas emissions under the Paris Agreement. Therefore, restructuring the power sector, phasing down old and inefficient fossil fuel based power production, and large-scale uptake of renewable energy are essential to achieve such goals.

Even as the Covid-19 pandemic-led disruption dominated 2020, India stayed on track to achieve the NDC goals. Effective implementation of energy efficiency and energy conservation endeavours by States has ensured that the pace and direction of such activities are not compromised. As per the updated NDC, India is committed to reducing Emissions Intensity of its GDP by 45 percent by 2030, from 2005 level and achieve about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. I am hopeful that the BRICS Energy Report 2022 will strengthen the BRICS Energy Research Cooperation Platform (ERCP) and enhance BRICS's contribution to agenda concerned.

Zhang JianHua

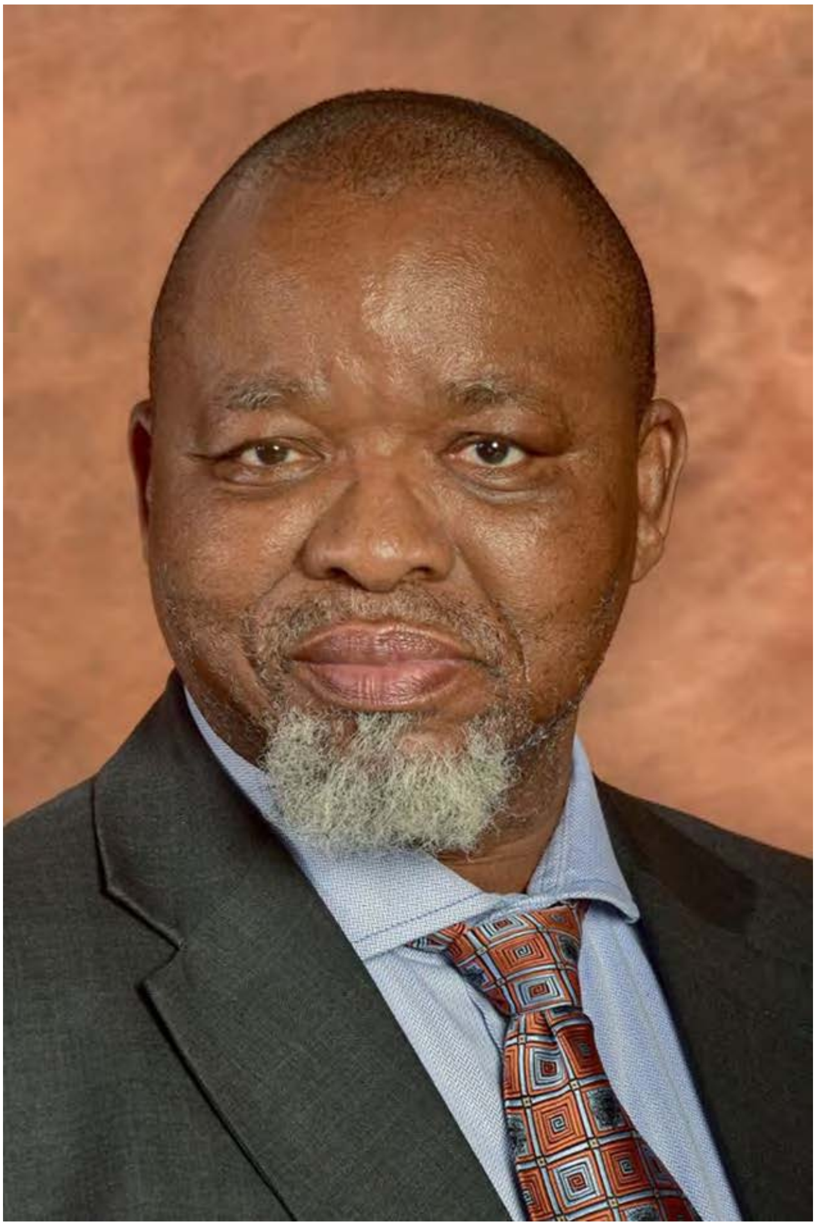
Administrator of National Energy Administration of the People's Republic of China

Having gone through a glorious journey of 16 years together, the BRICS countries have supported each other and emerged as an important force shaping the evolution of the international landscape. Their voice and influence in global governance have been on the rise steadily. Energy is a priority of cooperation among the member countries. It is of great significance to the global economy for the BRICS to work together to address risks and challenges, promote the establishment of a reliable, stable and affordable energy supply system, and jointly maintain an open, transparent and efficient international energy market.

In recent years, the BRICS countries have promoted green and low-carbon development. Their firm determination and pragmatic measures in boosting clean energy transition have contributed to the global response to climate change and carbon neutrality goals. As the world’s largest energy producer and consumer, China is steadfast in advancing green and low-carbon energy transition, boosting energy security, strengthening energy technology innovation, deepening international energy cooperation, and achieving carbon peaking and neutrality in an orderly manner, thus demonstrating the wisdom and sense of responsibility of China as a major country in addressing climate change with practical actions and remarkable fruits.

This year, under the leadership of President Xi Jinping, the “BRICS China Year” has been full of highlights, with fruitful results. The BRICS countries have forged ahead together in energy cooperation and overcome many difficulties to jointly complete the BRICS Energy Report 2022, which has further enriched their achievements on the energy research cooperation platform. The report is of vital significance for the BRICS to do better in basic information and data sharing, to deepen practical cooperation in the energy sector and to jointly participate in global energy governance.

China is willing to work with all BRICS partners, take measures to maintain the security and stability of energy supply and energy market, give full play to the respective advantages of all member countries in such areas as energy resources, technology, industry, market, and capital, consolidate the existing cooperation foundation and take the initiative to expand the scope of cooperation so as to jointly promote global economic recovery and long-term stable development.



Samson Gwede Mantashe

Minister of Mineral Resources and Energy of the Republic of South Africa

INTRODUCTION

The BRICS countries have become dominant players in the energy landscape over the past 16 years. In the past 16 years, we have witnessed continues improvement of the BRICS cooperation mechanism, expansion of collaboration areas, and enhanced global influence, which shows unique charm in maintaining and practicing multilateralism.

In 2009 in Yekaterinburg, since the first BRICS Summit, all BRICS have expressed the interest for energy co-operation of energy and energy efficiency. In the Delhi Declaration 2012, the BRICS leaders emphasized the need for energy co-operation within the BRICS framework. The first meeting of BRICS Energy Ministers was held in Moscow in 2015, a Memorandum of Understanding on energy conservation and energy efficiency between the BRICS ministries has been signed, the MoU also provided for exploring the possibility of further institutionalization of energy co-operation within the framework of BRICS.

In the Xiamen Declaration of 2017, BRICS leaders encouraged continued dialogue on the establishment of a BRICS Energy Research Co-operation Platform (BRICS ERCP). In 2018, Johannesburg Summit agreed the establishment of BRICS ERCP Platform. In 2019, the Terms of Reference of BRICS ERCP was approved by the BRICS Energy Ministers.

In 2020, at the Russian Presidency year, the BRICS ERCP launched the BRICS Energy Report 2020, Road Map for BRICS Energy Cooperation up to 2025 and BRICS ENERGY Technology Report, which included technological cooperation, digitalization, renewable energy, cooperation roadmap 2025 on energy sectors development in the BRICS countries. In 2021, at the Indian Presidency year, the BRICS ERCP launches the BRICS Energy Report 2021, BRICS Energy Technology Report 2021 and BRICS ENERGY RESEARCH DIRECTORY Book 2021 which included energy sector development, sustainability commitment, and sustainable global development and BRICS ERCP experts' directory book.

In 2022, at the Chinese Presidency year, BRICS countries jointly completed BRICS Energy Report 2022 The reports present the latest development in energy field of BRICS countries, which include the overview of energy development, technology innovation, policies and objectives, energy sustainability, energy security, prospects for BRICS co-operation. To advance BRICS energy cooperation, the report proposes that BRICS think tanks make collaborative research under ERCP on such topics as energy cooperation, energy investment, energy market stability as well as technology support for participating in global energy governance, to enrich and expand the areas of cooperation prioritized in the energy cooperation roadmap. BRICS countries have large populations, enormous economic output, and abundant energy resources. By enhancing energy cooperation across the board and leveraging their respective strengths in the global context of energy transition, BRICS countries will contribute greatly to global energy sustainability. This report is presented as one of the outcomes of the 7th BRICS Energy Ministerial Meeting.

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[I]

Brazil

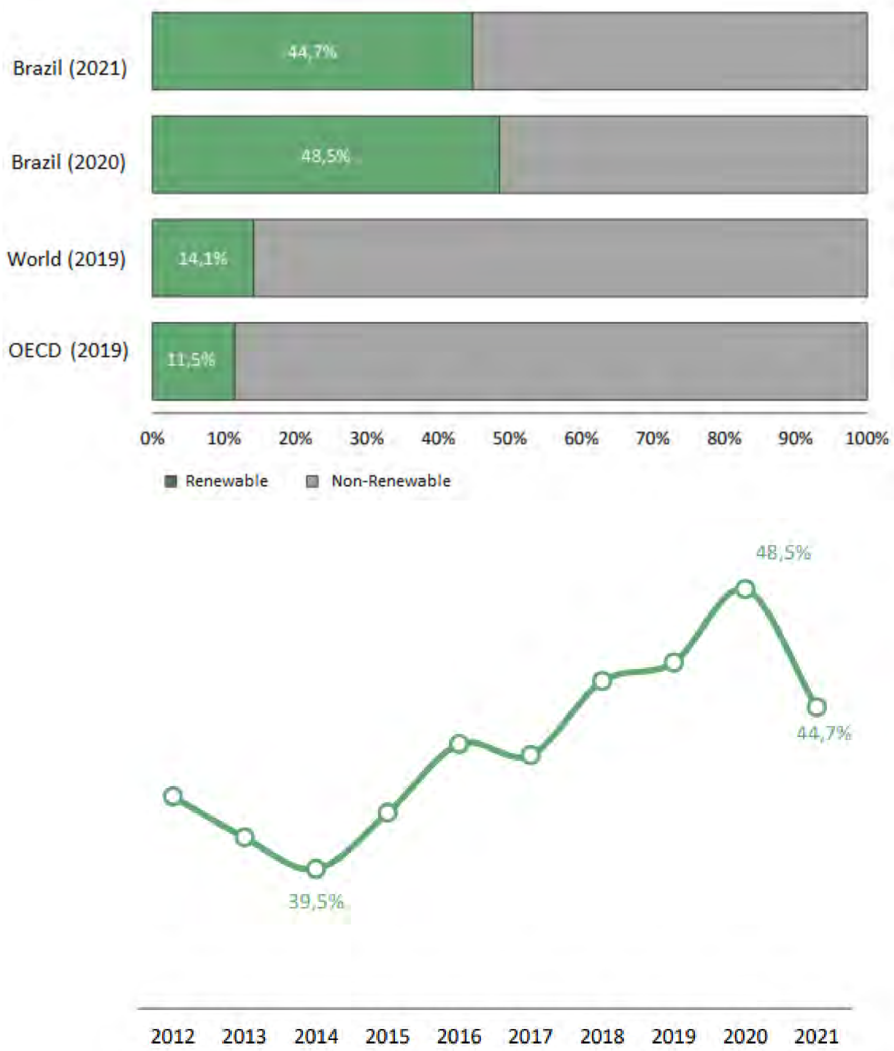
I. OVERVIEW OF ENERGY DEVELOPMENT

1. Brazilian Matrices

Total Energy Supply

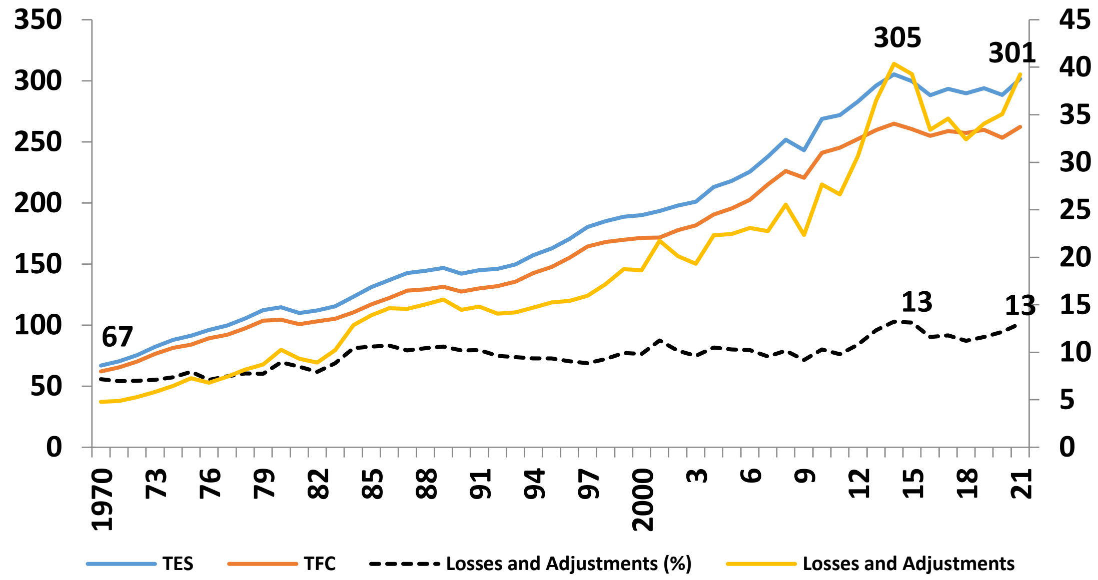
In 2021, the Total Energy Supply – TES (Fig. 1.1-1 and Fig. 1.1-2) reached 301.5 million tons of oil equivalent (10^6 toe), indicating a growth of 4.5% compared to the previous year. The renewable's share in the energy matrix was mainly affected by the drop in the supply of hydroelectricity, associated with water scarcity and the activation of thermoelectric plants for compensation. However, the increase in wind and solar sources in the generation of electricity (zero loss) and bio diesel contributed to keeping the Brazilian energy matrix at a renewable level of 44.7%, much higher than that observed in the rest of the world.

Figure 1.1-1 **Renewable share in Total Energy Supply**



Source: International Energy Agency (IEA) and Energy Research Office (EPE)

Figure 1.1-2 Total Energy Supply (TES) and Total Final Consumption (TFC) - 106 toe



Source: SIE Brazil

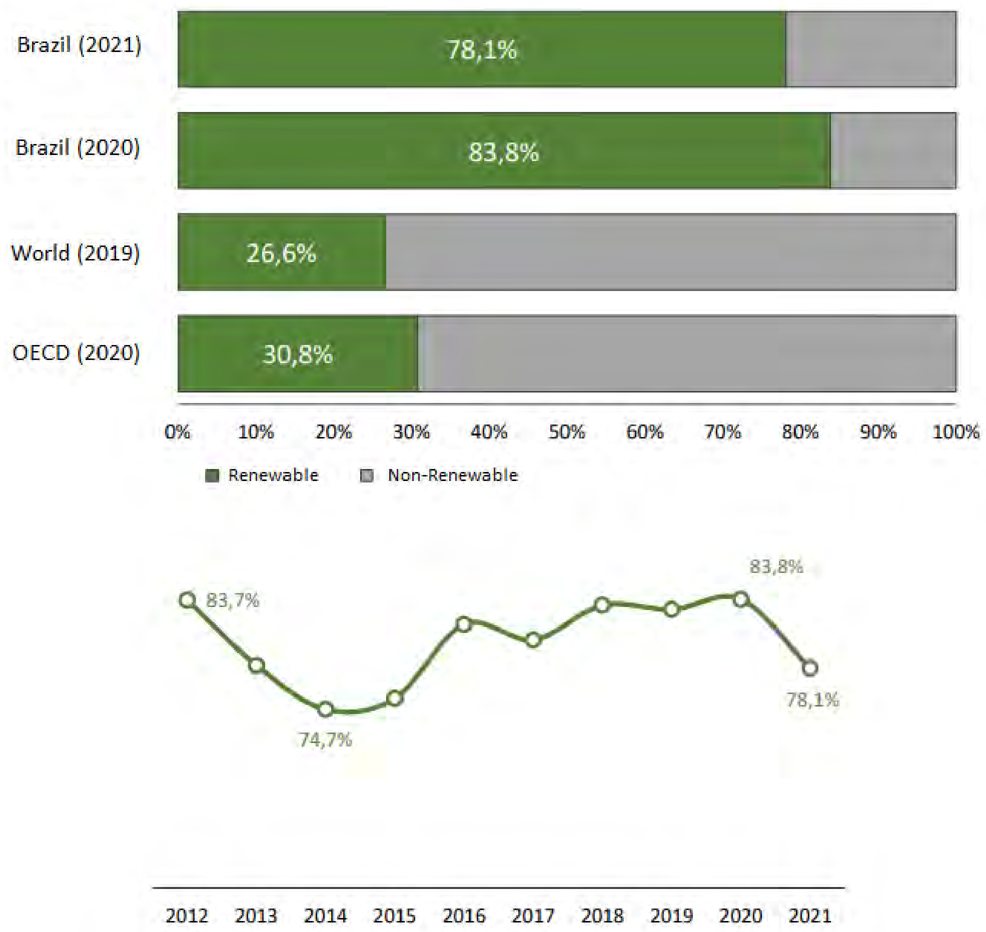
The difference between the Total Energy Supply and the Total Final Consumption (including the energy sector's own consumption), results from losses in the energy transformation and distribution processes. Brazil, highly reliant on electricity supply from hydropower plants, has low generation by thermoelectric plants and, as a result, has a level of losses much lower than the world average. Worldwide, the percentage of total losses in relation to supply is more than twice the Brazilian indicator.

Total Electricity Supply

Part of the total energy supply refers to the electricity demand, called the total electricity supply (Fig. 1.1-3), considering the entire amount of electricity necessary to supply Brazil's demands. In this case, there was an increase in domestic supply of 25.7 TWh (+3.9%) compared to 2020. The main highlight was the advance in generation based on natural gas (+46.2%), to face the water scarcity, since the hydraulic generation reduced 8.5%, following the fall in imports (-6.5%), whose primary origin is Itaipu.

Regarding intermittent renewable sources, wind generation reached 72 TWh - growth of 26.7%. Wind power installed capacity reached 20,771 MW, a 21.2% increase. Solar generation reached 16.8 TWh (centralized generation and MMGD), representing an increase of 55.9% compared to the previous year. As a result, the share of renewables in the electricity matrix stood at 78.1% in 2021.

Figure 1.1-3 Renewable share in Total Electricity Supply

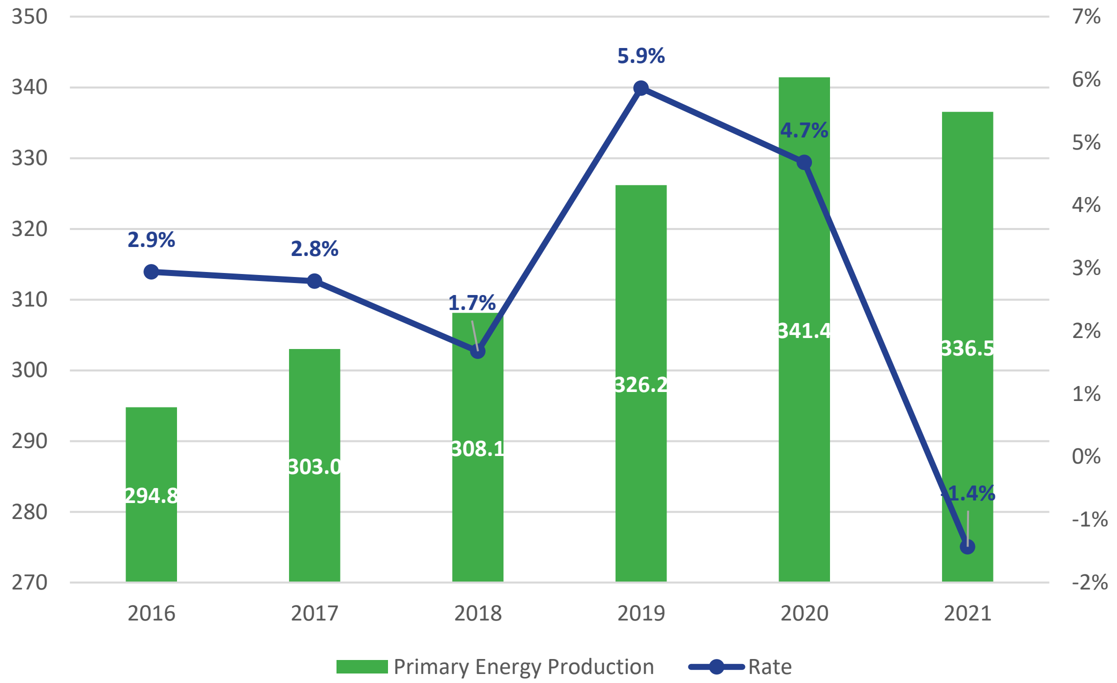


Source: National Energy Balance – BEN 2022

2. Energy Production

Brazilian energy production has undergone two decisive tests of its robustness in recent years. Firstly, in 2020, the Covid-19 pandemic generated an economic downturn in Brazil with its effects on the economy, being succeeded, in 2021, by a context of record water scarcity, with Brazil having the lowest hydrological inflow in its history in part of its reservoirs. Thus, from 2020 to 2021, there was a decrease in primary energy production of 1.4%, reaching 336.5 million toe (Fig. 1.1-4), mainly driven by the aforementioned decrease in hydroelectricity production (-8.5%) and also the drop in sugarcane products (-11.1%), due to the decrease in sugar production related to the food and beverage sector, as well as the retraction of ethanol production. On the other hand, the increase in solar (32.4%) and wind generation (26.7%) stands out, responsible for mitigating part of the observed retraction, demonstrating the prominent role of renewable sources in Brazil.

Figure 1.1-4 Primary Energy Production - 106 tep.



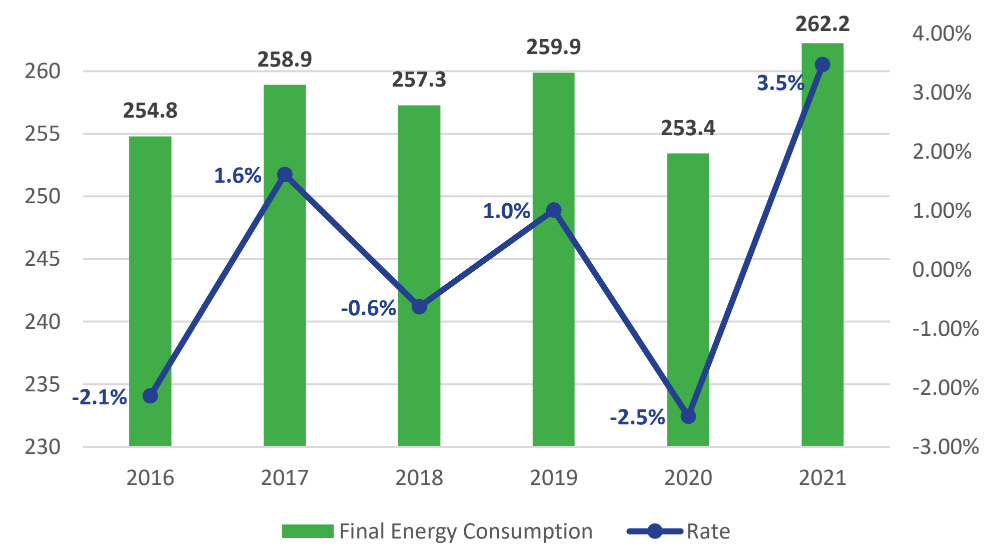
Source: SIE Brazil.

The main fossil sources participation in primary production continues to be oil (44.7%) and natural gas (14.4%), resulting from the strong production existing in the pre-salt fields currently, with expectations of expansion future until 2030. Among renewables, products derived from sugarcane (14.7%) and hydroelectricity (9.3%) are the main highlights.

3. Energy Consumption

The final energy consumption in Brazil was impacted by the economic variation and effects of the Covid-19 Pandemic. In general terms, there was an average increase of 0.14% during 2016 and 2021, very close to stability. Despite this, the economic recovery provided by the end of the influence of the direct effects of the pandemic on the Brazilian economy allowed the greatest growth in energy consumption within the indicated period, reaching 3.5% expansion, allowing Brazil to reach the level of 262.2 million toe (Fig. 1.1-5).

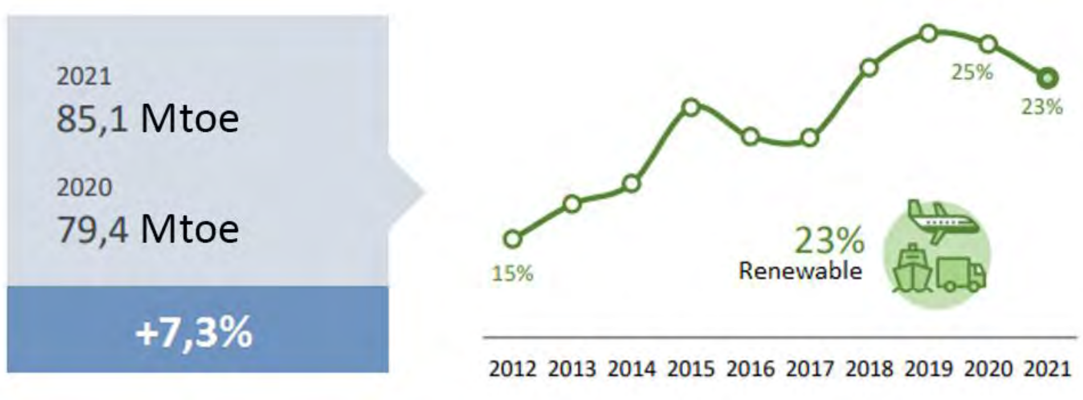
Figure 1.1-5 Total Final Consumption - 106 tep



Source: SIE Brazil.

In terms of the participation of economic sectors in consumption, the Transport Sector stands out (Fig. 1.1-6), reaching 32.5% of participation, with an increase of 7.3% compared to 2020. Aviation kerosene (32.8%), gasoline (9.8%), and diesel (9.1%) were the main fuels in terms of expansion, also causing a slight decrease in the transport renewability index, from 25% in 2021 to 23%. There was also a reduction in the need to import gasoline, with a strong drop of 43.9% compared the previous year, offset by the 19.1% expansion in production. There was a 3.2% reduction in ethanol consumption compared to 2020, while biodiesel managed to partially keep up with the consumption of its fossil counterpart, with an increase of 6.5%.

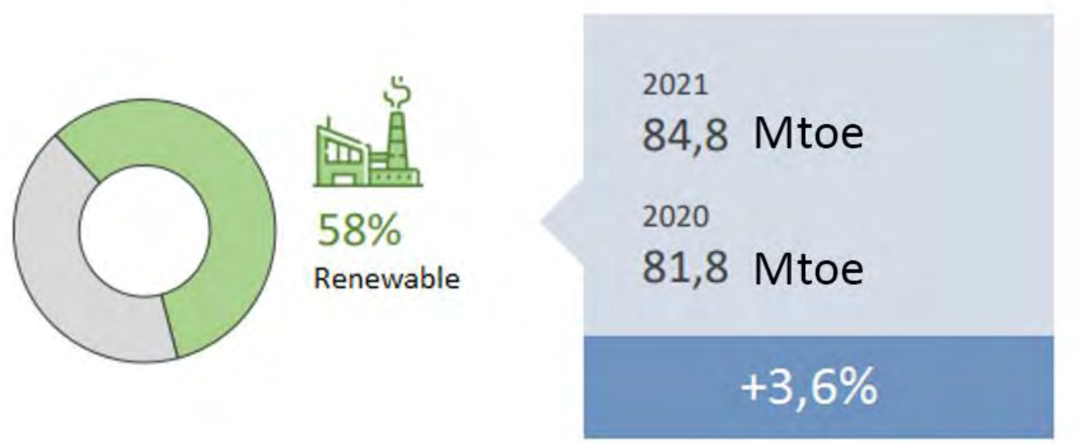
Figure 1.1-6 Energy Consumption in Transports Sector



Source: Adapted from National Energy Balance – BEN 2022

The Industrial Sector (Fig. 1.1-7), which was the main one in terms of participation in 2020, holds the second place, with 32.3% of the total, due to the increase in mainly all industrial segments in relation to the previous year, with the exception of Food and Beverages, which had a decrease of 10.5%. It is important to highlight the renewability index of the industrial energy matrix, which reached 58%, although there has been an increase in coal, due to the increase in steel production by reduction using coke, and natural gas, when compared to 2020.

Figure 1.1-7 **Energy Consumption in Industrial Sector**



Source: Adapted from National Energy Balance – BEN 2022

4. Energy Imports and Exports

In general, it is observed, through the simplified balance of imports for the years 2016 to 2021 (Table 1.1-1), that Brazil has followed a path of decreasing its dependence on energy products, effectively becoming a net exporter when observing the total amount. A large part of this value is due to the strong growth in oil exports, which, despite having seen a decrease of around 7.6% between 2020 and 2021, showed a significant increase of more than 60% when compared to the entire period. Natural gas had a significant decrease in imports, except for the last year due to the increase in thermoelectric demand to face the period of water scarcity. Also important is the constant growth observed in exports of sugarcane derivatives from 2019 onwards, which can be evaluated as a future vector of fuel exports to Brazil.

Table 1.1-1 Simplified Energy Balance for Net Imports 2016-2021 – 103 toe*.

Year	Oil	Natural Gas	Coal	Sugarcane Products	Petroleum Products	Hydro and Electricity	Others	Total
2016	-35804,00	10320,00	5756,00	-501,00	11280,00	3507,00	14270,00	8829,00
2017	-46391,00	9434,00	5840,00	246,00	16805,00	3125,00	16827,00	5887,00
2018	-46100,00	9324,00	6778,00	64,00	11124,00	3008,00	14593,00	-1208,00
2019	-54622,00	8628,00	5802,00	-250,00	13160,00	2146,00	13878,00	-10807,00
2020	-62201,00	8458,00	4834,00	-551,00	4085,00	2126,00	14107,00	-29142,00
2021	-57475,00	14833,00	6581,00	-736,00	11716,00	1987,00	15673,00	-7423,00

Source: National Energy Balance 2016-2021

*Negative values indicate net exports.

5. Energy Technology Innovation

Energy and Innovation

The economy and the energy sector are undergoing a digital revolution, combining state strategies and market forces, expanding connectivity, and introducing Artificial Intelligence - AI applications and other technologies. There is potential for high efficiency and competitiveness gains, as well as changes in the labor market, and cybersecurity will be an increasingly relevant issue.

The prospect of further digitalization in energy production and use, through increased diffusion of Information and Communication Technologies (ICT), is associated with the evolution of connectivity, big data collection and analysis, and automation. With regards to energy use, as demonstrated during the Covid-19 pandemic, ICT infrastructure already enables remote work to be performed by many professional categories.

The digitalization of energy systems, from the exploration and production of oil and natural gas, pipelines, refineries, agricultural systems for bioenergy, all the logistics of fuel distribution, the most diverse consumer units, such as industrial plants and ships, to homes and vehicles, brings enormous opportunities and potential for increasing the efficiency of these systems.

The prospection and creation of businesses based on the appropriation of these efficiency gains have dictated transformative competition and innovation at a fast pace, such as, for example, the greater openness and liquidity that can be promoted by the creation of digitalized trading systems, with price disclosure and information transparency in real time.

The electricity sector is very likely to see digitalization profoundly change its market structure and transactions, the way infrastructure is used, and consumers' relationship with this system. Ultimately, such a digital revolution will lead to the creation of smart grids in the electricity sector that will allow for greater observation capability, better control of assets and their performance, data analysis from system operation, and greater responsiveness of prices.

Allied with the so-called distributed energy resources, the implementation of smart metering, by providing bidirectional energy flow, better management of the consumption profile and enabling demand response, is one of the key variables for the decentralization of the electric system operation and for the creation of new energy business opportunities in retail.

This vision of the future is already becoming a reality in several countries and will reach Brazil at a greater or lesser pace depending on the policies formulated, the regulatory environment and the income profile of consumers. One has to recognize the many benefits of digitalization, but also the high investment costs required, bringing to the agenda the discussion about who bears these costs and how to share the benefits fairly.

The growing digitalization in the production and use of energy will enable new opportunities in terms of new businesses, more efficient tariff and pricing structures, and better adequate management of the various consumption profiles. Due to its profound changes, it is recommended to follow the pace of implementation of smart metering and monitor the possible impact of new technologies (internet of things, cloud computing, big data, data analytics, artificial intelligence, blockchain, etc.) on the energy sector, including analysis in planning studies. On the other hand, new challenges will also appear, such as vulnerability to cyber-attacks, vis-à-vis the cost of information security, and the new role of centralized operation in the integrity of the power system.

Brazilian Ten-Year Energy Expansion Plan (PDE 2031)

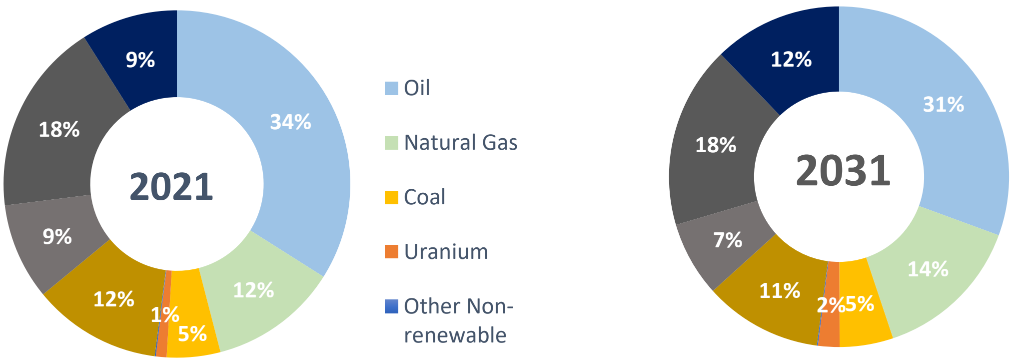
Launched in April 2022, the Ten-Year Energy Expansion Plan indicates the prospects for expanding the energy sector for the next 10 years (2022 to 2031) within an integrated vision for the energy sources. The plan is prepared annually by the Energy Research Company (EPE) under the guidelines and support of teams from the Ministry of Mines and Energy, coordinated by the Secretariats of Energy Planning and Development (SPE/MME) and Petroleum, Natural Gas, and Biofuels (SPG/MME). The studies of the plan support energy policy decisions and provide the market with information that allows the analysis of the development of the electric system and the supply adequacy conditions under different possible future scenarios.

For this, the PDE is built based on the most important dimensions associated with energy planning: economic, strategic, and socio-environmental. In the economic dimension, the plan aims to present energy needs from the perspective of planning to meet the expected growth of the national economy. In the strategic dimension, the PDE's studies highlight the best use of national energy resources, within a medium and long-term vision and encourage regional integration. Finally, in the socio-environmental dimension, the expansion of energy supply must be done with access to the entire Brazilian population and considering socio-environmental aspects.

As for highlights, there is a trend of relatively parallel growth between GDP, total energy supply (TES), and total electricity supply, which should grow, between 2021 and 2031, on average, 2.9%, 2.7%, and 3.4%, respectively. At the end of the period, it is estimated that the Brazilian GDP will reach 5.4 trillion reais, the TES will reach 384.4 billion toe, and the total electricity supply 945.1 TWh. For the TES (Figure 1.1- 8), the main highlights are the expansion of Uranium and Derivatives, and Other Renewables, which include Solar and Wind, with a decrease in the share of Oil and Hydroelectricity, indicating the path to less dependence on those that today

are the main sources of the energy and electricity matrix, respectively.

Figure 1.1-8 Total Energy Supply by Source 2021/2031

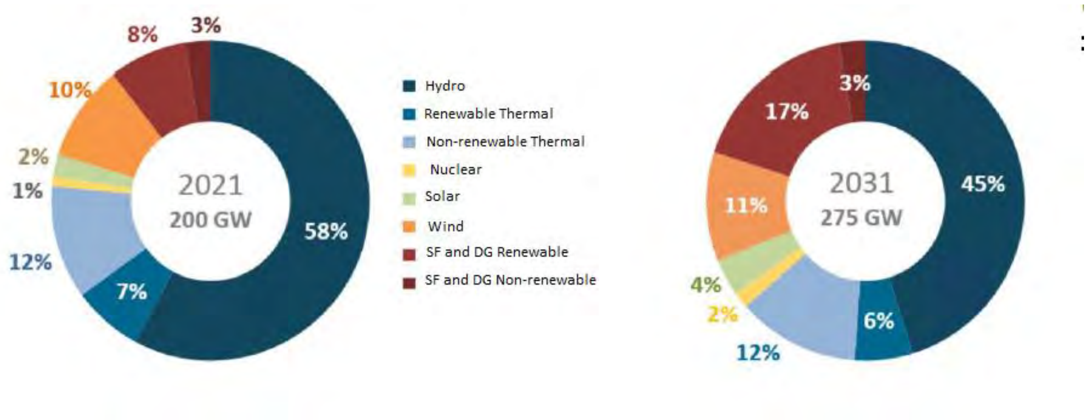


Source: PDE 2031

Regarding the renewability of the Energy and Electric Matrices, it is expected that the indexes will remain at levels similar to the current ones, for the former, from the current 45% to 48%, while for the second it is estimated an advance from the current 78% to 84%. There is a demonstration of Brazil's ability to expand its energy and electricity supply stably and economically, without, however, affecting its renewability and emissions, maintaining its recently reaffirmed commitments at COP-26, held in Glasgow.

In terms of electricity generation, the new paradigm for the Brazilian scenario stands out: the strong expansion of intermittent sources in the electricity matrix, with a large participation of the non-centralized sector, the Auto producers, the Mini/Micro Distributed Generation (MMGD), which will increase from the current 67 TWh (10% of the total) to 141 TWh (15%). This reflection also appears in the Installed Capacity of Electricity Generation (Fig. 1.1-9), with the ten-year increase for centralized generation reaching 23%, while for Auto producers and MMGD, reaching an impressive 162%.

Figure 1.1-9 Evolution of Installed Capacity



Source: PDE 2031

It is also interesting to note the prospect of expansion of oil and natural gas production until 2031, of 77% and 97%, respectively, mainly due to the supply coming from pre-salt reserves, with complementarity from post-salt and extra pre-salt. This scenario points to the expansion of the condition of net exporter of oil in Brazil, and by 2031, the total exported would correspond to 66% of national production, allowing Brazil to move towards becoming one of the five largest exporters in the world, increasing the geographic and political importance of Brazil in the world's oil market.

A major addition to the PDE made in the 2031 edition was a chapter referring to Hydrogen. It is known that currently, Hydrogen is one of the main fuels for the future in terms of energy disruption, being able to provide a decrease in the use of fossil fuels in extremely dependent sectors, such as transport, and at the same time, allowing a coupling with the electricity sector, as a complementary mechanism for intermittent sources (such as solar and wind). The PDE notebook deals with both the current scenario of production and the fuel market, as well as the global and national perspectives, presenting not only existing projects but also the estimated potential (Table 1.1-2) for production from the resources presented in the National Energy Plan (PNE 2050).

Table 1.1-2 PDE 2031 Estimates of Technical Potential for Hydrogen Production based on balance of PNE 2050 resources

Energy Resource	Hydrogen Potential 10^6 t/year
Renewable - Offshore	1.715,3
Wind Offshore - 10 km dist.	11,2
Wind Offshore - 50 km dist.	39,8
Wind Offshore - 100 km dist.	50,2
Wind Offshore - EEZ	249,2
Oceanic	8,8
PV Offshore	1.356,1
Renewable - Onshore	18,1
Biomass	50,5
Nuclear	6,9
Fossil	60,2
Total	1.851,0

Brazilian Long-Term Energy Plan (PNE 2050)

On December 16, 2020, the Minister of Mines and Energy approved the National Energy Plan 2050. Prepared by the Energy Research Company (EPE) based on MME guidelines, the plan is an instrument to support the design of the national planner's long-term strategy concerning the expansion of the energy sector. To this end, a set of recommendations and guidelines to be followed throughout the 2050 horizon is presented, with the strategy design defined by the Plan, with a subsequent implementation through an Action Plan and the monitoring and readjustment of the strategies through a Strategic Action Monitoring Plan. Recently, in cooperation between EPE and MME, it was decided that both plans (action and monitoring) would be "coupled" in an interactive tool capable of addressing both needs, while making public the strategies already in place and to come.

Despite certain similarities, the PDE and the PNE are not complimentary documents. The PNE is a document with a more strategic vision and its focus consists of grounding the government's position to orient and direct the strategies of the sector's agents to achieve the general expansion objectives in the long term, with adequate resources, reliability, moderateness, and sustainability.

The structure of this report is composed of two parts: the first part presents the main factors that condition the evolution of the energy sector, called cross-cutting questions. Also, the general results of the long-term analysis exercise and the main directions for the design of the long-term strategy are described; in the second part, the analysis is disaggregated by type of technology, energy-transportation infrastructure (electricity transmission and gas pipeline network), and by consumption segments, generating a total of 21 total studies on different themes that are the basis for the results and indications presented.

It is worth mentioning that because it was partly carried out and impacted by the initial effects of the Covid-19 Pandemic, the PNE 2050 was created in such a way as to address the difficulty in fully measuring future planning in face of the unusual moment in which it was inserted. Thus, its premise was based on different scenarios (Stagnation and Expansion Challenge) to generate a "cone of uncertainty" (Fig. 1.1-10) that allowed greater scope for evaluating different variations on the planned strategies. Thus, one can indicate that the Plan would serve as a "beacon" to indicate the path to the national planner, and not a way already fully paved, thus allowing the results not to become dated in the face of change.

Figure 1.1-10 Cone of Uncertainty

Source: PNE 2050.

Moreover, it is noteworthy that the PNE 2050 is aligned with the bases of the legal and infra-legal framework of long-term planning adopted by Brazil, these being: Technological Neutrality, Encouragement of Competition, Isonomy, Efficiency, Predictability, Simplicity, Transparency, Coherence, Sustainability, and Precaution. The main discussions of the PNE 2050 were separated into four main macro themes: Cross-cutting Questions, Sources and Technologies, Energy Transportation Infrastructure, and Consumption Segments.

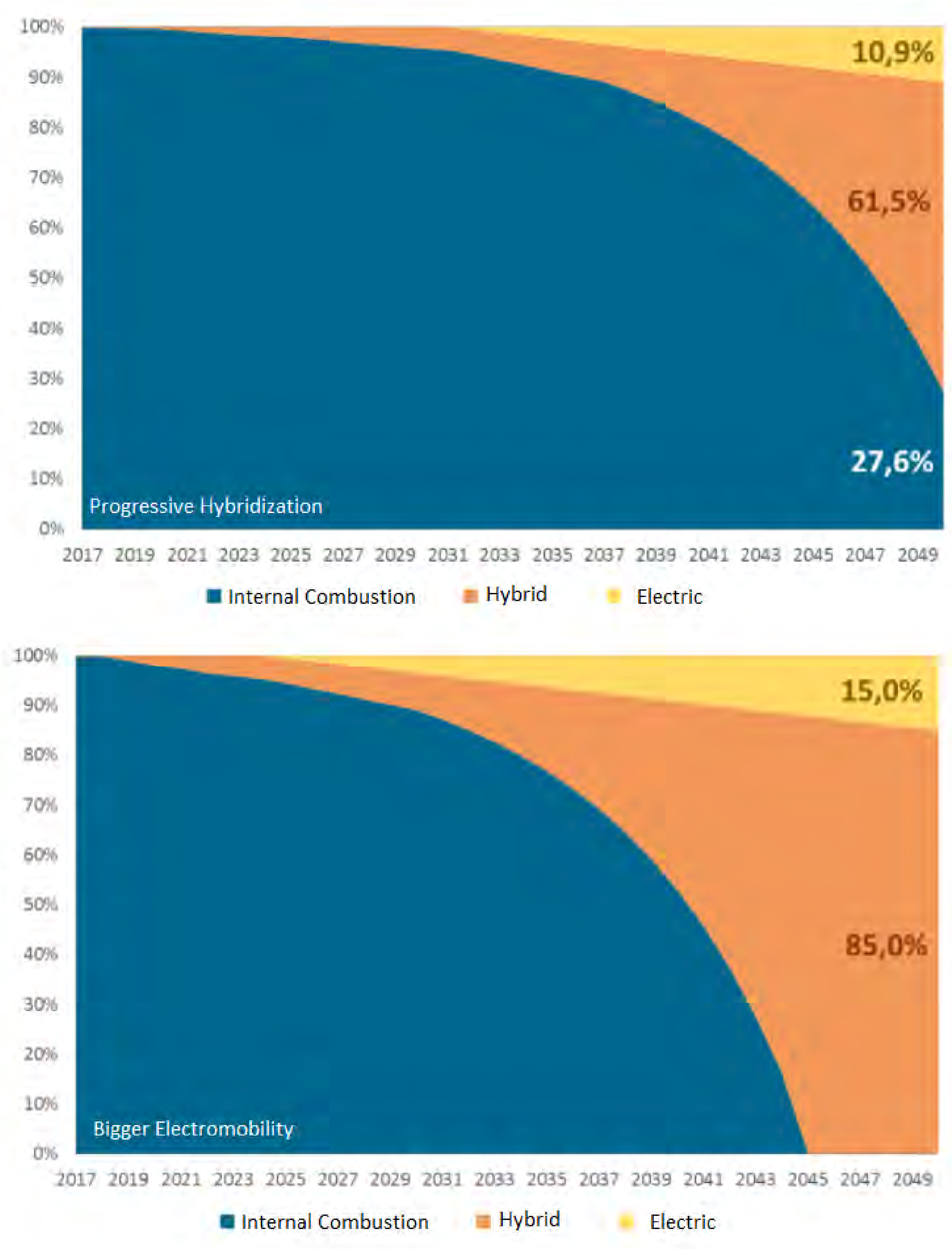
Concerning the Cross-cutting Questions, 9 main themes were mapped referring to planning, with emphasis on the relationship between energy transition, climate change, decentralization, and the market design of the various sources and technologies aiming not only at greater competitiveness but also greater participation of digitalization and regional (South American) energy integration in planning.

The Sources and Technologies address both those already existing and relatively consolidated, as well as new disruptive possibilities, indicating ways to improve and advance what is already done and fostering possibilities for new technologies, with the emphasis here on Hydrogen, where it is expected to be a relevant role of Brazil in global terms, offshore electricity generation, 2^{nd} generation Lignocellulosic Ethanol, Small Modular Reactors (SMR), Nuclear Fusion, Geothermal Surface and Wireless Transmission of Electricity.

In Energy Transportation Infrastructure, two main topics were mapped, Electricity Transmission and the Gas Pipeline Network, observing the insertion of Flexible Alternating Current Transmission System (FACTS) and High-Voltage Direct Current (HVDC) in terms of power electronics devices applied to the system, as well as the new reality of greater competitiveness for gas pipelines after the new market design initiated through the New Gas Market.

About the Consumer Segments, there are highlights for three main themes: Transportation, Industries, and Buildings. For the last two, there is an indication of technologies that can provide efficiency improvement and reduction of technical losses, as well as propositions for greater freedom of participation in the generation and consumption of the electric energy market. As for transport, the highlight is a separate book related to Electromobility of the car fleet and its perspectives for Brazil in a favorable context of biofuel use, as Brazil is at the moment, indicating two possible scenarios (Fig. 1.1-11) for electrification of the light car fleet: a scenario of progressive hybridization, desired by Brazil because of the potential of biofuels in both flex cars and Solid Oxide Fuel-Cell (SOFC) electric cars; and another scenario called greater electromobility, with a more ambitious and complex goal of complete abandonment of internal combustion cars by 2050.

Figure 1.1-11 Scenarios for electromobility proposed by PNE 2050.



6. Policies and Programs

Electricity Sector Modernization

The Electricity Sector Modernization lists a set of proposals to make improvement and modernization feasible, based on the pillars of governance, transparency, and legal-regulatory stability, dealing in an integrated way with topics such as market opening, allocation of costs and risks, criteria supply guarantee, reduction of bureaucracy and process improvement, pricing, governance, insertion of new technologies, ballast and energy, Energy Reallocation Mechanism (MRE), contracting process, rationalization of charges and subsidies, auction system, distribution sustainability, and transmission sustainability.

The basic guideline of the electricity sector modernization process is to bring electricity to consumers in a competitive manner, ensuring the sustainability of the expansion, with the promotion of market opening and efficiency in the allocation of costs and risks. However, to achieve these objectives it is necessary to ensure:

- Supply guarantee: al lelectricity consumers, free or captive consumers, must haveaccesstoelectricity, in the volume andatthe time theyneed it;
- Financing of the projects: the preservation of the economic and financial viability of the projects is a fundamental condition, because of the need to expand the system;
- Consumer freedom: consumers: must have information and the ability to choose their electricity services, including their supplier;
- Credible prices: prices must be transparent and adhere to the operating reality of the system, allowing agents to be reproducible and predictable;
- Environmental sustainability: responsibility in the use of natural resources; Competitiveness and innovation: the model should encourage competitiveness and innovation in all links in the electricity sector chain through market solutions;
- Insertionof new technologies: the legal and regulatory framework must be neutral to the insertion of new technologies; Integration with other sectors of the economy: the model must allow the capture of synergies with other sectors of the economy; and
- Universalization of access: the model must allow consumers to access electricity efficiently.

Thus, the main aspect of the Modernization of the Electricity Sector is to become a great promoter of innovation and continuous improvement of the models, structures, and markets that currently exist in the electricity sector.

Hydrogen National Program (PNH2)

As presented in the topic referring to the PDE 2031, hydrogen is one of the greatest global "bets" to address the need for decarbonization of the economies. In this sense, several countries have created efforts to implement and present strategies focused on the technological and economic development of hydrogen.

The PNH2 has as its goal the development and paving of the fuel and its obtaining technologies in the Brazilian energy matrix, allowing a trajectory of net neutral carbon emissions, considering the characteristics of the Brazilian economy and market, as well as Brazil's position in terms of opportunity at a world level, considering the high index of renewability of the electricity matrix that Brazil already has, as well as the growing offer of natural gas production, today, the main vector of hydrogen generation.

Therefore, the principles of the National Hydrogen Program are:

- - To value the potential of energy resources, recognizing the diverse sources for obtaining hydrogen, renewable or not, as well as the wide range of applications in multiple sectors of the economy (transportation, energy, steel making, and mining, for example);
- - Be comprehensive: recognizing the diversity of available or potential energy sources and technological alternatives, including possible synergies, for hydrogen production, logistics, storage, and use;
- - Align with the ambitions of decarbonization of the economy: considering trajectories that make it feasible for hydrogen to contribute to net carbon neutrality by 2050;
- - To value and encourage the national technological development: taking into account the investments and experiences already existing in Brazil and the need to continue the effort in research, development, and innovation, aiming at the qualification and technological autonomy and development of the national productive system;
- - Aim at the development of a competitive market: considering the potential of internal demand and export of hydrogen as well as the evolution of costs and risks in the short, medium, and long term;
- - Seek synergies and articulation with other countries: recognizing that this market must have global reachand its development can be accelerated through international cooperation and coordination; and
- - Recognize the contribution of the national industry: Brazil has a robust industrial base for the production of capital goods, products, and services able to contribute to the hydrogen economy.

From another perspective, the PNH2 proposes to define a set of actions that facilitate the joint development of 3 fundamental pillars for the success of the hydrogen economy development path: public policies, technology, and the market. These are interdependent pillars that need to evolve synchronously to promote an acceleration in the achievement of the desired results.

The first steps have already been initiated with the development of the program's guidelines, as well as studies and technical notes already produced by EPE regarding the various existing colors for hydrogen, indicating its different production origins. This aspect meets the principle of technological "no lock-in" on which the energy planning is based, allowing decisions to be made without technological regrets because of the abundant resources and possibilities that Brazil has. The existing projects related to Hydrogen and their scale and present stages are presented in Table 1.1-3.

Table 1.1-3: Hydrogen Projects in Brazil

Project	Company	Place	Scale	Phase
Purification of generated H_2	Eletronuclear	Angra I and II - RJ	150-300 kg H_2/d	R&D
H_2V	PTI	Porto do Pecém - CE	Pilot	R&D
Hybrid H_2V (UHE e FV)	Furnas	Itumbiara-GO	Pilot	R&D
Steam reforming of bioCH_4 to produce bioH_2 and NH_3V	Yara with CH_4 from Raízen	SP's Countryside	20.000m^3/d	Commercial in 2023
H_2V in public transport	Neoenergia	CE		MoU
Fertilizer (NH_3V)	Unigel	Camaçari – BA	Commercial	Conversion on end of 2022
H_2V e NH_3V - wind	Enterprize Energy	RN	Commercial	MoU
H_2V	Fortescue	Porto do Açu - RJ	Commercial (300 MW è 250 kt NH_3)	MoU
H_2V	Fortescue	Porto do Pecém - CE	Commercial	MoU
H_2V	Enegix	Porto do Pecém - CE	Commercial (600 kt H_2)	MoU
H_2V	Qair	Porto do Pecém - CE	Commercial (540 MW)	MoU
H_2V	White Martins (Linde/Praxair)	Porto do Pecém - CE	Commercial	MoU
H_2V	EDP	Porto do Pecém - CE	Commercial (250 m^3 H_2/h)	MoU
H_2 blue andgreen	Qair	Porto de Suape - PE	Commercial (540 MW)	MoU

Project	Company	Place	Scale	Phase
H_2V	Neoenergia	PE	Pilot	MoU

Source: PDE 2031.

Between 1999 and 2018, an amount close to R$ 200 million was invested in projects for the production of renewable hydrogen and research related to the development of hydrogen in various routes. It is also worth noting that CNPE Resolution No. 2/2021 is an important instrument, as it identifies fuel as one of the priority topics for allocating resources in Aneel and ANP Research programs. In addition, Brazil was the first in Latin America to develop a fleet of buses powered by a hydrogen fuel cell, used in a metropolitan section of São Paulo.

Decree 10,946/2022 – Assignment of use of physical spaces for offshore energy generation projects

Faced with the growing demand of several projects, mainly wind, in relation to offshore projects for electricity generation in Brazil, the need arose to fill a normative gap to define future bases for regulation. In this context, Decree 10,946/2022 emerges as a beacon for this discussion and realization of these projects.

Basically, the new Decree provides for the assignment of use of physical spaces and the use of natural resources in areas controlled by the Union for the generation of electric energy, including the areas of the Continental Shelf, Exclusive Economic Zone, Territorial Sea and the Areas indicated in the United Nations Convention on the Law of the Sea. The assignment of use will be the responsibility of the Ministry of Mines and Energy (MME), being onerous when it has the purpose of operating a power plant in the regime of independent production or self-production, one of the main bets of private companies, due to the potential for hydrogen generation. For cases of research activity, the assignment will be free of charge.

Thus, the decree is a clear signal for Brazil to attract investments and explore new modalities of energy production, with prospects for the creation of a new national energy market, with great potential for prominence at the international level. In this sense, the MME, through the SPE, held on May 11, an event called *"Workshop Desafios e Oportunidades – Geração Offshore no Brasil"*, bringing together various actors, public, private and sectorial agencies, for an open debate on the themes of environmental licensing, management and marine assignment, barriers to be overcome, impacts on the supply chain, regulatory challenges and opportunities for synergies from the decree, starting the procedures for future regulation.

New Natural Gas Market

The New Natural Gas Market is the program launched by the Federal Government, which aims to renew the natural gas market in Brazil, to promote greater openness, dynamism, and competitiveness. Its pillars are the promotion of competition, harmonization of regional and federal regulation, greater integration of the natural gas sector with the electricity and industrial sectors, and the removal of tax barriers. The main legislative instruments are Law No. 14,134 of 2021, called the “New Gas Law”, and Decree No. 10,712 of 2021, which regulates the law.

The main goal of the New Natural Gas Market is the search for increased fuel competitiveness in several sectors, especially considering that among fossil fuels, natural gas has one of the lowest emissions, being an excellent candidate for a thermoelectric generation as a source complementary to other intermittent generations (such as Solar and Wind), and also a good indicator for the reduction of carbon intensity in the energy matrix, replacing the space of petroleum derivatives and mineral coal, which have emissions at higher levels (in some cases almost the double).

In this sense, the increase in the price competitiveness of natural gas thermoelectric generation, the better use of pre-salt production, the Sergipe-Alagoas (SEAL) basin, and other discoveries, as well as the resumption of competitiveness in the industry, mainly in the pulp, fertilizers, petrochemicals, steel, are some of the expected results and already initially paved by the policy.

Despite being relatively recent, the New Natural Gas Market already presents some results and impacts on natural gas: the end of Petrobras' monopoly in the sector, allowing distributors to have their markets served by new production companies, at the moment 5, in addition to the state-owned companies that remain in the market despite the decrease in participation; and during the face of water scarcity, the need for natural gas thermoelectric plants for quick dispatch, made part of the fuel price rise, but still at lower prices than those practiced in the European and Asian market, allowing Brazil to maintain electric service even responsible for the reasonableness of the tariff. In addition, markets in the Northeast were capable of sign supply contracts with more advantageous conditions than those practiced in 2021.

Renovabio

O RenovaBio is a federal policy that recognizes the strategic role of all biofuels (ethanol, biodiesel, biomethane, biokerosene, second generation, among others) in the Brazilian energy matrix in terms of their contribution to energy security, the predictability of the market, and the mitigation of greenhouse gas emissions in the fuel sector. As a result, biofuels enable an increasingly sustainable, competitive, and safe energy supply.

RenovaBio is composed of 3 strategic axes: Decarbonization Goals; Certification of Biofuel Production; and Decarbonization Credit (CBIO). In the first axis, the Government annually sets national goals for 10 years, which are deployed to fuel distributors, who are an obligatory part of the policy. In the second axis, producers voluntarily certify their production and, as a result, receive energy-environmental efficiency scores. These notes are multiplied by the volume of biofuel sold, which results in the amount of CBIOs that a given producer can issue and sell on the market, which is the third axis.

One CBIO is equivalent to 1 ton of avoided emissions, which is equivalent to 7 trees in terms of carbon capture. By 2029, it is expected that greenhouse gas emissions representing the planting of 5 billion trees will be offset, which would be equivalent to all existing trees in Denmark, Ireland, Belgium, the Netherlands, and the United Kingdom combined.

The goals were regulated by Decree No. 9,888/2019 and the certification by ANP Resolution No. 758/2018. In November 2019, the MME published MME Ordinance No. 419/2019, which regulated transactions with the CBIO. And, in December 2019, the ANP published Resolution No. 802/2019, which established the procedures for generating the necessary ballast for the primary issuance of the CBIO. This was the last regulatory action before the full operation of RenovaBio on December 24, 2019, when Brazil started to offer the solution for the low carbon economy that large companies in the world are looking for: the CBIO, an environmental asset that supports the largest decarbonization program on the planet. With the implementation of the policy, it is foreseen R$ 1 trillion in investments in the biofuel sector by 2030.

Future's Fuel Program

Created by the National Energy Policy Council (CNPE) through Resolution CNPE No. 07, of April 20, 2021, the Fuel of the Future Program can be described as an expansion of Brazil's successful experiences in programs related to ethanol (Pro-Alcohol), Biodiesel (Pro-Biodiesel) and Renovabio, allowing to further address the use of sustainable and low carbon intensity fuels. Its main objectives can be stated as:

- Integrate public policies aligned to the fuels theme (RenovaBio, National Program for Biodiesel Productionand Use, Proconve, Rota 2030, Brazilian Vehicular Labeling Program, and the National Program for the Rationalization of the Use of Petroleum and Natural Gas Derivatives - CONPET);
- Propose measures to improve the quality of fuels, promote the reduction of the average carbon intensity of the fuel matrix, the reduction of emissions in all modes of transportation, and the increasing energy efficiency;
- propose a methodology for full life cycle analysis (from well to wheel) in the various modes of transportation;
- evaluate the possibility of approximating the reference fuels to the fuels used;
- propose actions to provide the consumer with adequate information to contribute to the conscious choice of the vehicle and energy source considering the life cycle of the fuels;
- Propose studies to create a specification for high-octane gasoline;
- Propose studies to enable the use of ethanol fuel cell technology (SOFC), one of Brazil's future bets for fleet electrification, taking advantage of already existing strengths with the use of biofuels;
- Evaluate conditions for the introduction of sustainable aviation kerosene in the Brazilian energy matrix;
- establish a national strategy for the use of sustainable fuels in maritime transportation; and
- Establish conditions for the use of carbon capture and storage technology associated with the production of biofuels.

The Program has a Technical Committee (CT-CF) that meets periodically to evaluate, adjust and debate the program's guidelines and its integration with other programs related to the fuel sector. Within the committee, there are six other subcommittees, namely: Otto Cycle, Diesel Cycle, ProBioCCS (referring to Biofuels), ProBioQAV (referring to aviation fuels), Marine Fuels, and R&D&I (research, development and innovation). Each of them can still be divided into working groups for specific themes, according to the needs of each of the topics to be addressed.

Recently, the CT-CF during the meetings presented proposals for more direct integration between Renovabio and two other programs, Rota2030 and the Brazilian Vehicular Labeling Program, aiming not only at establishing energy efficiency goals, but also the well-to-wheel and tank-to-wheel life cycle analysis. Furthermore, aiming at the establishment and promotion of the use of sustainable aviation fuels (SAF), conversations were generated regarding the mandatory adoption of the addition of SAFs between 2027 and 2037, with decarbonization targets set by the CNPE, starting from 1% and going up to 10%.

II. ENERGY SECTOR

1. Coal

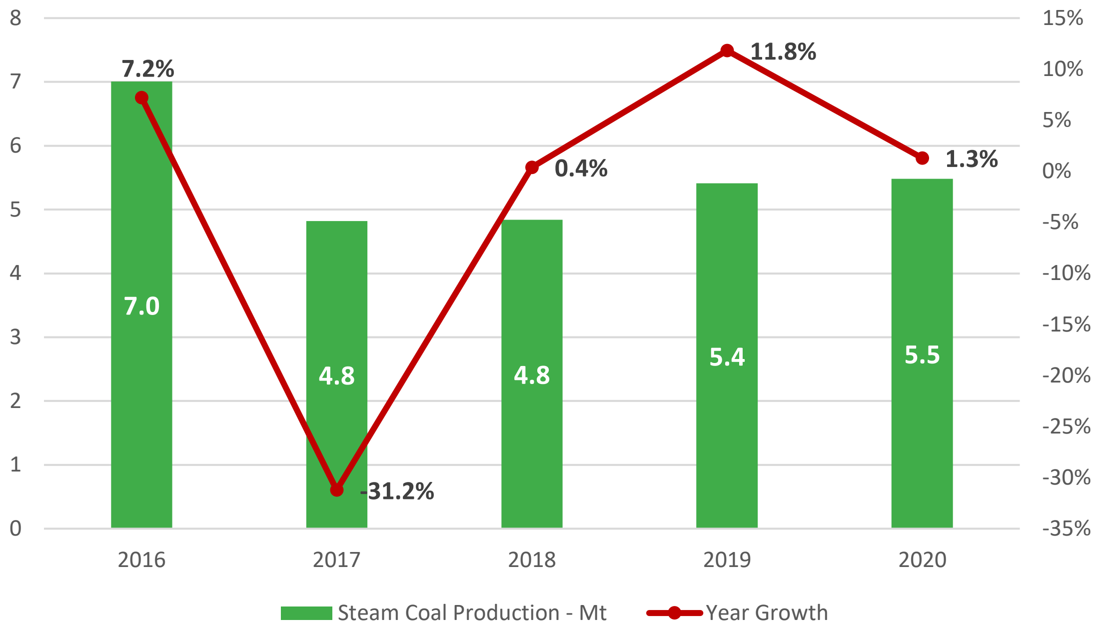
Resource Endowment

Estimates for total coal and peat reserves in Brazil are submitted through the National Energy Balance (BEN), with measured, indicated and rejected reserves being accounted for. Accounting for the aggregate, Brazil has 32,243 million tons of mineral coal reserves in 2020, 1.9% less than in 2019, with 27,095 million in steam coal and 5,148 million in metallurgical coal. In addition, another 487 million tons of peat are also considered.

Supply

The mineral coal used in Brazil can be separated into steam coal and metallurgical coal, which is not produced in Brazil and is being imported for its use. In concern to steam coal, Brazilian production (Fig. 1.2-1) fell by 21.8% between 2016 and 2020, representing an annual decrease of around 2.1%. Despite this, there was a recovery between 2018 and 2019, and although on a smaller scale, 2020 still maintains a growth trend.

Figure 1.2-1 Brazil's Steam Coal Production - 103 t

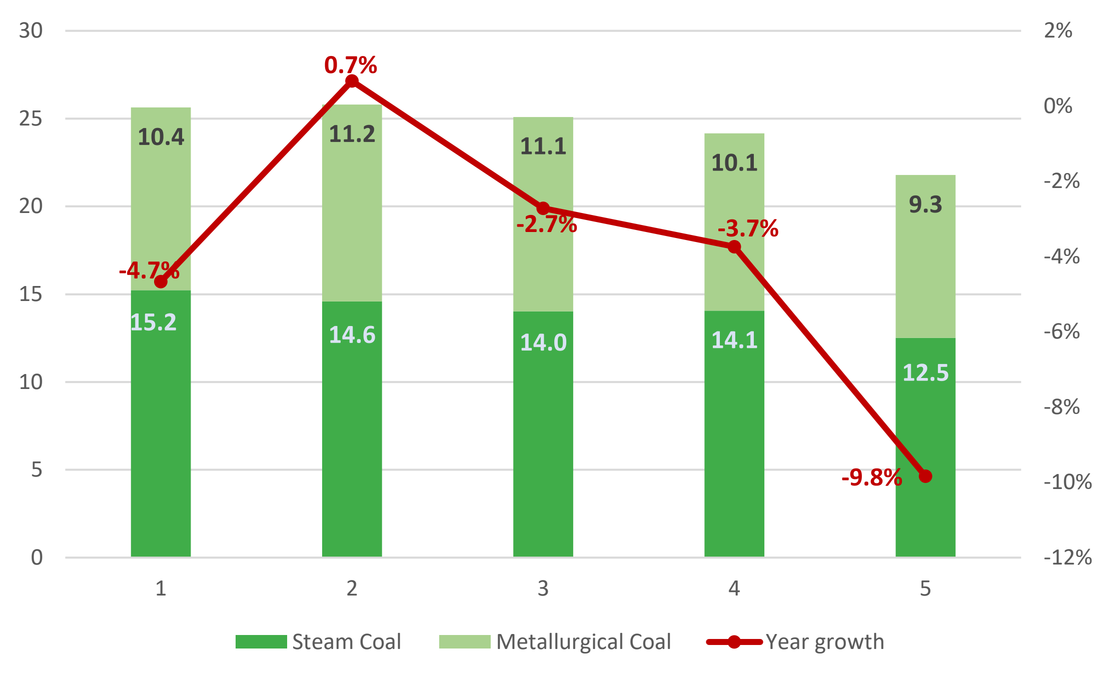


Source: BEN 2021

Consumption

The consumption of mineral coal in Brazil (Fig. 1.2-2) has observed a downward trend since 2016, with an accumulated decrease of 15% until 2020, mainly driven by the falls in both metallurgical coal and steam coal that occurred in 2020, due to the effects of the pandemic, considering that, especially the first, it is a basic input of several industrial sectors that were severely impacted, such as the metallurgical industry. Currently, the total consumption of coal, when added together, is 21.8 million tons.

Figure 1.2-2 Brazil's Coal Consumption - 106 t



Source: BEN 2021

Import and Export

As mentioned in the topic related to “Supply” of Coal, Brazil can be considered a net importer of the material, since for one of the types, metallurgical, there is no internal production, due to the quality of the type of national coal. Thus, Brazil's balance of imports and exports shows a net import (that is, minus exports) of 16.1 million tons for 2020, a decrease of 17.6% compared to 19.5 million tons in 2016, when considering the sum of both types of coal mentioned. The average annual fall was around 4.2%.

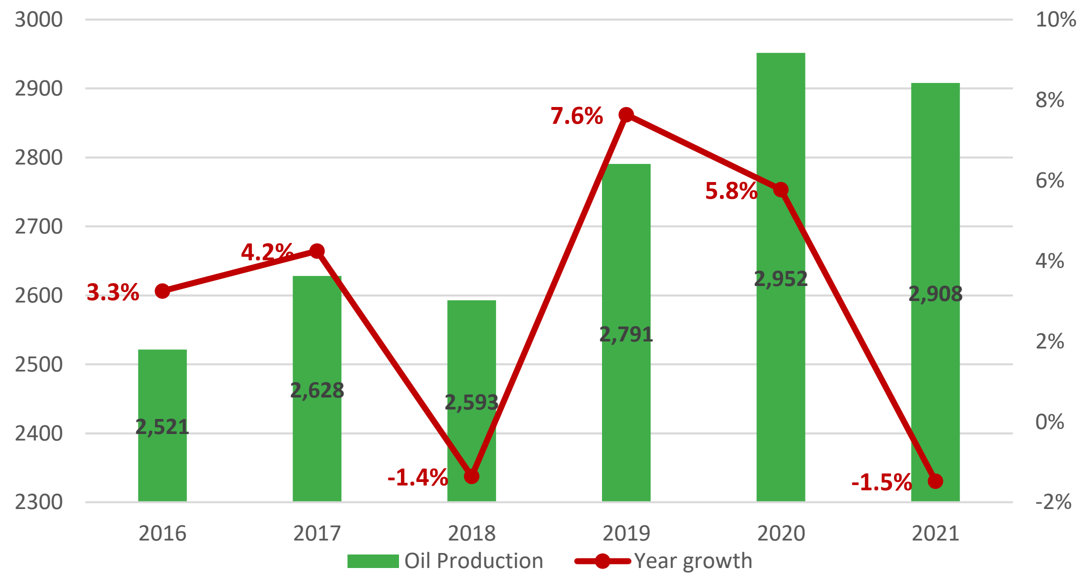
2. Oil Resource Endowment

The estimate for oil reserves is presented by the ANP through the Annual Bulletin of Resources and Reserves (BAR 2021), through 428 fields, which include 4,255 producing units possessing hydrocarbons from 14 sedimentary basins in 11 units of the Federation. In this sense, 13,242 million barrels (MMbbl) of proved reserves were declared in 2021, an increase of 11.0% compared to 2020. From the production of the year, the replacement rate of proved reserves was 227.6 %, representing an additional 2,366.8 MMbbl in new reserves.

Supply

Brazil produces around 2.9 million oil barrels per day (Figure 1.2-3) and is the 9th largest oil producer in the world. PDE 2031 estimates that this oil production could reach 5.2 million barrels per day by 2031, and that net exports of 1.2 million barrels per day in 2020 could rise to 3.4 million in 2031, raising the importance of Brazil in the international oil trade.

Figure 1.2-3 Oil Production - 10^3bbl/day

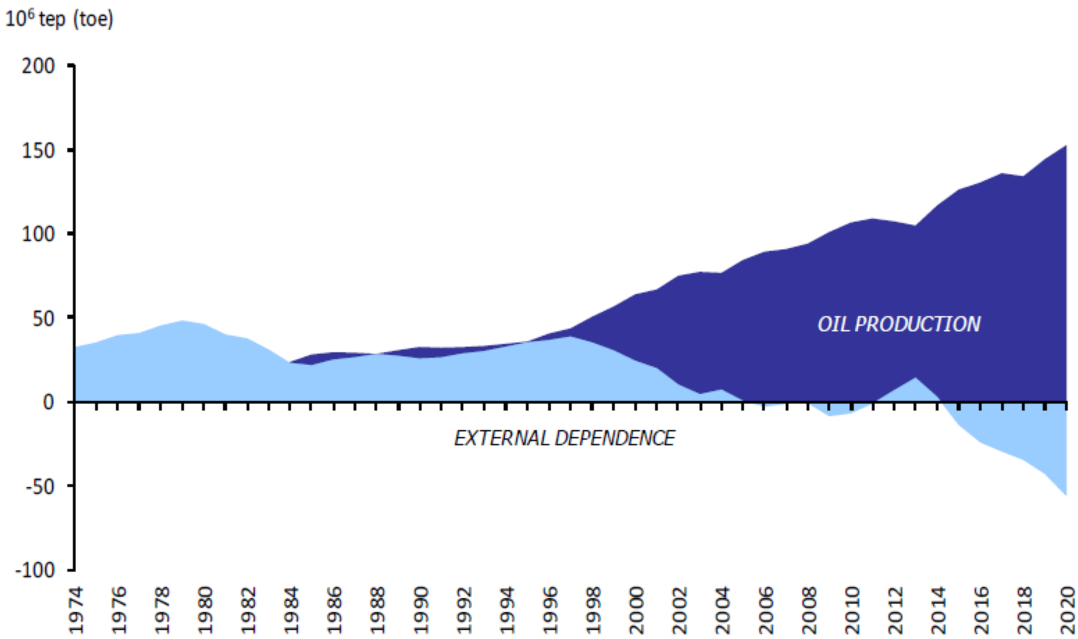


Source: BEN 2018-2022

Net oil exports have grown substantially over the last decade (more than 300%) because of increased production and stability in the refinery load. The high expansion of biodiesel and ethanol use in transport, the substitution of fuel oil for natural gas and the reduced economic growth have contributed to the stagnation of petroleum products consumption.

As of 2015, Brazil has faced a sharp decrease in its percentage of foreign oil dependence (Fig. 1.2-4), considered the relationship between the national demand for oil and its derivatives and the total production of the fuel, indicating a technical external independence from crude oil. The index in 2019 was -40.8%, advancing to -56.2% in 2020.

Figure 1.2-4 External Dependence on Oil

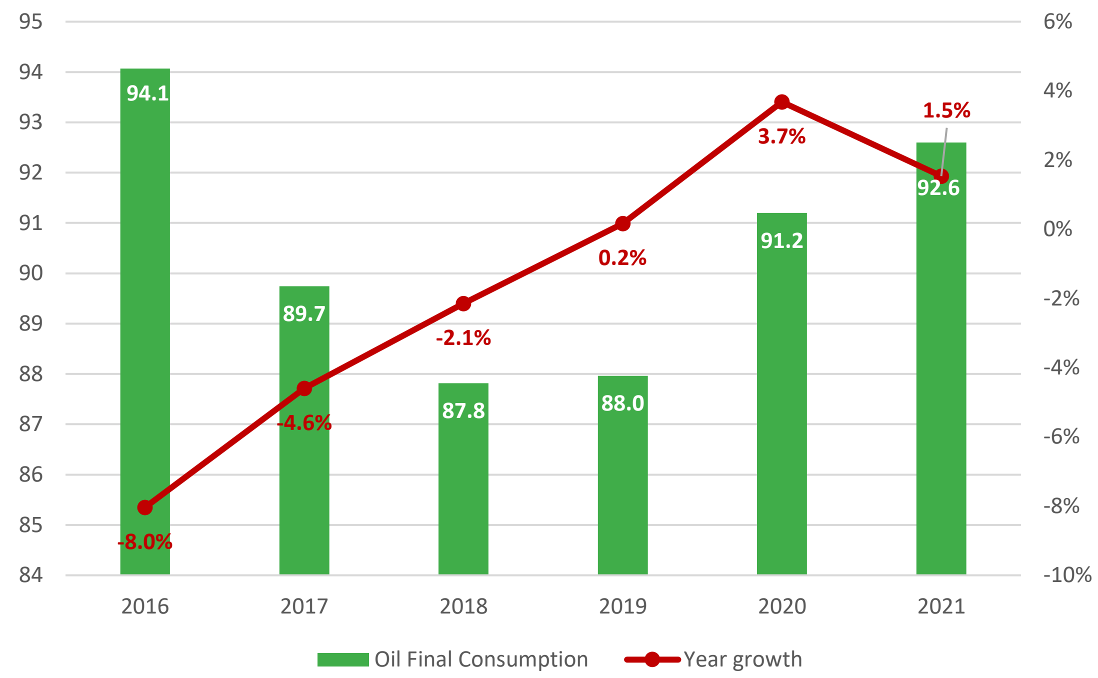


Source: Adapted of BEN 2021

Consumption

The consumption of oil (Figure 1.2-5) shown is estimated through the gross domestic supply of fuel for transformation, incorporating all the sums of oil used in refineries and other transformation processes. It is possible to observe that between 2016 and 2018, Brazil experienced a linear deceleration in consumption declines, and then began to grow at progressively higher rates, except 2021, which increased at a lower level than that observed in the previous year, due to the effects of the escalation of the international price of fuel in the face of the economic recovery of post-pandemic countries, as well as geopolitical issues. In total, consumption fell by almost 1.6% between 2016 and 2021, which meant an average annual drop of also 1.6%, from 94.1 million tons to 92.6 million in 2021.

Figure 1.2-5 **Oil Consumption - 106 toe**



Source: BEN 2021

Import and Export

Between 2016 and 2021, Brazil observed a considerable variation in its profile in the import/export balance. While there was a relevant drop of 9,51% in imports, from 8.0 to 7.2 million toe in purchased oil, exports saw a significant increase of almost 47,7%, from 43.8 to almost 64.7 million toe, expressing the profile of a net exporter of the fuel provided by the share of production from the pre-salt fields, as indicated above.

3. Natural Gas Resource Endowment

As in the case of oil, the measurement reference for natural gas reserves is presented by the ANP through BAR 2021. For 2021, 378,653 million cubic meters (MMm^3) of proved reserves were declared, an increase of 11.7 % compared to 2020. The total reserves of natural gas currently existing show that there are commercial projects for additional exploration of 75% of the volume already produced in Brazil by the end of the year.

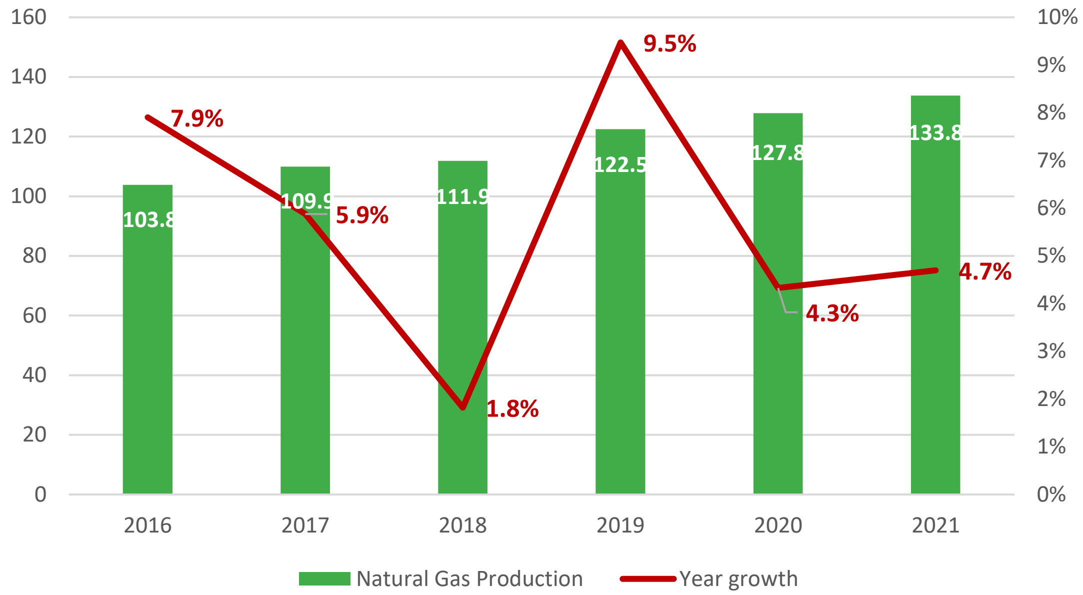
Supply

Natural gas in Brazil is used in 2 ways: Wet and Dry Gas. All gas produced from natural resources is classified as wet, while dry gas comes from gas plants, or Natural Gas

Processing Units (NGPUs) and from foreign trade. So, for wet gas, the entire gross production is accounted for identifying the non-utilized and reinjected fractions, for energy uses in oil and gas production, exploration and the volume processed in a NGPU. NGPU's products are dry gas and petroleum derivatives, also called natural gas liquids (NGL).

Brazil produced about 133.8 million m³/day of natural gas in 2021 (Fig. 1.2-6), an increase of 28.9% when compared to the total for 2016, also presenting prospects to reach a total of 277 million m³/day in 2031, considering the inflow of resources from the reserve, contingent and not yet discovered, with a large part of this total being in the form of "associated gas", where the Campos and Santos basins would account for 88% of the total production of this type of gas. In the case of non-associated gas, the influence of production units in the Campos, Paraíba, Santos, Sergipe-Alagoas (SEAL), and Solimões basins would follow.

Figure 1.2-6 **Natural Gas Production (106 m^3/day)**



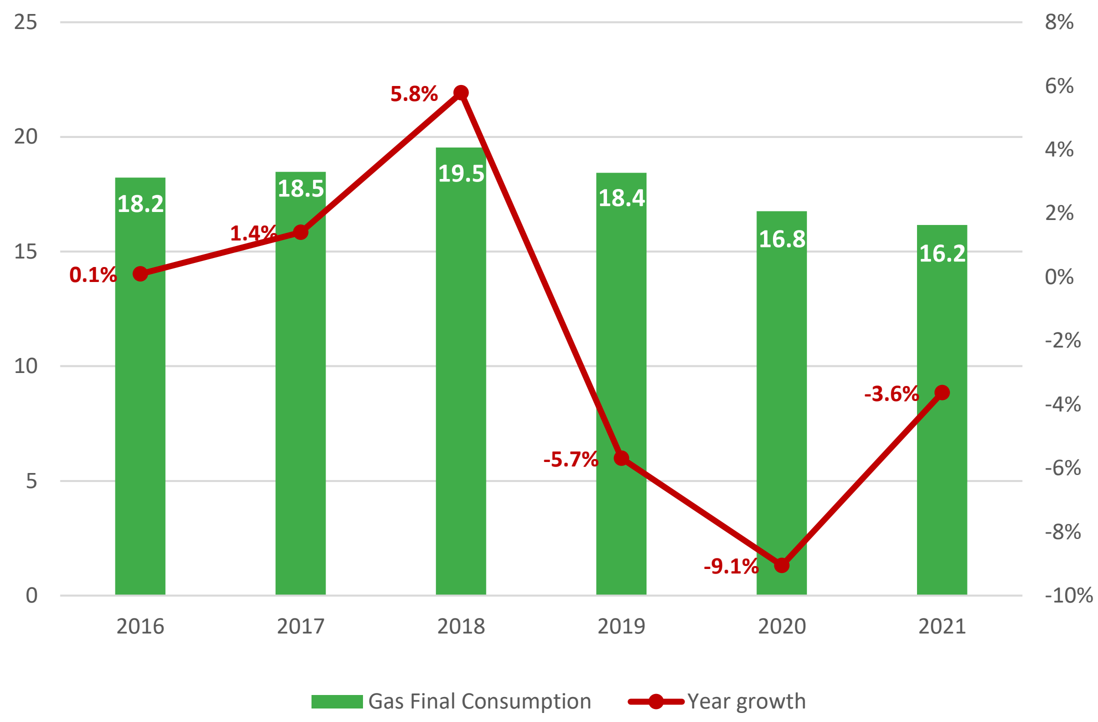
Source: BEN 2018-2022

It is expected that for the coming years the impact of the New Natural Gas Market can help in the projection of supply for the following years aiming at 2031. According to the PDE 2031 projections, there could be an advance of up to 53.4% of the total supply until 2031, when compared to the estimated demand unrelated to this projection, with the program helping to build greater integration over the period, in addition to the construction of hypothetical projects at competitive prices added to other criteria used for simulation.

Consumption

When observing the final consumption of natural gas in Brazil (Fig. 1.2-7), it is notable the presentation of 2 behaviors: initially increasing until 2018, reaching a peak of 19.5 million toe, with a subsequent fall until the 2021 level of 16.2 million. Thus, between 2016 and 2021, there was a total decrease of 11.33%, representing an index of almost 1.9% of annual decrease. Despite this, the deceleration of this decrease is visible when comparing 2020 and 2021, mainly due to the increase in fuel demand in the face of the scenario of water scarcity, for electricity generation, as well as its greater use in the industrial sector, where it increased by almost 20.8% compared to 2020.

Figure 1.2-7 Natural Gas Consumption - 106 toe



Source: BEN 2021-2022

Import and Export

Natural gas imports reached around 9.6 million toe in 2021, a decrease of almost 2% compared to the previous year and close to 48% compared to 2015, indicating a decline of 11.1% per year, a large part due to the increase in national production in association with the advance of oil production, since about 90% of the gas produced comes from associated fields. The main shares of imports came from the USA, in the form of liquefied natural gas (LNG), and from Bolivia, in the form of natural gas in a gaseous state, through the main gas pipeline in South America, the Brazil-Bolivia gas pipeline (GASBOL), which connects both countries.

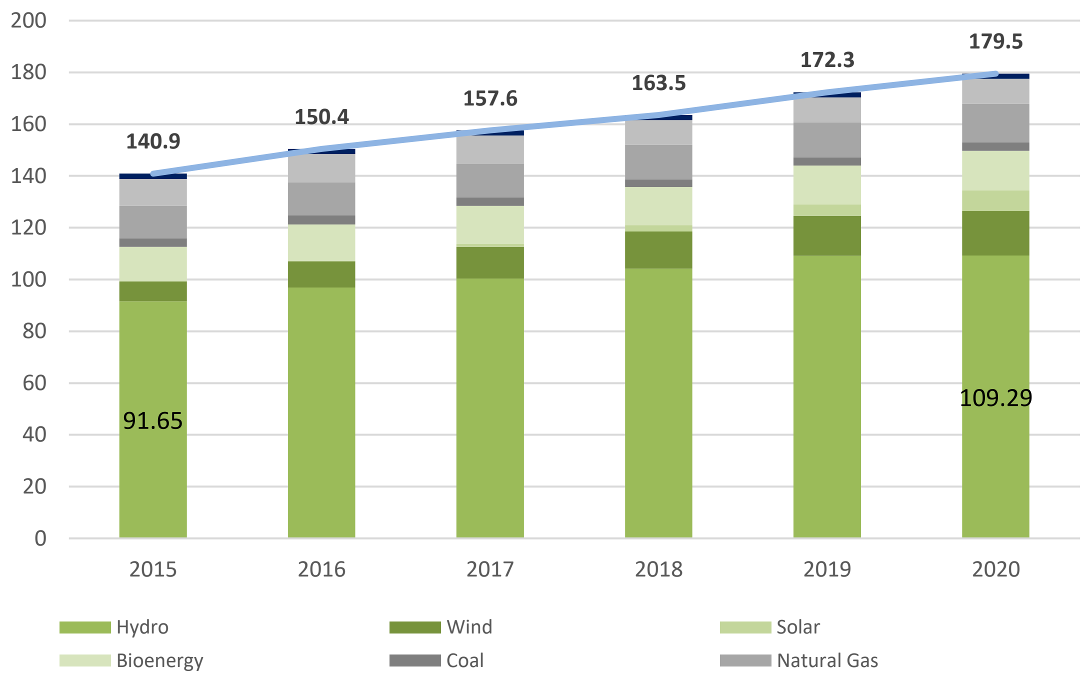
Brazil is a net importer of natural gas, not having a significant export of the fuel, mainly due to the structural limitation, national and South American, for the flow of production, which, as in the case of oil, has been heavily concentrated in the pre-salt layer. In this sense, the New Natural Gas Market is a strong approach to this issue, a regulatory framework for innovation in the sector, to attract investments and modify the current market, allowing Brazil to better manage its production and evaluate questions about exports to neighboring countries. Advances in discussions in the Southern Common Market (MERCOSUL)

Working Subgroup No. 9 have also evaluated the strategic stage for gas integration in the region, which could help Brazil to change this importing profile.

4. Electricity

For 2020, Brazil's installed electricity generation capacity (Fig. 1.2-8) reached 179.5 GW, an increase of approximately 4.2% compared to 172.3 GW in 2019. When comparing the entire period evaluated (2015 to 2020), the increase was 27.4%, representing an average annual rate of almost 5%. The strong growth in the share of wind and solar sources stands out, with an increase of 124.6% and 25,172.7%, respectively, indicating the success of federal strategies to stimulate and implement these sources in the electricity matrix, in order to increase the renewability already characteristic of Brazil, but decreasing dependence on hydroelectricity, which despite also observing an increase in the period of 19.3%, still decreases in total participation, falling from 65.0% to 60.9%. The 5.5% decrease in installed capacity related to mineral coal and the 8.3% decrease in other non-renewable sources (diesel, refinery gas, industrial effluents, etc.) the increase in the renewability index of the Brazilian installed capacity, from 79.9% in 2015 to 85.2% in 2020.

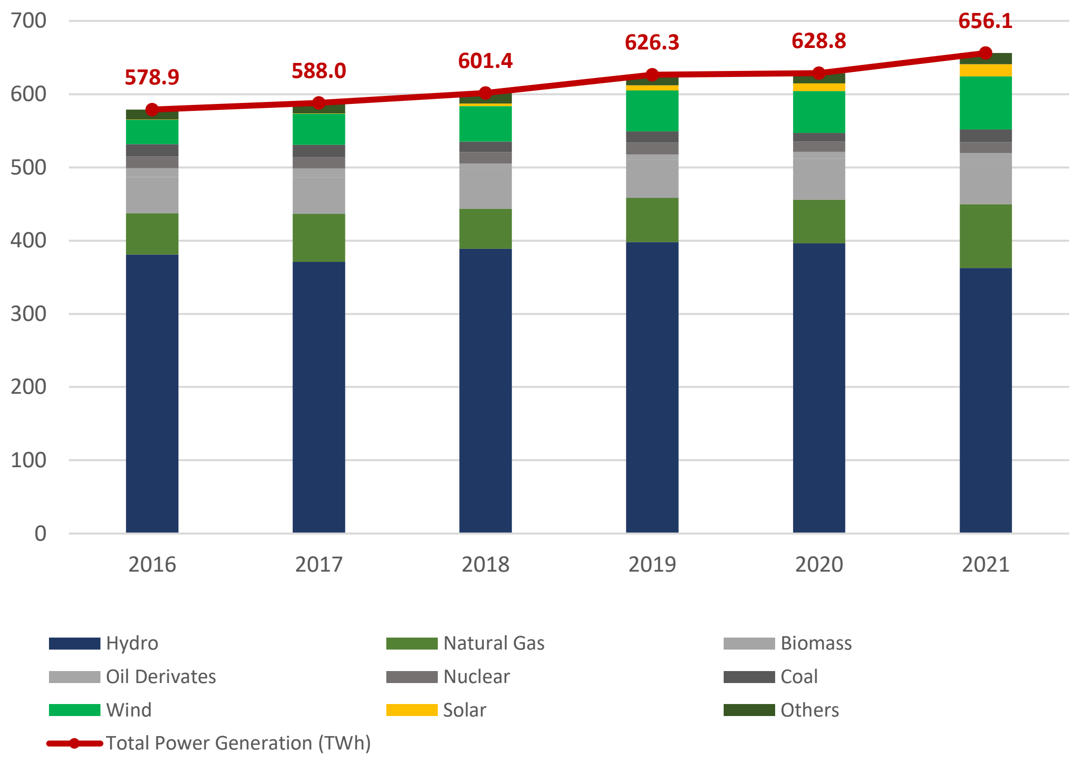
Figure 1.2-8 Brazil's Installed Power Capacity 2015-2020 - GW



Source: SIE Brazil

In terms of electricity generation (Fig.1.2-9), Brazil expanded the total by 4.4% compared to 2020, from 628.8 to 656.1 TWh, mainly driven by the advance of solar and wind generation and non-renewable thermal plants to mitigate the effect of the water scarcity suffered by Brazil during the year, indicated by the significant increase in the use of natural gas-fired thermal plants (mainly), mineral coal and oil derivatives. Although due to scarcity (there was a retraction of 8.5% in relation to the previous year), hydroelectricity is still the main source in relation to the total share, with 55.3%, followed by natural gas (13.3%) and wind power (11.0%). In general, the renewability index of the Brazilian electricity matrix suffered a slight drop, from 82.7% to 76.9%, but still remaining at a level far above that presented internationally, demonstrating Brazil's ability to face atypical and adverse situations, without, however, compromising its general profile of generation in line with environmental commitments. The economic recovery allowed by the end of the effects of the pandemic, also did not compromise Brazil's supply capacity, which increased the domestic supply of electricity by 3.9% from 2020 to 2021, with a decrease in imports by 6.5%.

Figure 1.2-9 **Brazil's Power Generation Structure (TWh) 2016 - 2021 - Source: BEN 2018 - 2022**



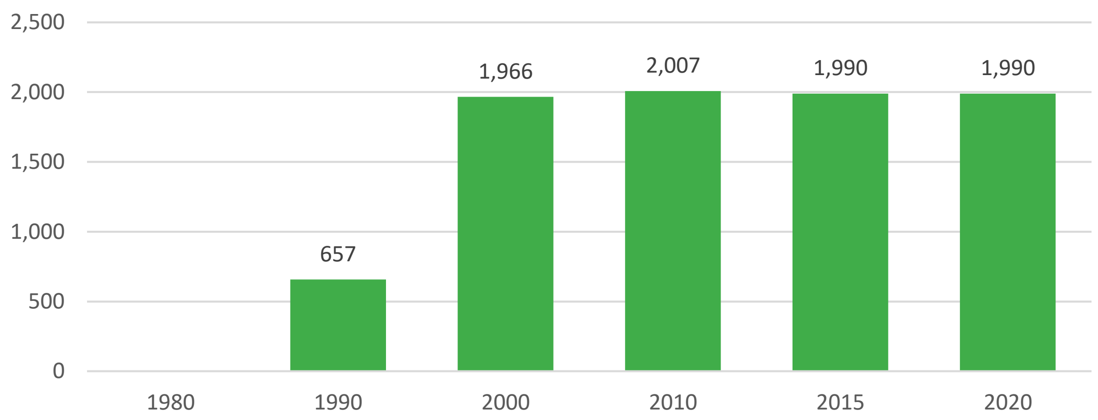
For 2031, as presented in the PDE 2031, generation is expected to increase to 945 TWh, representing an advance of 48.6% concerning the level in 2021, based mainly on the expansion of wind, solar, natural gas, and growing share of Micro and Mini-Distributed Generation (MMGD). In this sense, the advance of self-producers and MMGD will change the profile of the planning and management of the system, making it more decentralized and dynamic, allowing more investments, but also a greater number of uncertainties. The Modernization of the Electricity Sector, a program mentioned previously, is one of the government's main actions to address both fronts in this context, seeking to promote an attractive, competitive, and efficient environment, at the same time as safe and reliable.

Briefly highlighting non-renewable sources, natural gas is undoubtedly the main bet in terms of non-renewable complementarity for intermittent sources (solar and wind), and in terms of Installed Capacity, 72.3% (4.5 GW) of non-renewable contracted expansion and 90.4% (22.6 GW) refer to natural gas thermoelectric plants. However, within the scope of the variability of renewable energy sources, national coal-fired thermoelectricity can be a lower-cost alternative, when compared to natural gas, and can mitigate the effects of this variation throughout the renewable sources dispatch in the operation of the national interconnected system. It is imperative to highlight that the substitution of fuel is not proposed, but that both have space in the electricity matrix considering the majority expansion of renewables in the plans issued by the Federal Government.

4. Nuclear

Directly contextualizing the participation in the Electricity Sector, nuclear is responsible for 14 TWh of the total electricity generation. Brazil currently has 2 nuclear power plants in operation, Angra 1 and 2, corresponding to 1% of the total installed capacity.

Figure 1.2-10 Installed capacity (MW)



The above graph shows the constancy concerning the installed capacity of this source in Brazil since Brazil's nuclear park has only 2 plants. Angra 1 was implemented in 1985 and Angra 2 in 2000, resulting in the great leaps observed in those dates.

The Ten Year Energy Expansion Plan (PDE) indicates that, for 2031, nuclear electricity generation is expected to increase to 33 TWh, corresponding to 4% of total electricity supply. In terms of Installed Capacity, the source represents 1% of the existing 200 GW in 2021, with a perspective of reaching 5.5 GW in 2031, which would represent 2% of the total.

For this projection, the PDE 2031 considered the commercial operation of Angra 3 in 2027 and another nuclear power plant in 2031.

Regarding the relevant legislation, it is worth noting the recent creation of the National Nuclear Security Authority (ANSN) through Law No. 14,222/2021, an advance in the perspectives of efficient and rational use of the source, mainly considering the abundant uranium reserves that Brazil has.

It is important to mention that Angra I and II have hydrogen production plants with a capacity of 150 kg/day, intended for internal applications to ensure the integrity of the equipment. The hydrogen currently produced and used in power plants is discarded into the atmosphere. To be commercialized, the gas will have to go through a purification process.

5. Renewable Energy

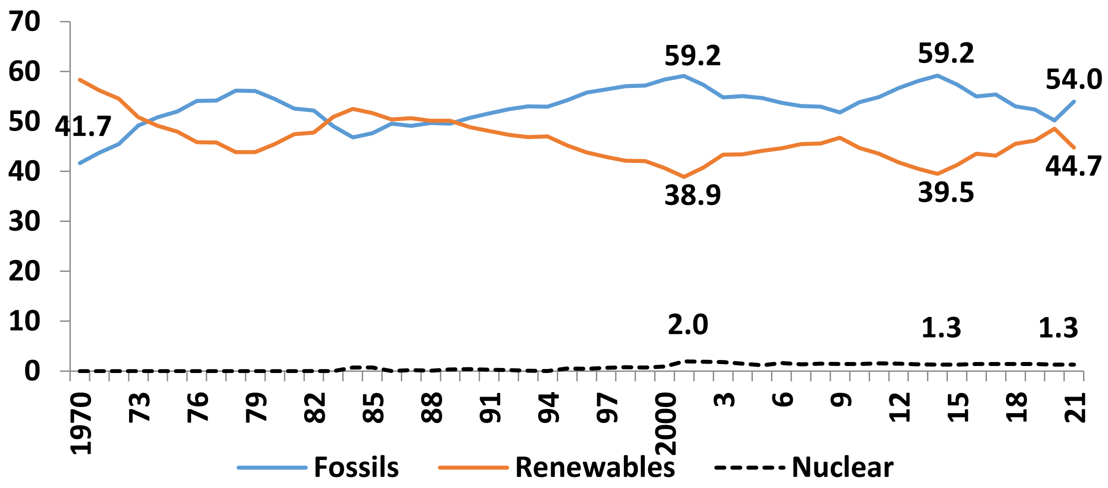
The Brazilian energy sector is one of the least carbon intensives in the world, as renewable energies represent almost half of the total energy supply (44.7% in 2021). Contributing to Brazil's low indicator are: a) renewables share near 80% in the electricity supply, b) solid bioenergy share above 40% in industrial energy consumption, and net bioenergy share above 20% in transport consumption.

Table 1.2-1 Total Energy Supply by Source in Brazil (toe and %)

Sources	million toe			% share		
	2000	2010	2021	2000	2010	2021
Oil	86,7	101,7	103,6	45,6	37,9	34,4
Coal	13,0	14,5	17,0	6,8	5,4	5,6
Gas	10,3	27,5	40,2	5,4	10,2	13,3
Other Fossils	1,0	1,1	1,8	0,5	0,4	0,6
Nuclear	1,8	3,9	3,9	1,0	1,4	1,3
Hydro	30,0	37,7	33,2	15,8	14,0	11,0
Bioenergy	47,3	82,2	93,1	24,9	30,6	30,9
Wind	0,0	0,2	6,2	0,0	0,1	2,1
Solar	0,0	0,0	2,4	0,0	0,0	0,8
Other Renewables	0,0	0,0	0,0	0,0	0,0	0,0
Total	**190,0**	**268,7**	**301,5**	**100,0**	**100,0**	**100,0**
of which, Renewables	*40,7*	*44,7*	*44,7*	*40,7*	*44,7*	*44,7*
of which, Fossils	*58,4*	*53,9*	*54,0*	*58,4*	*53,9*	*54,0*

Source: SIE Brazil.

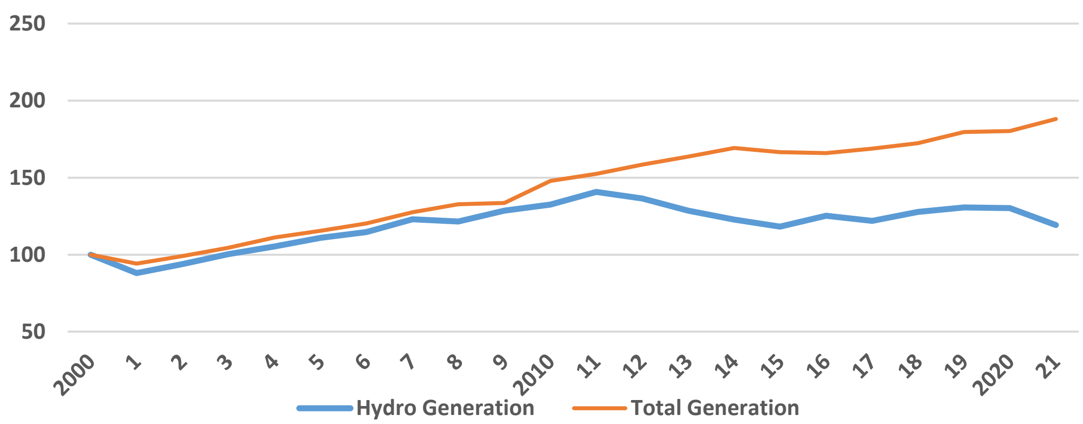
Figure 1.2-11 **Share of total energy supply by source in Brazil (%) (Source: SIE Brazil).**



Hydraulic

In the Brazilian Electricity Supply, the hydroelectricity has always been preponderant, close to 90% between 1970 and 2000, and being close to 62% in 2022. The record participation occurred in 1994, with 94.1% of the supply (including imports from the Paraguayan Itaipu share). Environmental constraints have limited further expansion of hydroelectric plants, especially large ones.

Figure 1.2-12 **Total Installed Capacity and Hydro Generation (2000 = 100)**



Source: SIE Brazil

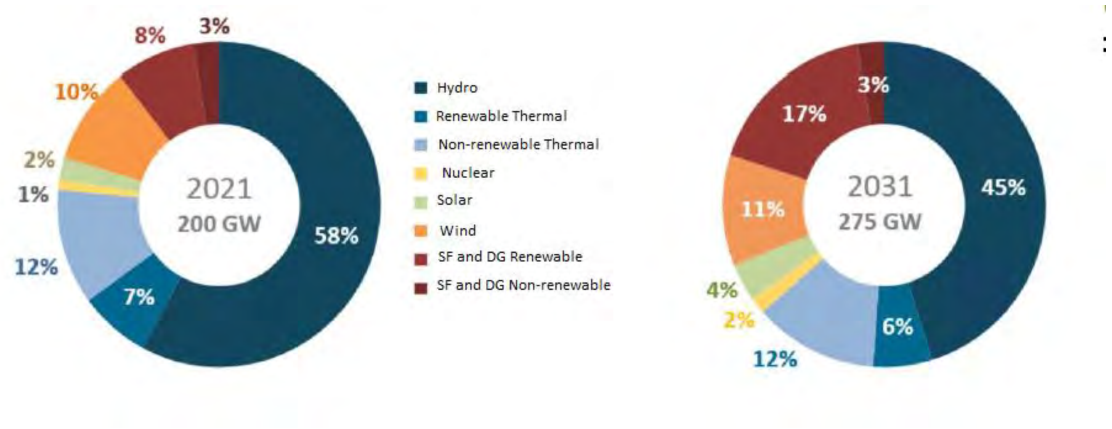
Other energy sources such as bioenergy, wind and solar are replacing the hydro electricity, so that renewable sources continue to maintain a prominent proportion in the electricity supply (Fig. 1.2-13).

Figure 1.2-13 Electricity Supply by Source in Brazil (TWh and %)

Sources	TWh			% share		
	2000	2010	2021	2000	2010	2021
Oil	13,6	13,8	17,3	3,5	2,5	2,6
Coal	7,7	7,0	17,6	1,9	1,3	2,6
Gas	4,1	36,5	87,0	1,0	6,6	12,8
Other Fossils	5,3	6,6	12,0	1,3	1,2	1,8
Nuclear	6,0	14,5	14,7	1,5	2,6	2,2
Hydro	348,7	437,9	385,9	88,7	79,6	56,8
Bioenergy	7,9	31,9	55,7	2,0	5,8	8,2
Wind	0,0	2,2	72,3	0,0	0,4	10,6
Solar	0,0	0,0	16,8	0,0	0,0	2,5
Other Renewables	0,0	0,0	0,0	0,0	0,0	0,0
Total	**393,3**	**550,4**	**679,2**	**100,0**	**100,0**	**100,0**
of which, Renewables	*356,6*	*472,1*	*530,7*	*90,7*	*85,8*	*78,1*
of which, Fossils	*30,6*	*63,9*	*133,8*	*7,8*	*11,6*	*19,7*

Source: SIE Brazil

Figure 1.2-14 Evolution of Installed Capacity



Source: PDE 2031

Centralized Solar and Wind

Regarding centralized Solar and Wind considering the total electricity generation, the 2 sources combined advance from 74 TWh (67 from wind and 7 from solar), which represents 11% of the total for 2021, to 136 TWh (114 and 22 TWh, respectively), representing 14% of the total for 2031, according to the PDE 2031. However, this expansion indicates challenges related to complementary sources, due to the limited ability for meeting the power requirements and its intermittent nature of generation. In this way, the expansions bring with them the need for complementary sources, even though wind resources are complementary with a large part of national water resources, with the winds being stronger in the drier periods, constituting a tool in the face of the water restrictions.

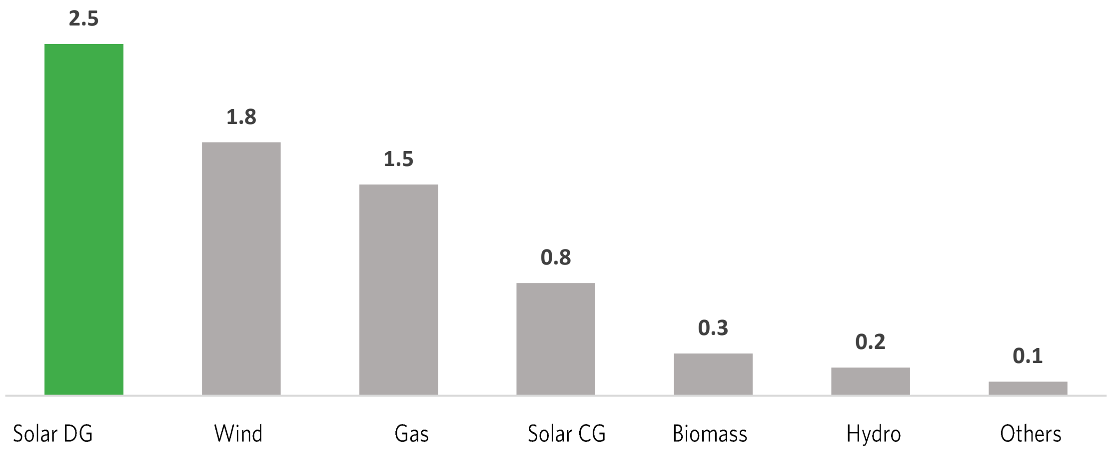
Offshore Generation

Also mentioned previously are the prospects for offshore electricity generation paved by Decree 10.946/2022, which are also a very relevant advance for the electricity sector, mainly due to Brazil's potential in various generation modalities, such as wind and solar, and its ability to also serve as a vector for enhancing the development of the green hydrogen market in Brazil, which, in the future, is expected to make Brazil one of the main "players" in this scenario.

Micro and Mini Distributed Generation (MMDG)

At a much faster pace, Brazil is currently experiencing a strong expansion of Micro and Mini Distributed Generation (MMDG), which in 2020 surpassed the expansion of all centralized sources.

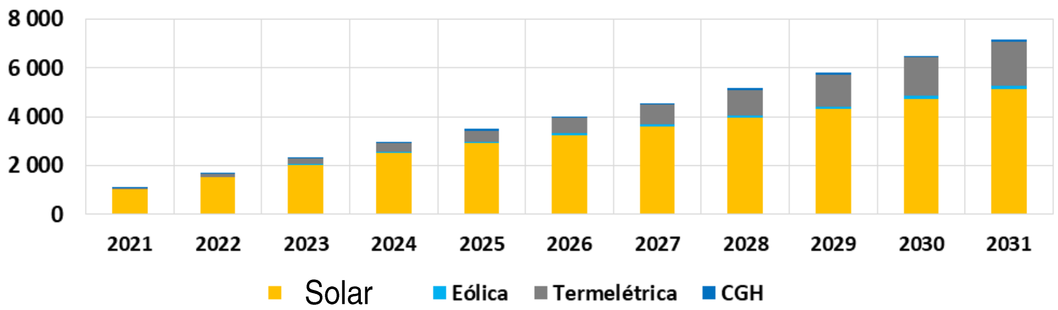
Figure 1.2-15 **Expansion of Electricity Generation Offer in 2020 [GW] - Start of Operation**



Source: PDE 2031

The forecast is that the installed capacity will reach an average of 37.2 GW for 2031, compared to 8 MW in December 2021 and a 7.1 GW average.

Figure 1.2-16 - Expansion in eEnergy of MMDG (GWmed) (Source: PDE 2031).



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6. Energy Efficiency

The Brazilian Atlas of Energy Efficiency of 2021, which set 2005 as the base year, covers the industrial, residential, and transport sectors and Brazil globally. In the period, all analyzed sectors showed efficiency gains, with the biggest gains being in the residential sector (23%) and the transport sector (16%). The Energy efficiency index of industry (ODEX) calculated in 2019 shows that Brazil was 21% more energy efficient in the period.

For the next 10 years, it is estimated that energy efficiency will reduce by 17 million toe in

2031, equivalent to 7% of Brazilian final energy consumption in 2020. Electricity efficiency, on the other hand, will reduce by 32 TWh in 2031.

Electricity Losses

In 2020, the percentage of electricity losses in distribution and transmission was 16% of the energy supply, almost twice the worldwide indicator. This is due to: a) the Brazilian territorial dimensions, with great transmission of hydraulic and wind generation between regions and; b) unbilled consumption, resulting from improper connections.

Analyzing a ten-year horizon, the greatest difficulty is investing to reduce losses, causing the level of this indicator to remain close to stability in the first 5 years. In the second quinquennium, greater economic growth generates investments that lead to a reduction in losses.

III. SUSTAINABLE ENERGY DEVELOPMENT

1. Energy Access

Achievements in Energy Access

Brazil has a continental dimension, with vast natural resources and favorable climatic and soil fertility conditions. Such characteristics have endowed Brazil with a significant potential for renewable energy resources. This potential has been progressively exploited by the Brazilian economy throughout its history through the design and redesign of legal and regulatory frameworks, as well as public policies and technological innovations. Thus, Brazil constituted a considerable hydroelectric park interconnected by an extensive electricity transmission system, which would allow the interconnection of the entire European territory, from Lisbon to Moscow. With the National Interconnected System (NIS) different subsystems can be connected. Such an arrangement allows for more energy security, as well as greater economy for consumers since one subsystem can meet the demand of another in periods of low generation and also the ability of the system to exploit the seasonality of rainfall with sources complementary to hydraulics. Thus, this system, in addition to intervening in energy access problems, such as blackouts, also encourages the use of renewable energy. Currently, the NIS is 169,914 km long and serves a large part of Brazil. The 165 locations not included in the NIS represent less than 1% of Brazil's total load (PEN SISIL 2022).

Concrete Actions to Achieve Energy Access

Brazil understands the importance of making this resource universal and even with the advance resulting from the NIS, programs have emerged to ensure energy security for the entire population. Among these, the Luz para Todos Program (LFA) emerged, since its implementation in 2004, it has already invested more than BRL 29 billion, which resulted in the service of 3,177,253 consumer units in the interior of Brazil. Several demands are met by the program, from the implementation of lighting poles to complete photovoltaic solutions. The LFA benefited more than 16 million people (ELETROBRAS, 2021).

In 2020, seeking even further expansion of access to electricity, the More Light for the Amazon Program was created to serve areas that are difficult to access via the conventional electricity grid. The program values not only the universalization of the resource but also the renewability of the source associated with the generation of these communities. BRL 124.11 million has already been invested in serving 1,556 consumer units (ELETROBRAS, 2021).

Another program aimed at providing access to electricity for the Brazilian population is the Social Electricity Tariff, a benefit granted by the Federal Government to the low-income population. Through it, the citizen receives a discount of 10 to 65% on the monthly value of the electricity bill, depending on the range of consumption. Currently, 12.3 million families benefit from the tariff and the government expects that more than 11 million will have access to the benefit.

It is worth mentioning, in particular, the Electricity Sector Modernization, the New Gas Market, and RenovaBio. Such initiatives will adapt the institutional, legal, and regulatory frameworks to guarantee universal access to modern, clean, and accessible energy sources for the entire Brazilian population, in line with the Sustainable Development Goals established by the United Nations in the 2030 Agenda. Brazil, a signatory of this Agenda, has steadfastly pursued its achievement.

The table below shows the evolution of Brazil in the struggle for the electrification of the entire country.

Table 1.3-1 Domiciles Characteristics (Source: SieBR - Domiciles Characteristics).

Description	Unit	1990	2012	2020
Total Domiciles	10^3	33.735,87	63.646,84	73.770,51
Ofwhich, rural	10^3	6.945,62	8.442,60	8.826,40
DomicileswithElectricity	10^3	28.911,64	63.283,33	73.600,42
Ofwhich, rural	10^3	4.167,37	8.130,23	8.660,99
DomicileswithoutElectricity	10^3	4.824,23	363,51	170,08
DomicileswithoutElectricity (%)	10^3	14,300%	0,571%	0,231%

Successful Experience

In light of the above, Brazil's efforts to guarantee access to energy for all are remarkable, based on Brazil's energy planning, which has always followed solid premises: respect for contacts, energy security, and universal access.

2. Green and Low-Carbon Transformation

Commitments and Goals for a Green and Low-Carbon Transition

The Brazilian government has already committed at the Leaders Summit on Climate to achieve climate neutrality (net-zero emissions) in 2050, bringing forward the indication signaled in the review of the Nationally Determined Contribution (NDC) presented in 2020 by ten years.

In 2021, at COP26, Brazil committed to mitigating 50% of its greenhouse gas (GHG) emissions by 2030, using 2005 as a baseline, a bolder goal than the one established in 2015 in the NDC Brazilian. The NDC text maintained the option of not allocating formal goals among the different sectors so that Brazil can achieve the goals through different alternative paths. On that occasion, the Brazilian government also assumed a global commitment to reduce methane emissions.

A Roadmap for Green and Low-Carbon Transition

The energy transition is an important topic today. There is a lot of uncertainty about how this transition will take place, as well as the speed. However, there is consensus that it is an essential part of the transition to a low-carbon economy that aims to limit global warming.

Brazil has great advantages over other countries, as it already has a predominantly renewable energy matrix, a greater use of biofuels in transport, and a great abundance of wind and solar energy, among many other advantages.

Brazil has always been a protagonist in policies to encourage the renewal of energy and electricity matrices and is making an important contribution by treading a path of socio-economic development with sustainability. To enable a successful energy transition, reconciling objectives, however, is necessary for society, especially in a country with the dimensions and complexities of Brazil. There is no right or single energetic path to a transition. It is a huge challenge to ensure the consistency of all public policies and initiatives.

Concrete Actions for Green and Low-Carbon Transition

Brazil has implemented additional measures that are consistent with its NDC. To this end, it has redesigned its energy markets and established instruments to accelerate the entry of new renewable sources for electricity generation such as wind, solar, and biogas, as well as to expand the decarbonization of its fuel matrix.

The Electricity Sector Modernization has among its objectives to facilitate the insertion of innovations in the electricity sector, reinforcing the impetus that energy auctions were already giving to wind, solar, and biomass projects, in addition to hydropower. The redesign of the electricity sector has also favored the growth of distributed energy resources, in particular solar. Even the thermoelectricity, required to guarantee the system's reliability, has migrated to low carbon sources such as biomass and natural gas, whose supply will be reinforced with the New Gas Market, which is redesigning this market for a competitive arrangement. The decision to resume the construction of Angra III will also contribute to maintaining the low carbon emission of the Brazilian electricity sector. Brazil is also studying other nuclear plants and the best use of this technology, given its strategic role in national development, including applications for health and agriculture.

RenovaBio, on the other hand, by establishing a target of reducing the carbon intensity of fuels by around 10% and creating a carbon market to operationalize the policy (the CBIO market), will bring a new moment for the production and use of biofuels in the transport sector in Brazil. The expectation is for an increase of around 45% in the supply of ethanol by 2030 (from 33 to 48 billion liters between 2018 and 2030), enabling total ethanol (hydrated and anhydrous) to respond to 60% of national Otto cycle demand in 2030. The supply from sugarcane bagasse and biogas/biomethane from vinasse and filter cake for electricity generation projects will also grow considerably.

Biofuels are Brazilian technological solutions to the decarbonization of transport, which can bring immediate results due to the flex-fuel fleet and/or for being drop-in. Subsequently, such technological solutions can be made compatible with the new automotive paradigms based on electrification. There are already efforts in this direction in the Brazilian market with the launch in 2019 of flex-fuel hybrid vehicles and with the advancement of research and development of fuel cell electric vehicles using ethanol. The Rota 2030 program, launched by the government, structured a policy that favors innovations in the automobile industry.

Energy efficiency policies have also been reinforced in Brazil. In the last 14 years, 14% of efficiency gains were registered in Brazil. It is projected that by 2030 Brazil will reach the equivalent level, due to labeling programs, the ANEEL Energy Efficiency Program, National Electric Energy Conservation Program (PROCEL), and the Route 2030 (which, like Inovar Auto, seeks to increase energy efficiency, including through hybrid and electric vehicles), among other programs. It is also noteworthy that there are segments that are difficult to electrify, based on the new energy transition, such for example, long-distance trucks, ships, and planes.

The first 2 segments have shown favorable medium-term dynamics for Liquefied Natural Gas compared, respectively, to diesel (in blue corridors, for example) and the maritime bunker. The New Gas Market will be able to create the business environment and competitive conditions for the dissemination of these technologies in Brazil.

Civil aviation can benefit from the international effort to find sustainable aviation fuels. The technological routes mainly involve alternatives with blends of advanced biofuels (in the longer term, the power to liquids route may also become a relevant alternative).

There are research efforts and innovation networks in Brazil for the development of sustainable aviation fuels, covering large aviation companies, airlines, biofuel producers, biotechnology startups, universities, and research institutes. There is still a need to expand the cost-effectiveness of the alternatives, but it is believed that RenovaBio can also generate a business and innovation environment favorable to the development of these fuels in this market.

Regarding aviation biokerosene, it is estimated that it will reach 1% of the total volume of aviation fuels in Brazil in 2030, even with significant economic challenges to be overcome. By 2050, sustainable aviation fuels could account for 10-14% of the sector's total energy consumption.

Thus, instead of seeking to expand ambitions for longer terms, Brazil has made an effort to establish adequate institutional, legal, and regulatory frameworks for the energy sector for its sustainable development, implementing additional policies and measures that allow it to reach the commitments assumed by Brazil in the Paris Agreement.

3. Energy Security

The General Situation of Energy Security

As previously mentioned, Brazil's energy planning follows 3 solid premises: respect for contacts, energy security, and universal access. Given this, with the 2021 water crisis, Brazil created the Chamber of Exceptional Rules for Hydro energetic Management (CREG). CREG brought with it greater realism and predictability to the energy expenditure that occurs in the Hydropower plants, and thus greater efficiency in Brazil's hydrological management, to guarantee the maintenance of supply and the preservation of the volume of the reservoirs, even in the face of the record rain drought that was experienced associated with the global Covid-19 crisis.

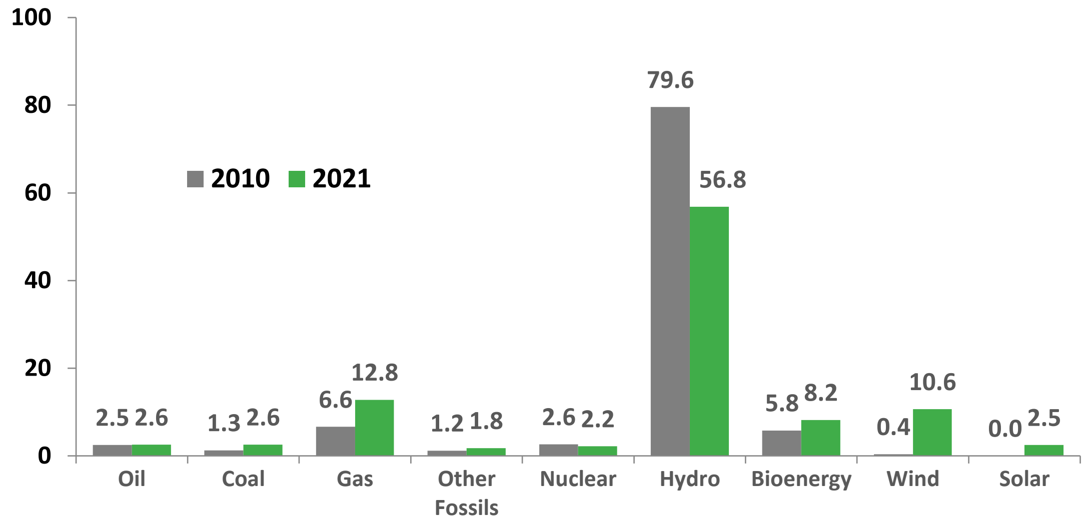
Despite this scenario, Brazil still ranked 6th in the energy security item by the World Energy Trilemma Index, published by the World Energy Council, being the only non-European country and not a member of the Organization for Economic Cooperation and Development (OECD) to be among the top 10 of the ranking.

Measures To Be Taken for Energy Security and How to Coordinate Energy Security and Low-Carbon Transition

The water crisis faced by Brazil in 2021 once again brought up the issue of dependence on hydraulic sources concerning national energy security. However, several agents in the sector, such as Empresa de Pesquisa Energética (EPE), observe a major change in the profile of the Brazilian electricity matrix since 2000.

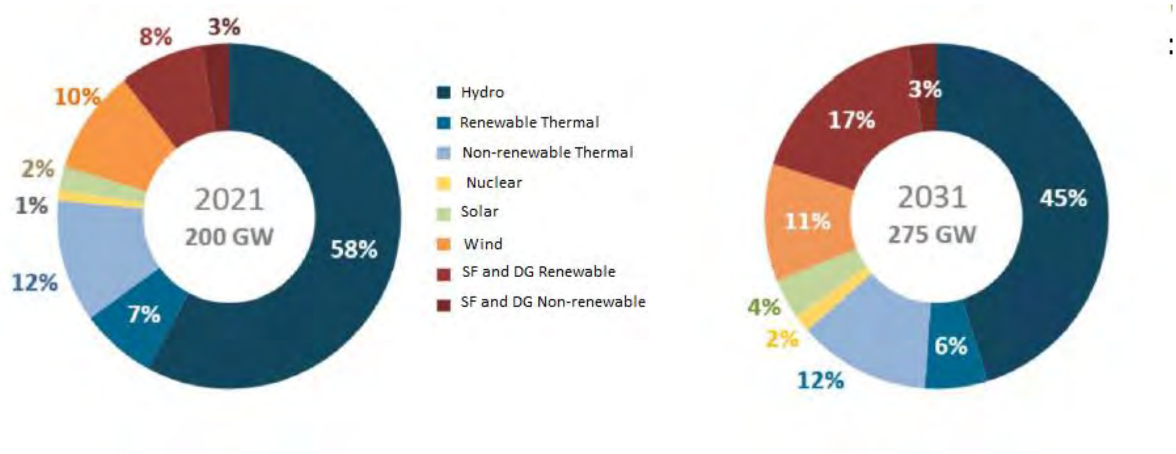
In terms of electricity supply, the basket of sources available for a generation has changed significantly over the decades of energy planning. Although, in general, the main participants in the electricity matrix are based on hydroelectric generation, it is important to highlight the significant growth of centralized solar and wind sources and distributed photovoltaic generation, contributing strongly to the diversification of the portfolio, guaranteeing greater security and risk management of load, not service.

Figure 1.3-1 Total Electricity Supply by Source - 2010 and 2020 (%)



The PDE 2031 presents prospects for the advancement of this decentralization and at the end of the ten-year horizon, about 84% of the installed capacity will be renewable, even with the considerable decrease in hydraulic participation.

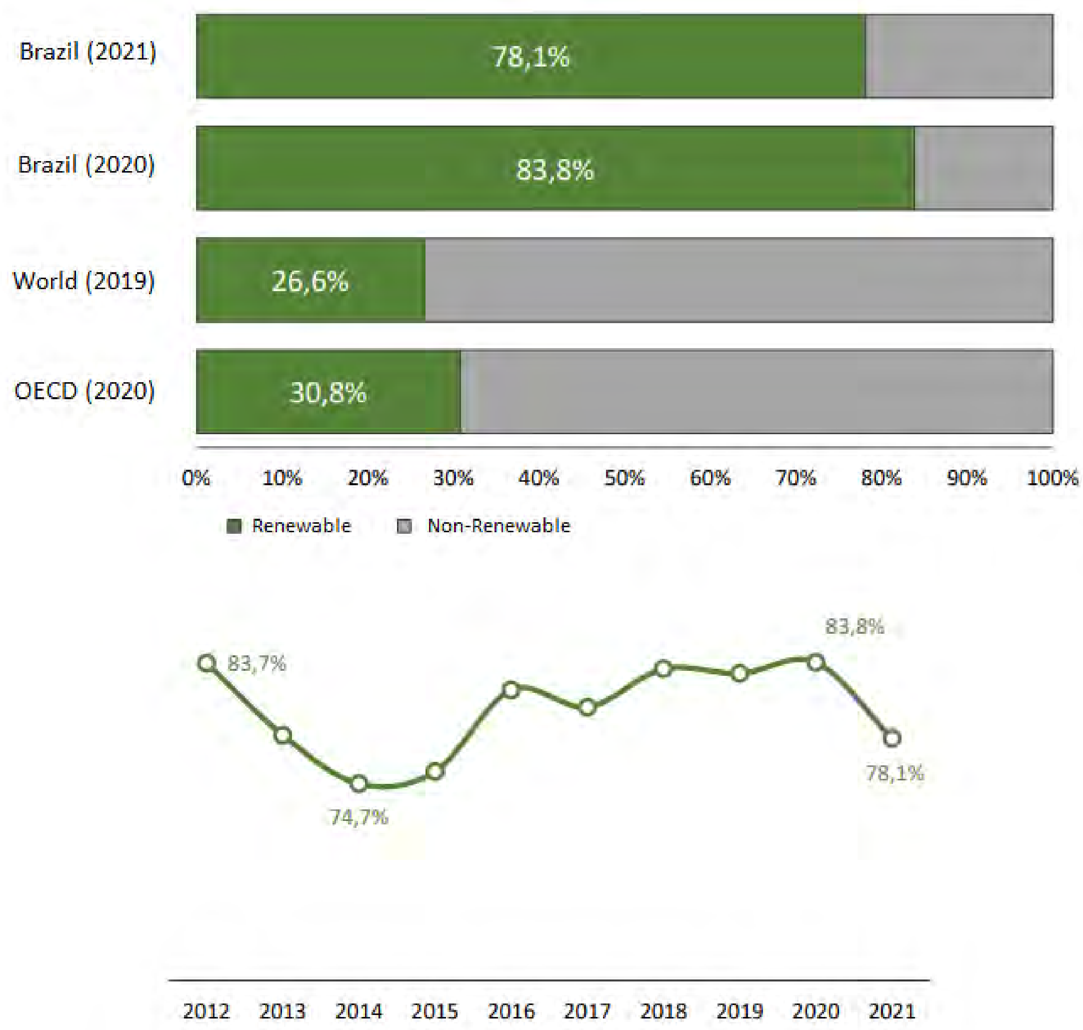
Figure 1.3-2 Evolution of Installed Capacity



Source: PDE 2031

Thus, it is safe to say that Brazil has moved towards less dependence on hydroelectricity, while maintaining a renewable electricity matrix, aiming at lower CO2 emissions, in line with what is presented today in the rest of the world, mainly with the post-COP26 panorama.

Figure 1.3-3 Renewable share in Total Electricity Supply



Source: National Energy Balance – BEN 2022

[III]

RUSSIA

I. General Energy Sector Overview

1. Power generation and consumption

The total power generation in the Russian Federation is growing from year to year. The indicator is currently equal to 1,490 MTOE at year-end 2021.

Natural gas accounts for about 40 % of the total power generation in Russia, it is considered to be the most environmentally friendly fossil fuel. About 35 % of the total power generation structure is done by oil stock, about 15 % – coal and about 10 % – on primary electricity, including renewable energy sources and other types of fuel.

Natural gas holds the largest share in the primary energy consumption structure of the Russian Federation – 54 %. Oil stock share is 18 % and coal share is 12 %. However, the share of primary electricity and other types of fuel, including renewable energy sources, is 16 %.

Russia's energy consumption level shows moderate positive growth rates every year. This indicator amounts to 771 MTOE at year-end 2021.

An increase in electricity consumption per capita has been recorded in Russia due to domestic economic growth. At year-end 2021, the indicator reached 7.8 MWh and exceeded 2020's level by 12.8 %.

2. New energy technologies

The identification of advanced research and technology development areas is strategically important for the scientific and technical development in fuel and energy complex industries.

To that end, the Technological Forecast for fuel and energy complex industries approved in 2016 was updated in 2021 for the period up to 2035 in accordance with the power generation sector's technological progress forecasting and monitoring system.

The updating process included considerations regarding the changes to foreign and internal conditions and development trends of the Russian economy and power sector. Areas and opportunities for technological development in Russia's fuel and energy complex industries were updated and adjusted. Special focus was made on the essential interconnections between the technological development of the Russian power sector and national technological development and provision of national and energy security.

In terms of the main energy transition scenarios, the document outlines the rationale for modernization and the use of technical and organizational solutions to improve the production performance and competitiveness of Russian fuel and energy complex products, services and technologies on global markets, and for the application of the latest solutions and digital transformation of the power sector.

High technology development is of key importance for the implementation of Russia's fuel and energy complex scientific and technological potential. In 2021, the Russian Federation adopted the following high technology application development roadmaps: “Electric power transmission and distributed smart grid technologies” and “Hydrogen economy development and industry and transport decarbonization by means of natural gas. The documents include measures aimed at developing a whole range of critical hydrogen energy and electric power equipment, including high-temperature superconductors and digital transformer substations, a domestic component base for process control systems, introduction of energy accumulation systems, development of renewable energy in the regions where centralized electric power supply is not available, and introduction of smart electricity metering system.

In order to achieve technological sovereignty and introduce state-of-the-art technology into the Russian fuel and energy complex industries, Russian companies are implementing projects using big data, artificial intelligence, IoT, robotics, digital twins and new materials. Key projects are aimed at increasing hydrocarbon production efficiency and safety, hydrocarbon processing, reducing greenhouse gas emissions in fuel and energy complex industries, carbon capture and storage, and increasing the quality of service provided to power consumers. The promising projects include developing systems, technology and research in the field of nuclear power. The purpose of the project is to ensure a technological breakthrough in order to retain Russia's global leadership in nuclear power technology, and the development of nuclear power as a "clean" uninterruptible power supply source. One of the project areas involves the development of new technological products for dual-component nuclear power systems, including thermal neutron reactors and power water reactors, and a brand-new segment – low power nuclear power plants.

Currently, Russian manufacturing companies, equipment manufacturers and service companies, and mining companies directly, are experiencing problems caused by supply chain disruptions, significant growth in the cost of products and services that were easily imported before within a wide range of projects implemented on the basis of industrial cooperation, and disruption to international engineering, manufacturing and scientific cooperation.

Most industrial consumers in the world are experiencing similar problems. BRICS is capable of transforming this situation for its own benefit and for the benefit of the whole world by means of its own significant industrial capacities and human resources.

3. Policy and goals

The priority areas of national energy policy in the Russian Federation include providing energy security to the whole country and individual regions, especially those located in geostrategic areas, top-priority satisfaction of domestic demand for energy products and services, and developing exports towards friendly countries.

Additionally, transition to environmentally friendly and resource-saving energy is of key importance in order to adapt to the global energy transitions. In 2021, the Government of the Russian Federation developed and approved the Strategy for socio-economic development of the Russian Federation with low greenhouse gas emissions up to 2050, in order to implement the Paris Climate agreement. The purpose of the Strategy is to reduce greenhouse gas emissions down to 70 % compared with 1990 as early as by 2030, taking into account the maximum possible absorbing capability of forests and other ecosystems and subject to the sustainable and balanced socioeconomic development of the Russian Federation. Fuel and energy complex industries shall make a clear contribution in the achievement of this goal. A range of initiatives have already been implemented in order to reduce the man-made impact on the environment and climate. In addition, the industry-specific plan of adaptation to climate changes in fuel and energy complex industries was developed in 2021 in order to ensure sustainable energy development in the climate change conditions that have been forecast.

Low-carbon and zero-carbon energy development is one of the most important components of greenhouse gas emission reduction. In 2021, the Russian Government approved a list of socioeconomic development initiatives for the Russian Federation up to 2030. These initiatives include clean energy (hydrogen and RES), and new nuclear power, including small nuclear reactors for remote regions.

A special focus in the Russian national energy policy has been placed on the technological development of fuel and energy complex industries and the maximum possible use of Russian-made energy equipment and technologies in order to achieve technological sovereignty. Projects aimed at reducing the dependence of fuel and energy complex industries on imported equipment and technology are being extensively implemented in Russia.

The key technological development initiatives implemented in fuel and energy complex industries include projects for the increase in production of difficult-to-recover hydrocarbon reserves, including the Arctic Regions, increase in oil production and oil refining performance, increase in the yield of light products, production of Russian-made gas turbines, smart electricity metering, capturing, using and storage of hydrogen, bottom ash waste recycling, etc.

Additionally, digital transformation is also being facilitated in fuel and energy complex industries. In 2021, the Russian Government approved the Strategic approach in the field of digital transformation of fuel and energy complex up to 2030, including measures to digitally transform fuel and energy complex industries as part of the implementation of five projects. They are aimed at the involvement of electric power market consumers in control of demand, development of microgeneration, improvement in the quality of service provided to consumers, introduction of artificial intelligence technology, and increasing security at fuel and energy complex facilities.

In 2021, the Government of the Russian Federation adopted a plan of actions to implement the National energy strategy up to 2035, the updated fuel and energy complex technological forecast for the same period, the Long-term LNG production development program, the Hydrogen energy development concept of the Russian Federation, and the General national oil and gas development schemes up to 2035 have also been approved, in order to ensure the reinforcement of the energy sector's strategic foundation.

II. Energy Sector

1. Coal

In 2021, coal production amounted to 439.5 million tons which is 9.2 % higher than in 2020, including 326.5 million tons of open-pit coal mining and 113 million tons of underground coal mining.

In 2021, coal was produced by 171 Russian companies, including 117 coal pits and 54 coal mines. The total coal production during all months of 2021 exceeded the coal production level of 2020 which is primarily associated with the recovery of industrial production and increase in demand for coal products on the foreign market as a result of economic growth in most foreign countries.

Processing plants and facilities processed 211.7 million tons of coal in 2021 (+2.1 % compared with 2020), including 116 million tons of power-generating coal (+8.4 % compared with 2020) and 95.7 million tons of coking coal

(-4.7 % compared with 2020). The amount of washable coal increased by 77.9 % in the period from 2011 to 2021.

In 2021, the demand for Russian coal on foreign markets was stable. At the end of the year, coal exports amounted to 223.3 million tons (+5.8 % compared with 2020).

Regionally, in 2021, 52.2 % of Russian coal exports were to Asia-Pacific region markets. The total coal load for this area was 124.7 million tons (+3.7 % compared with 2020). In 2021, 47.8 % of Russian coal exports were to Western countries. Coal exported to European countries amounted to 72.5 million tons (+3.7 % compared with 2020).

In 2021, 159.3 million tons (+4.9 % compared with 2020) of coal products were supplied to the domestic market of the Russian Federation, including 72.2 million tons (1.8 % compared with 2020) for electric power generation, 37.2 million tons (+7.5 % compared with 2020) for coking, and 27.7 million tons (+26.5 % compared with 2020) for public utility use.

One important event in the coal industry in 2021 was the start of production at the Vostochnaya Denisovskaya mine, which has a capacity of 4 million tons of coal/year. In addition, measures to restructure the coal industry continued to take place.

In order to reduce the man-made impact on the environment by coal companies, an action plan (roadmap) was adopted in 2021 in order to reduce the negative environmental impact of coal companies using the best available technologies.

2. Oil

In 2021, oil and gas condensate production volume amounted to 524.5 million tons, which is 2.2 % higher than in 2020. Production indicators are still being influenced by the Agreement between the Russian Federation, Organization of petroleum exporting countries (OPEC) and non-OPEC countries, which has been in force since 2016.

In 2021, the General oil industry development scheme up to 2035 developed by the Ministry of Energy was approved, it aims to detail the target vision for the development of the oil industry that was included in the Energy strategy of the Russian Federation up to 2035.

The general scheme defines the economically justified strategic oil industry development areas in order to increase competitiveness, performance and technological infrastructure, and to retain the role as a driver of the Russian economy. For this purpose, the document reflects oil industry performance scenarios according to key indicators with identified target levels.

In 2021, 22 oil and gas condensate fields were put into operation. The implementation of active production projects was continued, including those in the Arctic region on the continental shelf of the Russian Federation.

In 2021, the federal project "Difficult-to-recover hydrocarbon production technologies" was approved. Implementing the project may provide an incremental annual production of up to 50 million tons for Russia at both current and new fields in Western Siberia. The federal project involves the creation of Russian technologies for nonconventional resources development, primarily the Bazhenov suite – the world largest nonconventional hydrocarbon source.

Primary oil refining volume increased by 3.4 % in 2021 compared with 2020 and amounted to 284,13 million tons.

The amount of oil transported via the main oil line system amounted to 449.7 million tons in 2021 (+1.7 % compared with 2020), the amount of oil products transported amounted to 38.9 million tons (+2.9 % compared with 2020).

In 2021, the internal oil product market of the Russian Federation was fully provided with Emission Class 5 motor fuels in accordance with the Technical regulation of the customs union. The production rate of Class 5 motor gasoline amounted to 39.8 million tons (+7.3 % compared with 2020), and diesel fuel amounted to 74.5 million tons (+3.9 % compared with 2020).

3. Natural gas

In 2021, the production volume of natural gas and associated petroleum gas increased by 10.1 % compared with 2020 and amounted to 762.8 billion cubic meters (bmc) – a record amount for the Russian gas industry. Liquefied natural gas (LNG) production rates at Russian companies amounted to 42.4 bmc, remaining at the 2020 level.

Gas supplies to the internal market and for export, including LNG, amounted to 516.1 bmc (+12.1 % compared with 2020) and 246.5 bmc (+1.3 % compared with 2020), respectively.

In 2021, the General gas industry development scheme of the Russian Federation up to 2035 prepared by the Ministry of Energy was approved by the Russian Government and included the Eastern gas program and internal gas market development concept.

The document details the target vision for gas industry development included in the Energy strategy of the Russian Federation for the period up to 2035. The document defines economically justified strategic areas of gas industry development aimed at reliable gas supply for the existing and future Russian consumers, fulfilment of obligations under intergovernmental agreements and contracts entered into for gas supply to foreign countries, and the implementation of new cost-efficient projects for gas supply to foreign markets.

According to the document, the role of natural gas in Russia's power balance will grow within the next decades and will reach 53–55 % by 2035 depending on the scenario (in 2019, it was 52 %). In 2021, the Government of the Russian Federation approved a long-term domestic liquefied natural gas production development program, and a plan of actions to implement the program.

In 2021, an action plan (roadmap) to implement a socially oriented and cost-efficient gasification and gas supply system for the constituent entities of the Russian Federation was approved. The gasification level is expected to grow by more than 10 % by 2030 to reach 82.9 %.

By 2021, the total volume of gas consumption as motor fuel amounted to 1.37 bcm (+23.6 % compared with 2020) and the total number of functioning natural gas filling stations reached 734.

In order to expand the consumption of natural gas as environmentally friendly motor fuel, the implementation of the motor gas fuel market development program launched in 2020 was continued. Investment in the natural gas conversion for existing automotive vehicles is one of the key drivers of this program.

The petrochemical industry's share in raw hydrocarbons consumption (LHG, ethane, naphtha) at year-end 2021 amounted to 29.8 % (+2.2 p.p. compared with 2020) of the total utilization of raw hydrocarbons, or 13.3 million tons. And production rates of bulk polymers grew by 5.7 % compared with 2020 and reached 7.4 million tons. In terms of volume, export of bulk polymers amounted to 1.8 million tons in 2021.

4. Electric Power

Electricity generation by the Russian power plants amounted to 1131,3 billion kWh (+6.4 % compared with 2020).

The energy production structure is dominated by thermal generation with prevailing natural gas power plants. The UN has declared natural gas the most environmentally friendly fossil fuel. About half of the total electricity generation in Russia is accounted for by gas generation. And the share of low-carbon and zero-carbon generation presented by nuclear power plants, hydroelectric power plants and renewable energy sources amounts to 40 % of the total electricity generation level. The share of renewable energy sources, including large hydro power plants, amounts to almost 20 %.

The construction and modernization of generating capacities and power supply network facilities continued in 2021, with several large facilities put into operation. A total of 2.8 GW of new capacity was commissioned in Russia (+38.3 % compared with 2020).

In 2021, the Russian Ministry of Energy continued to on the creation of a system for confirming sources of low-carbon origin of electric power through the introduction of generation attributes and certificates of origin of electric power.

It is envisaged to create the possibility of independent confirmation of electricity production at a specific low-carbon and zero-carbon generating facility (NPP, HPP, other types of renewable energy sources without fuel combustion) and the possibility of subsequent secondary circulation of the relevant instruments, taking them into account in a register. This measure is important for confirming the compliance of the activities of consumers and producers of electric power with the principles of ESG.

5. Nuclear power

Russian nuclear power sector plays an important role in the national electric power generation, being an effective and safe power source. As of 2021, the Russian nuclear power sector consists of 10 NPP with 35 power units, including the floating nuclear heat and power plant unit, with a total installed capacity of 29.6 GW and annual production of about 222.4 TWh and about 20 % of the total electric power generated in the country.

The main nuclear power development areas in Russia include:

expansion and modernization of power water reactors (PWR);

development of NPP with fast neutron reactors for nuclear fuel cycle closure;

development of small and average-sized nuclear power plants;

nuclear heat supply;

introduction of nuclear capacities into power-intensive sectors;

providing a full nuclear fuel cycle service package.

Large-scale development is possible only with the development of new technological products for dual-component nuclear power system, including thermal neutron reactors PWR and industrial fast neutron reactors, in order to ensure nuclear fuel cycle closure, and a new segment – low power nuclear power plants to supply power to hard-to-reach and isolated areas and local consumers.

Currently, the construction of power units No. 1 and 2 of Kursk NPP 2 with PWR-TOI reactors is underway (typical optimized and IT-based project for a twin-reactor NPP with a power water reactor). Construction and commissioning of power units with PWR reactors is also planned.

In 2021, the construction of the world's first power unit with BREST-300 IV generation hot lead metal reactor was started as part of an experimental demonstration energy complex, also including a uranium-plutonium fuel fabrication module, spent nuclear fuel reprocessing, and a refabrication module. This energy complex will demonstrate possibilities of nuclear fuel cycle closure. In order to ensure power supply to remote and isolated areas of the Russian Federation, NPP construction projects based on small nuclear power plants (SNPP) are being implemented. Currently, the main high-availability and high-readiness option is the RITM-200 reactor which serves as the basis for ground and floating SNPP options.

The pilot ground SNPP construction project with the RITM-200N reactor with an installed capacity of 55 MW is being implemented in the technologically isolated region of the Republic of Sakha (Yakutia) in order to ensure power supply to industrial and municipal consumers. Russian nuclear generation development plans are reflected in the General electric power facility location scheme up to 2035 updated in 2021 by order of the Government of the Russian Federation.

In particular, the construction and commissioning of 16 NPP power units are planned for the period up to 2035.

The strategic goal for Russian nuclear generation development includes a transition to dual-component nuclear power with a closed fuel cycle to achieve a target share of the national energy balance of 25 % by 2045 and make a significant contribution into gradual approach to carbon neutrality.

6. Renewable Energy

Since 2013, the Russian Federation has been implementing a renewable energy source (RES) support program on the wholesale electric power market, which is the dominating national market. Competitive bidding for investment projects for the construction of RES-based generating facilities is carried out annually for solar and wind generation, and hydrogeneration with an installed capacity of lower than 25 MW, taking into account the established target indicators.

The first investment cycle for the government support program for RES started in 2013 and is planned to last until 2024, with the last competitive bidding event for projects in this investment cycle having been held in November 2020. In total, almost 5.3 GW of capacity was selected as part of the competitive selection of RES investment projects between 2013 and 2020. Competitiveness occurring as a result of the competitive business means that the mean planned capital expenses amount for the projects with an installed capacity of 1 kW is able to be reduced significantly.

In 2021, the RES use support program on the wholesale electric power market was extended to last from 2025 to 2035. It is still based on the use of a system of contracts for the supply of RES generating facility capacity to the wholesale market, but with additional requirements established for potential program participants both in terms of compliance with power equipment localization indicators and the presence of export supply packages. The implementation of the measures mentioned above will ensure that RES facility investment measures using wholesale electric power market mechanisms can be terminated and the Russian RES sector can be competitive in internal and global markets.

In 2021, 1,242 MW of new RES capacity was put into operation (+2.9 % compared with 2020), including a range of large facilities, in particular, a 340.2 MW wind power cluster in the Astrakhan Oblast, a 120 MW Marchenkovskaya WPP in the Rostov Oblast, a 120 MW Bondarevskaya WPP in the Stavropol Krai, etc.

7. Hydrogen energy

In 2020, the Government of the Russian Federation approved an action plan (roadmap) for the development of hydrogen energy in the Russian Federation up to 2024, which is aimed at increasing hydrogen production and expanding the application of hydrogen as an environmentally friendly energy carrier, as well as at making the country one the world leaders in hydrogen production and exports.

As part of the roadmap, in 2021, the Government of the Russian Federation approved the Hydrogen energy development concept of the Russian Federation, which establishes the goals, tasks, strategic initiatives and key measures for the development of hydrogen energy in the Russian Federation in the medium (up to 2024) and long-term (up to 2035) period and also sets out the main focuses for further extension up to 2050.

Russia has significant competitive advantages in terms of hydrogen production and exports. The main competitive advantages for hydrogen production and potential exports include the available energy potential (electric power with low relative carbon dioxide emissions, solar and wind power potential), natural resources, underloaded generating capacities in the Unified Energy System of Russia, experience using steam methane reformation and electrolysis in industry, a well-developed research and development basis, and an advantageous geographical position. Russia can ensure that hydrogen is priced competitively taking into account these advantages.

In 2021, the development of other statutory instruments was continued aimed at hydrogen energy development within the Russian Federation. The Ministry of Energy of the Russian Federation alongside federal executive authorities, public agencies, and the largest energy, industrial and financial companies are preparing a Comprehensive program of development of the low-carbon hydrogen energy sector in the Russian Federation.

The main goal of this Program is to prepare a comprehensive document to act as a basis for strategic planning documents aimed at creating hydrogen energy infrastructure, government support mechanisms and developing research and human resources.

One important area of focus is the creation of domestic hydrogen energy technology, especially hydrogen production technology (by pyrolysis, carbon dioxide extraction, separation of methane-hydrogen mixtures, short-cycle adsorption, electrolysis, and carbon gasification) and hydrogen storage and transportation technology (composites for pressure vessels and hydrogen transportation using organic compounds).

The initiative to aid in the Russian economy's adaptation to the global energy transition includes a draft action plan for hydrogen energy and carbon capture and storage (CCUS) technology.

8. Energy efficiency

The Russian Federation is characterized by its GDP having high energy consumption, which is indicative of significant potential to increase energy efficiency via a reduction in relative fuel, heat and electricity consumption, and rational energy use.

In 2020, the total consumption of energy resources in Russia amounted to 826.9 million tons of conventional fuel (resulting in greenhouse gas (GHG) emissions amounting to 2,150 million tons of CO2 equivalent) which is 3 % or 27 million tons of conventional fuel lower than in 2019. The reduction of GHG emissions amounted to 70.2 million tons of CO2 equivalent. The most power consuming sectors include electric power generation, processing industry and the housing and utilities sector.

In order to increase energy efficiency in individual fuel and energy complex industries, the following standards were approved on the federal level in 2021:process loss standards for raw hydrocarbons during production associated with the adopted field development scheme and technological field development, and during heat energy transfer and coolant in heating systems located in settlements, urban districts with the population of 500 thousand people or more, and in federal cities; fuel stock standards for heat energy sources during electric power production, and electricity and heat power production in combined electric and heat energy generation mode with an installed capacity of electric power production of 25 MW or higher; relative fuel consumption standards during electric power production, and specific fuel consumption standards for heat power production performed by heat power sources in combined electricity and heat energy generation mode with an installed capacity of electric power production of 25 MW or higher.

Increasing the energy efficiency of the Russian economy is an important public policy area both at federal and regional levels.

As of 2020, 81 Russian regions have adopted regional energy saving and energy efficiency programs. The total amount of resources saved as a result of the implementation of these programs amounted to 895 million tons of conventional fuel in 2019, and 1,133 million tons of conventional fuel in 2020.

In addition, 56 Russian regions have regional energy saving centers, essentially specialized public competence centers in this area that provide information, analytical and expert methodological support for the implementation of state policy.

Russia is placing emphasis on the development of energy-saving lighting, which has a significant impact on electric power consumption parameters. The number of LED lighting fixtures in outdoor lighting systems is gradually growing. As of 2020, the number was 41.2 % of the total number of lighting fixtures.

The number of public sector buildings and multifamily residential buildings equipped with local heat distribution and metering stations with weather control is growing, allowing heat energy consumption to be reduced.

In 2020, relative heat energy consumption in multifamily residential buildings was reduced by 16 % (in 2019 it was 0.107 Gcal/m2 a year, and in 2019 it was 0.090 Gcal/m2 a year).

Strong focus is made on the development of the energy service market. The number of annual energy service contracts made between 2016 and 2021 grew by 45 %. The market is growing both by the number of contracts and by the total value of contracts.

In order to further promote energy saving and increase energy efficiency in the most energy consuming sectors, in 2021, Russian President Vladimir Putin set out a goal to develop the national program Energy saving and increase in energy efficiency up to 2035 (hereinafter referred to as the "Program").

The Program will be developed in conjunction with the Socio-economic development strategy of the Russian Federation with low greenhouse gas emissions up to 2050 and is aimed at increasing energy efficiency in the power sector, as well as the industry, transport and housing and utilities sector. As a result of the Program being implemented, GDP power consumption is expected to be reduced by 35 % in 2035 compared with the level of 2019.

In addition, an annual state report on energy saving and increase in energy efficiency in the Russian Federation is prepared and distributed, and a state energy saving and energy efficiency information system (SIS Energy Efficiency) is active. This is done in accordance with the requirements of energy saving and energy efficiency legislation, in order to provide updated information on legislative requirements for energy saving and energy efficiency, to provide information on the requirements introduced by the legislation to individuals, organizations, and public and local authorities, and to obtain objective data on the following: power consumed by the Russian economy (including its industries), the potential reduction of such energy consumption, the most efficient projects and outstanding achievements in terms of saving energy, increasing energy efficiency.

III. Sustainable Energy Development

The Russian Federation wholly supports and shares the global view of the need to provide universal access to affordable, reliable, sustainable and modern power sources. Sustainable energy development is one of the priorities of the national energy policy. Russian fuel and energy complex provides a balance between energy security, economic development and environmental protection.

In order to ensure energy security, Russia is committed to ensuring that a stable supply of accessible power resources to the internal market is prioritized. Russia is one of the world leaders in hydrocarbon reserves, the production and export of energy resources, as well as in the development, use and export of nuclear energy technologies. The Russian energy infrastructure, which is based on Russia's Unified Energy System, the Unified Gas Supply System, and the trunk oil and oil products transportation pipeline, is one of the longest in the world and operates in various climatic conditions, from the Arctic to the subtropical zone.

One important sustainable energy development support area in the Russian Federation is the facilitation of the use of low-carbon energy, nuclear energy, hydro power, and zero-carbon energy renewable energy sources (RES). In 2021, all these types of energy were included in the green taxonomy of the Russian Federation.

In addition, in 2021, the Government of the Russian Federation adopted the following socioeconomic initiatives: New nuclear power, including small nuclear reactors for remote regions and Clean energy (hydrogen and RES), and extended the state RES support program for the wholesale electric power market up to 2035. Moreover, the RES support program on retail electricity and power markets is being implemented, and the development of microgeneration up to 15 kW is being promoted.

Measures to prevent climate change in compliance with the Paris Climate Agreement will make a great contribution to sustainable energy development in the Russian Federation. In 2021, the Russian Government approved the Socio-economic development strategy of the Russian Federation with low greenhouse gas emissions up to 2050 and the sustainable development (including green development) project criteria in the Russian Federation and requirements for the verification of sustainable development projects containing the taxonomy of these projects.

1. Energy accessibility

Russia ensures universal access to energy within the country. However, increasing the accessibility of energy infrastructure is one of the key high-priority fuel and energy complex development areas in Russia.

In order to increase energy accessibility for the population, Russia is performing extensive work, including providing a simplified connection to electricity and gas supply systems. Gasification of the Russian regions with natural gas, which is the most accessible and environmentally friendly type of fossil fuel, is of high importance. Between 2005 and 2021, 39 thousand km of gas pipelines were built in 69 Russian regions. More than 1.1 million households and apartments were connected to gas supply and more than 6 thousand boiler houses and industrial facilities were connected to gas supply during this period. In 2021, according to the goal set out by the President of the Russian Federation, the gas supply program entered the new stage of development – the Government of the Russian Federation approved a socially-oriented gasification roadmap It assumes a phased completion of gasification by 2024 and 2030.

Between 2014 and 2019, Russia demonstrated the best possible results in the reliability of supply and transparency of tariffs (power rates) in the World Bank's Doing Business rating. According to the rating, in 2019, Russia was the seventh best among 189 countries in terms of getting electricity and went up by 181 points over six years. According to the rating, until the results ceased publication in 2021, a reduction in time taken to connect to electricity systems and the cost of connecting utilities was observed.

2. Energy Transitions

The Russian Federation is vigorously involved in international efforts aimed at mitigating climate change. In order to implement the Paris Climate Agreement, Russian President Vladimir Putin signed a Decree in 2020 On the reduction of greenhouse gas emissions, according to which greenhouse gas emissions are to be reduced by 2030 to 70 % compared with 1990, taking into account the maximum possible absorbing capacity of forests and other ecosystems. The same Decree sets out the task for the Government of the Russian Federation to develop the Socio-economic development strategy of the Russian Federation with low greenhouse gas emissions up to 2050. In an address to the Federal Assembly on April 21, 2021, the President of the Russian Federation emphasized the challenges of climate and the need for sectors in the national economy to adapt to them, and pointed out the importance of greenhouse gas emission reduction, organizing control and monitoring of greenhouse gases, and establishing an industry for CO2 recovery. During the Russian Energy Week International Forum in October 2021, the President said that Russia understands the severity of the climate crisis and claimed that the country is committed to achieving carbon neutrality for the economy no later than 2060.

In 2021 in compliance with the Russian Presidential Decree, the Government of the Russian Federation approved the Strategy of socio-economic development of the Russian Federation with Low Greenhouse Gas Emissions up to 2050. According to the strategy's intensive scenario, net greenhouse gas emissions in 2030 and 2050 will amount to 1,673 and 630 million tons CO2 equivalent. According to the national greenhouse gas inventory submitted to the UN's FCCC authorities in 2022, it is reasonable to expect that fulfilling the strategy will ensure an absolute reduction of greenhouse gas emissions by 1,416 million tons CO2 equivalent in 2030 and by 2,459 million tons CO2 equivalent in 2050 compared with 1990.

Currently, an operation plan is being developed in Russia in order to achieve the targets set out in the Strategy. The measures for decarbonizing national economy include support for the introduction, replication, and scaling of low-carbon and zero-carbon technologies, promoting the use of waste energy, changing tax, customs and budgetary policy, developing green financing, measures to maintain and increase the absorbing capacity of forests and other ecosystems, and supporting technology for the capture, utilization and recovery of greenhouse gases.

These measures also include a document package approved by the Government of Russia to create a legal framework for a sustainable financing market, including green financing. The provisions set out by this package include criteria for sustainable development projects (in particular, green projects) and requirements for a sustainable development project verification system in the Russian Federation (in particular, for green projects) containing a taxonomy for these projects. The taxonomy consists of two sections: the list of projects considered as green projects in accordance with the international practice, and a taxonomy of projects aimed at adapting the economy to changes in climate.

In 2021, Federal Law On the reduction of greenhouse gas emissions was adopted. In accordance with this law, organizations (legal entities and individual entrepreneurs) whose annual greenhouse gas emissions exceed 150 thousand tons (until 2024) and 50 thousand tons (from 2025) CO2 equivalent must carry out mandatory greenhouse emission reporting. Despite the fact that the Federal Law contains no provisions on the absolute reduction of greenhouse gas emissions, it provides a basis for the implementation of targets set out in the decrees and statements of the President thanks to the introduction of a transparent and verifiable national reporting system. In addition, the document sets out greenhouse emission reduction targets as the basis for the development and introduction of emission allowances by governmental statutory instruments.

The Federal Law On the greenhouse gas emission reduction experiment in certain constituent entities of the Russian Federation adopted in 2022 in order to achieve carbon neutrality for certain regions of Russia follows the greenhouse gas emission reduction policy. The law sets out a carbon neutrality achievement procedure using two complementary tools – emission quotas for regional organizations with the introduction of fiscal measures in case of failure to meet the quotas (“top-down” system) and project activity and carbon unit trading mechanisms in order to meet the established quotas (“bottom-up” system). In addition to an annual inventory of greenhouse gas emissions and absorption in the experiment participant’s area, the law includes the promotion of the introduction of technologies to reduce greenhouse gas emissions and increase greenhouse gas absorption, as well as create an independent verification system for mandatory carbon reports for regional organizations. The experiment will be held in the Sakhalin Oblast from September 01, 2022 to December 31, 2028. However, law enforcement practice provides for this experiment to be extended to other parts of the country. Bashkiria, Khabarovsky krai, Irkutskaya oblast, and Kaliningradskaya oblast have already expressed their intention to join the carbon neutrality targets at the regional level.

3. Energy security

The Russian Federation is pursuing a balanced and economically justified energy policy based on the efficient use of all energy sources, including fossil fuel, new and renewable energy sources, and one that is focused on the application of advanced environmentally friendly technologies and protecting the environment

For the Russian Federation, energy security is one of the essential components of national security. Due to a model based on the principle of interconnection and fair division of risks between all energy chain participants, a balance of interests of not just the generators and consumers of power resources, but also of the countries of transit, Russia ensures it has the highest possible level of energy security, as well as preventing it from being reduced and preventing risks and crises directly related to the country-wide power supply from emerging.

The state is responsible for the energy security of the Russian Federation via a system of legislative, regulatory and other measures for identified hazards and destabilizing factors.

The energy security system of the Russian Federation is defined by federal laws, acts of the President of the Russian Federation and Government of the Russian Federation, and decisions by the Security Council of the Russian Federation.

In 2019, the Energy Security Doctrine of the Russian Federation was approved, and in 2021, so was the National Security Strategy of the Russian Federation, whose national strategic priorities include Russia's energy security target, in particular, improving the energy efficiency of the economy and FES governance.

The Action plan for the implementation of the energy strategy of the Russian Federation up to 2035, which was approved in 2021, includes a separate section containing Russia's issues in terms of energy security, especially regarding national, public, and cyber security.

The main areas of focus in terms of energy security in Russia include the improvement of energy security governance; maintaining fuel and energy complex mineral resources bases and fixed production assets of fuel and energy complex companies at a level required to ensure energy security; international legal protection of interests of Russian fuel and energy complex and power-plant engineering organizations; and support for products, technology and service exports.

One of the important areas of activity includes consistent import replacement in areas critical for the sustainable functioning of the fuel and energy complex, including localizing the manufacture of foreign equipment or creating equivalent Russian production facilities, and developing technology (including IT and telecommunications) and software. This is one of the strategic tasks in guaranteeing the technological independence of the Russian fuel and energy sector with a focus on the current state of energy security.

The priority energy security provision areas include monitoring external and internal energy security challenges, hazards and risks, developing preventive measures in order to minimize potential damage caused by existing and potential hazards, continuously assessing the impact on current changes, reviewing the focus of measures, and selecting the most efficient ways to manage energy security in accordance with the updated strategic energy development targets of the Russian Federation. Energy security risk management is carried out as part of the energy policy of the Russian Federation and the plan for ensuring energy security

Russia is committed to developing international cooperation with regards to energy security and makes a significant contribution to global energy security, being one of the largest energy resource suppliers in global markets.

Energy cooperation between BRICS countries involved in the global regulatory system is becoming an important factor in global energy development and energy security as a way to overcome global problems by consolidated efforts in economic partnerships in priority areas, including assistance and mutual support in the diversification of power sources and types of power resources; the development, protection and security of critical energy infrastructure and transit; improving energy efficiency, including joint development and exchanging of power-efficient and more environmentally friendly energy technologies; improving the efficient use of clean energy sources, including natural gas; and introducing environmentally safe power resource production, storage and consumption technology.

[III]

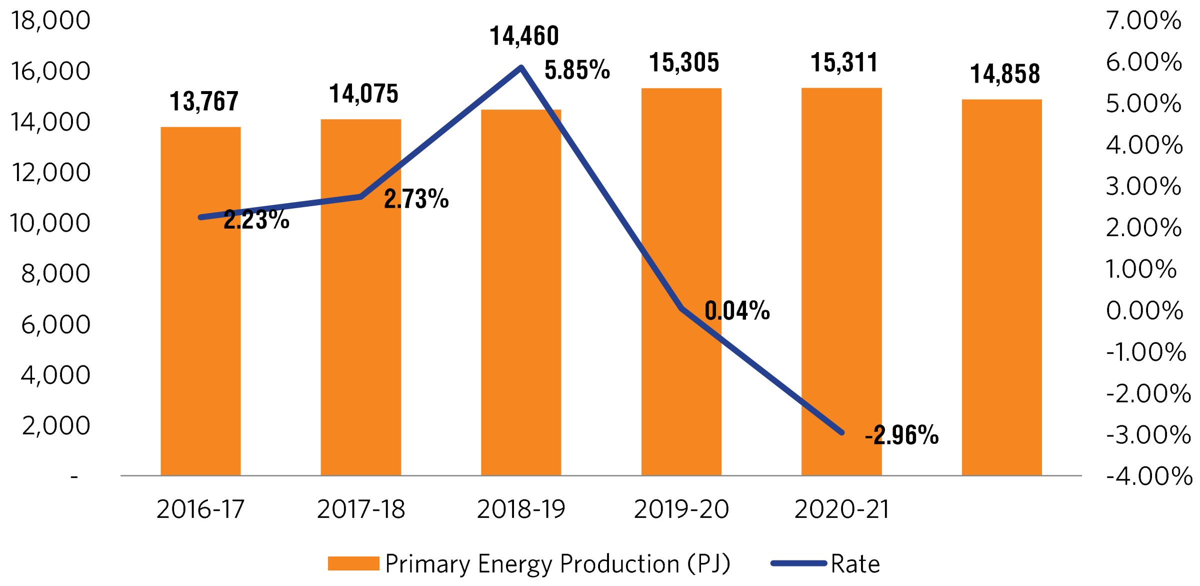
INDIA

I. OVERVIEW OF ENERGY DEVELOPMENT

1. Energy Production

Energy production in India since 2016 has been increasing at a steady pace till 2018. During 2020-21, the total produced energy was 14,858Peta Joules (PJ), which decreased by 2.96% from 523 MTCE in 2019-20 due to the impact of COVID-19. The average annual growth rate from 2016 to 2021 was 1.66%.

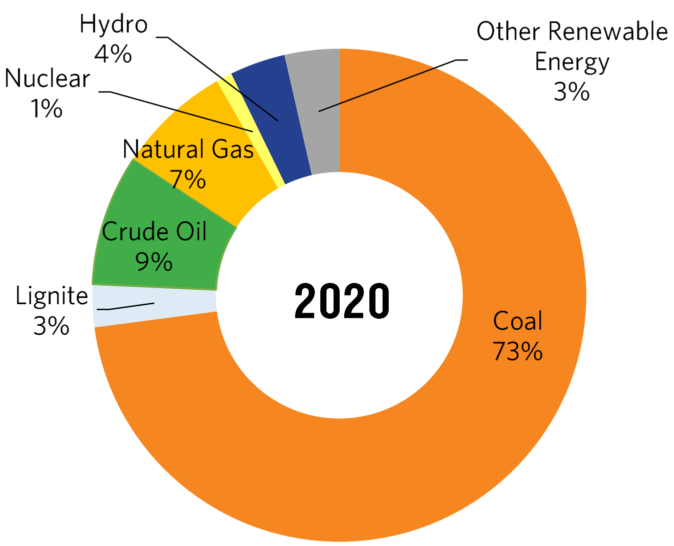
Figure 3.1-1 Primary Energy Production（PJ）



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

As per the Primary Energy Production Mix, coal is the major energy source in India, accounting for 73% of the total share. It is followed by Crude Oil (8.59%) and Electricity (from Hydro, Nuclear and other Renewable energy sources) (8%). It is depicted in the Figure 3.1-2.

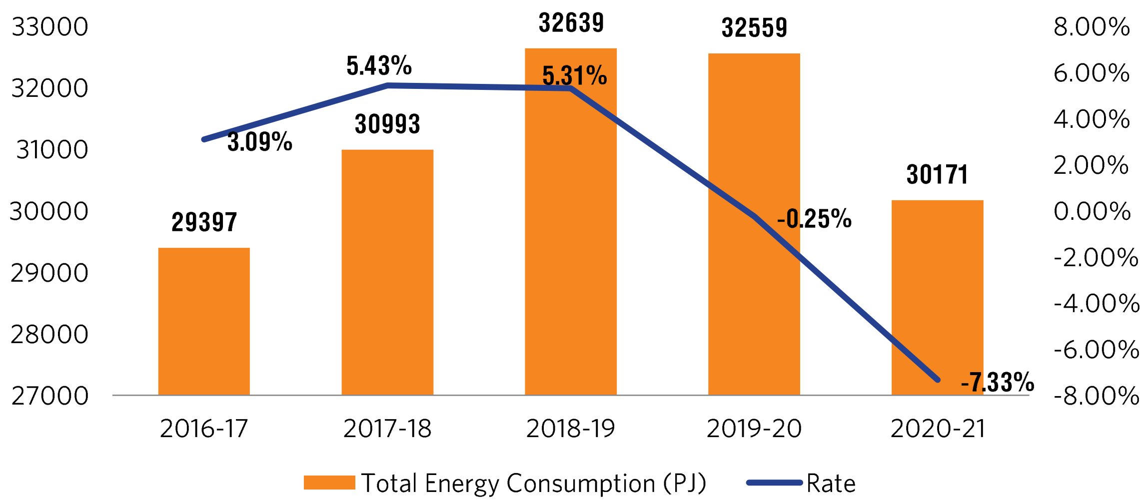
Figure 3.1-2 Primary Energy Production Mix



2. Energy Consumption

During the 2020-21, India has experienced a rather slow consumption rate, mainly because of the COVID-19 pandemic. Consumption of Energy is same trend as in Energy production. Reduction rate in Energy consumption in the 2020-21 (30171PJ) is 7.33%.

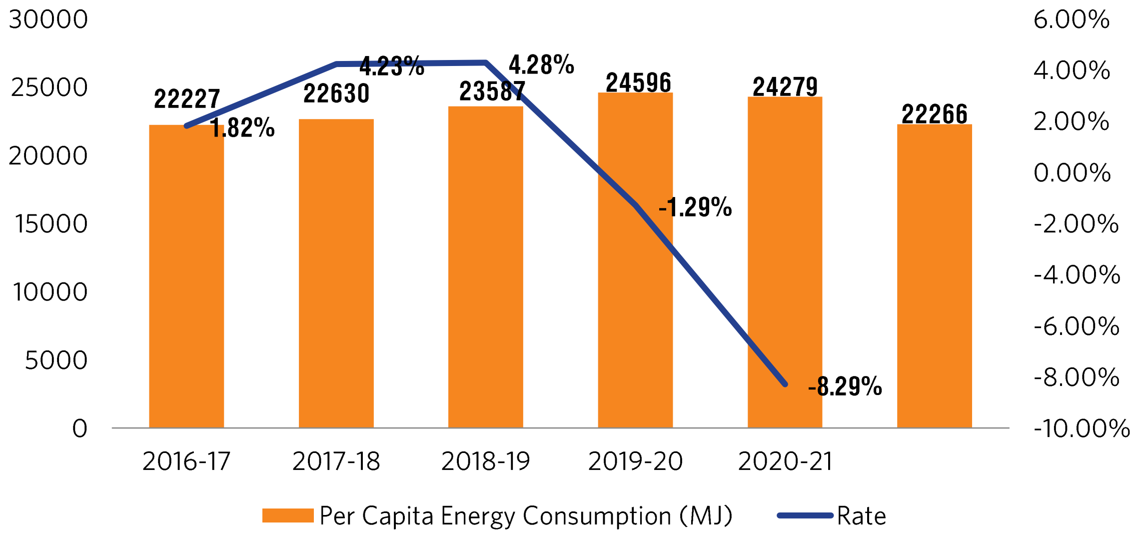
Figure 3.1-3 Energy Consumption（PJ）



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

The per capita Energy Consumption has also decreased after the year 2018-19. It is 760 kgce in the 2020-21 at the rate of -8.29% over the 2019-20 (22266 MJ).

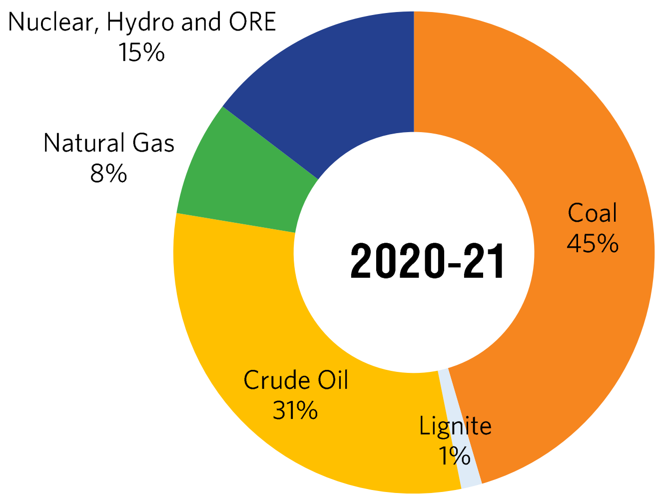
Figure 3.1-4 Per capita energy consumption



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

The consumption of energy from Coal and Lignite was highest, which accounted for about 46.84% of the total consumption during 2020-21, followed by Crude Oil (30.78%) and Electricity (14.64%).

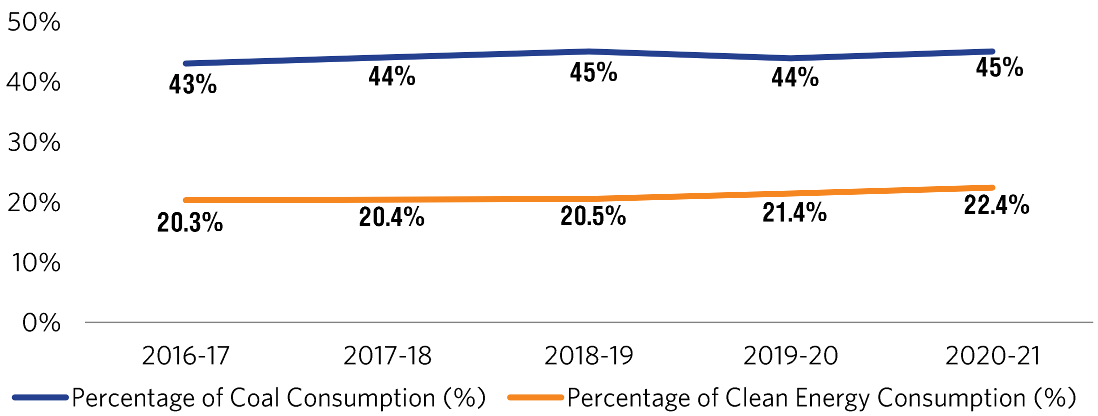
Figure 3.1-5 Energy Consumption Structure



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

India is one of the largest producers and consumers of Coal globally. Coal consumption has persisted over the last five years and has not increased much. It has varied slightly and stayed around 44%. On the other hand, clean energy consumption has grown steadily at about 1%.

Figure 3.1-6 Percentage of Energy Consumption



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

3. Energy Imports and Exports

The table below shows India's Export and Import of different energy commodities from 2016-17 to 2020-21.

Table 3.1-1 Export and Import by Source

	Coal (million tons)			Natural gas (billion cubic meters)			Crude oil (million tons)			Petroleum Products (million tons)		
Indicator	Exports	Imports	Net Imports	Exports	Imports	Net Imports	Exports	Imports	Net Imports	Exports	Imports	Net Imports
2016-17	1.77	190.95	189.18	0.00	24.85	24.85	0.00	213.93	213.93	65.51	36.29	-29.22
2017-18	1.50	208.25	206.75	0.00	27.44	27.44	0.00	220.43	220.43	66.83	35.46	-31.37
2018-19	1.31	235.35	234.04	0.00	28.74	28.74	0.00	226.50	226.50	61.1	33.35	-27.75
2019-20	1.03	248.54	247.51	0.00	33.89	33.89	0.00	226.95	226.95	65.69	43.79	-21.90
2020-21	2.95	215.25	212.31	0.00	33.03	33.03	0.00	198.11	198.11	56.76	43.48	-13.28
Average annual growth rate from 2016-17 to 2020-21	34.18%	3.57%	3.50%	-	8.32%	8.32%	-	1.83%	1.83%	-0.89%	9.11%	-14.12%

Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

There has been an increasing trend in the net Import of Coal from 2016-17 to 2019-20 but has decreased in 2020-21, as shown in Table 3.1-1. Further, India also relies on the Import of Crude oil Import. However, India is an exporter of Petroleum Products. Exporting petroleum products increased from 65.51 MT during 2016-17 to 65.69 MT during 2019-20. But it was reduced to 56.76 MTs in 2020-21. The AAGR of exports of petroleum products from 2016-17 to 2020-21 is (-)0.89%. The trend in India's Import and export of power is tabulated in table 3.1-2.

Table 3.1-2 Export and Import of Power

Years	Import (TWh)	Export (TWh)	Net Import (TWh)
2016-17	5617	6710	-1093
2017-18	5072	7203	-2131
2018-19	4396	8469	-4073
2019-20	6351	9491	-3140
2020-21	8765.5	9426	-660.5
Average annual growth rate from 2016-17 to 2020-21	13.31%	11.66%	-

Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

4. Energy technology innovation

India is in the midst of an unprecedented energy transition. Driven by economic progress, the country's growing energy demand is projected to double by 2030. India has made significant strides toward meeting this demand through increased generation capacity from existing and new energy sources. It has expanded its electricity service to millions of its citizens. Simultaneously, India is pursuing ambitious clean energy and climate change mitigation goals. The transition has been enabled by the deployment of many inventive technologies and policies. India's energy future will rely on continued innovation and capitalizing on new opportunities in the sector.

Energy research, development and deployment (RD&D) can be a strong enabler of India's energy policy goals while contributing to broader national priorities such as the "Make in India" manufacturing initiative.

Through the initiative, the government is working to attract global companies to produce solar PV, lithium batteries, solar charging infrastructure and other advanced technologies in India. The government is strengthening its innovation efforts in many energy technology areas, including cooling, electric mobility, smart grids and advanced biofuels.

India's innovation-specific policy support has been influential in driving energy technology development. As part of its climate policy agenda, the government has pursued a mission-based approach in many policy areas, including solar, water and energy. India has also been a leader in Mission Innovation and other multilateral collaborations.

5. Policies and objectives

In the NDC communicated at COP 21, India has committed to improving the emissions intensity of its economy by 33 - 35% by 2030, compared with 2005 levels, and to achieve a 40% share of non - fossil fuels in electricity generation capacity by 2030. The Prime Minister of India has further increased these targets by announcing the Panchamrit at COP 26 aimed at reducing the energy intensity by 45% of GDP over 2005 levels and increasing the share of non-fossil fuels to 50% of installed electricity capacity in the country by 2030.

India has the 4th largest wind power capacity in the world. India has also set a target of installing offshore wind capacity of 30 GW by 2030 under the "National Offshore Wind Energy Policy" to harness the potential of offshore wind energy along India's coastline.

India has also notified the "National Wind-Solar Hybrid Policy", providing a framework for promotion of large grid connected wind-solar PV hybrid projects for optimal and efficient utilization of transmission infrastructure and land, reducing the variability in renewable power generation and achieving better grid stability.

India is among the few countries in the world to design a Cooling Action Plan (CAP) with a long-term vision (spanning a 20-year period from 2017-18 to 2037-38) that addresses cooling requirements across sectors. It identifies possible actions to reduce cooling demand arising from residential and commercial buildings, cold chains, etc., covering aspects of building design and technological innovations that do not compromise on energy efficiency.

- Some of the recently announced policies in the field of clean energy include:
- Advancement of Ethanol Blending Target to 2023 (2021)
- Allotment of 50 GWh of battery capacity under the Production Linked Incentive (PLI) scheme for Advanced Chemistry Cell (ACC) Battery Storage (2022)
- Production Linked Incentive (PLI) scheme for High Efficiency Solar PV Modules with a total corpus of Rs. 24,000 crores (4500 crores (2021) + 19500 crores (2022)).
- Green Energy Open Access Rules 2021
- Revised “Guidelines and standards on EVCI” (2022)
- Specifying RPO trajectory beyond 2022
- Specifying Hydropower Purchase Obligation (HPO) trajectory upto 2030
- Waiver of ISTS charges
- Development of Green Energy Corridor (GEC)
- Green Hydrogen Mission
- Establishment of Renewable Energy Management Centres (REMCs) at National, State and Regional level to support forecasting and scheduling of RE generation
- Revised Scheme for Flexibility in Generation and Scheduling of Thermal/Hydro Power Stations through bundling with Renewable Energy and Storage Power
- Revised Policy for Biomass Utilisation for Power Generation through Co-firing in Coal based Power Plants

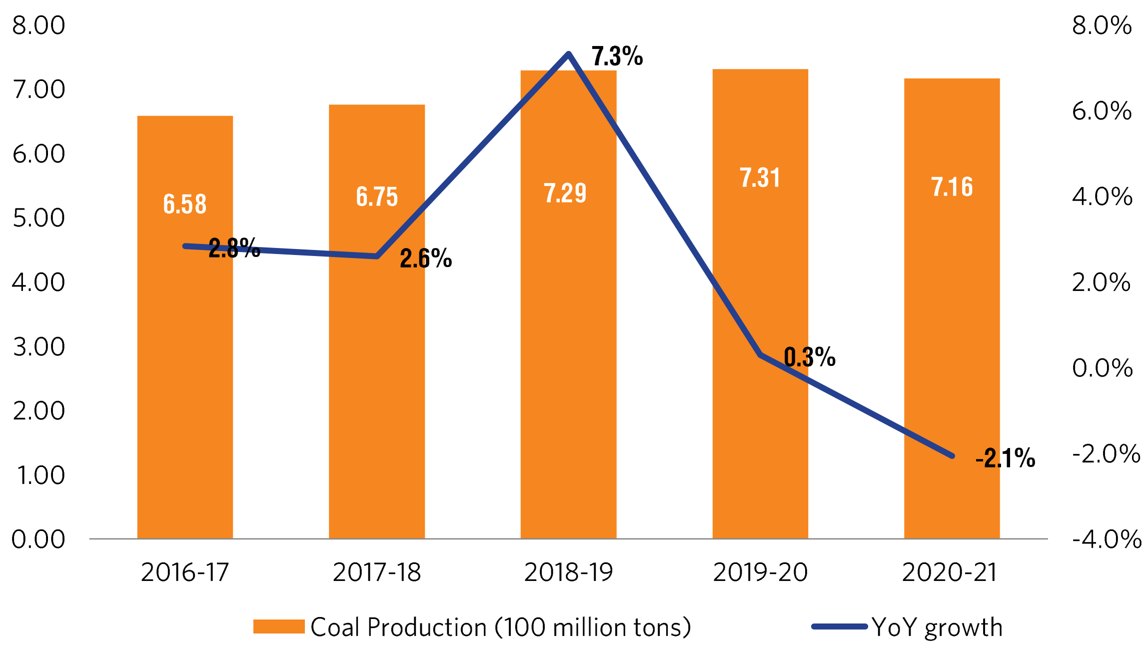
The focus is also on improving energy efficiency across sectors. Several innovative energy efficiency mechanisms and national programs have been successfully designed and implemented like the Perform Achieve and Trade (PAT), Standards and Labeling for Energy Efficient Appliances, UJALA for households, Street Lighting National Programme (SLNP), Energy Conservation Building Codes (ECBC) leading to significant reduction in carbon emissions.

II. ENERGY SECTOR

1. Coal

India, being one of the largest reservoirs of Coal, has displayed a steady increase in the availability of Coal during the last five years. The total availability of Coal in 2020-21 stood at931.334 MT out of which, a significant portion (76.89%) was produced domestically and 215.25 MT was imported. Within Coal, Public sector has the dominating share in production. During 2020-21, almost 96% of total production has come from public sector.

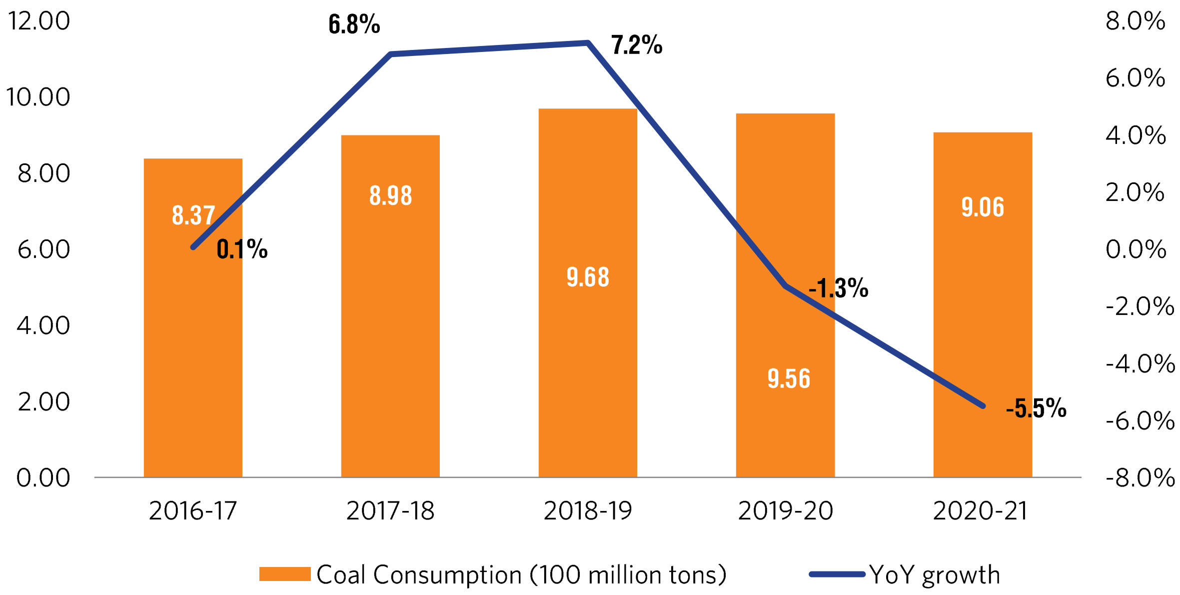
Figure 3.1-7 Coal Production from 2016-17 to 2020-21



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

Coal consumption decreased in 2020-21 over 2019-20 by 5.19%. This decreasing trend is observed from2019-20.

Figure 3.1-8 **Coal Consumption from 2016-17 to 2020-21**



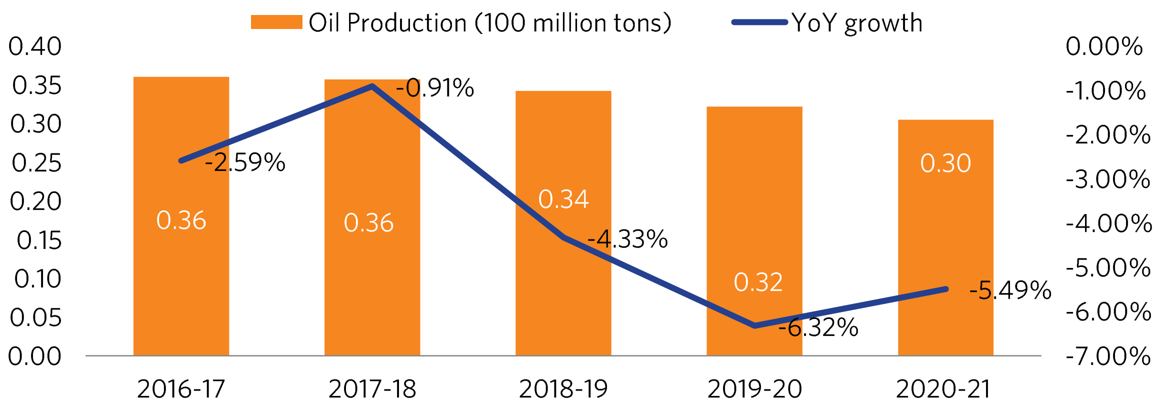
Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

There has been an increasing trend in the net Import of Coal from 2016-20 to 2019-20, but has decreased in 2020-21, with an average annual growth rate of 3.5%. While the Coal export from 2016-17 to 2019-20 has decreased but has increased in 2020-21. Net Import of Coal steadily increased from 100.83 MTs in 2011-12 to 247.51 MTs in 2019-20. In 2020-21, there is a sharp decline of over 14% in the Net Import of Coal w.r.t the 2019-20. During 2020-21, the net-Import of Coal came out to be 212.31 MTs as compared to 247.51 MTs during 2019-20.

2. Oil

The total availability of crude oil has decreased by 11.78% over last year (from 259.12 MT in 2019-20 to 228.61 MT during 2020-21). This decline in 2020-21 is because of a marginal decrease in domestic crude oil production and a considerable reduction in net imports.

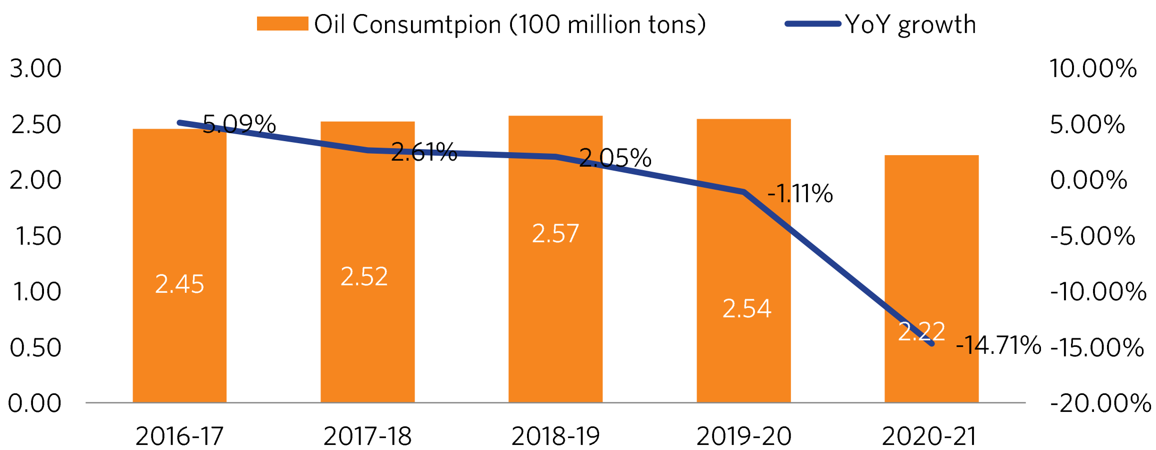
Figure 3.1-9 Oil Production from 2016-17 to 2020-21



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

The decreasing trend in crude oil consumption can be observed in the below graph.

Figure 3.1-10 Oil Consumption from 2016-17 to 2020-21



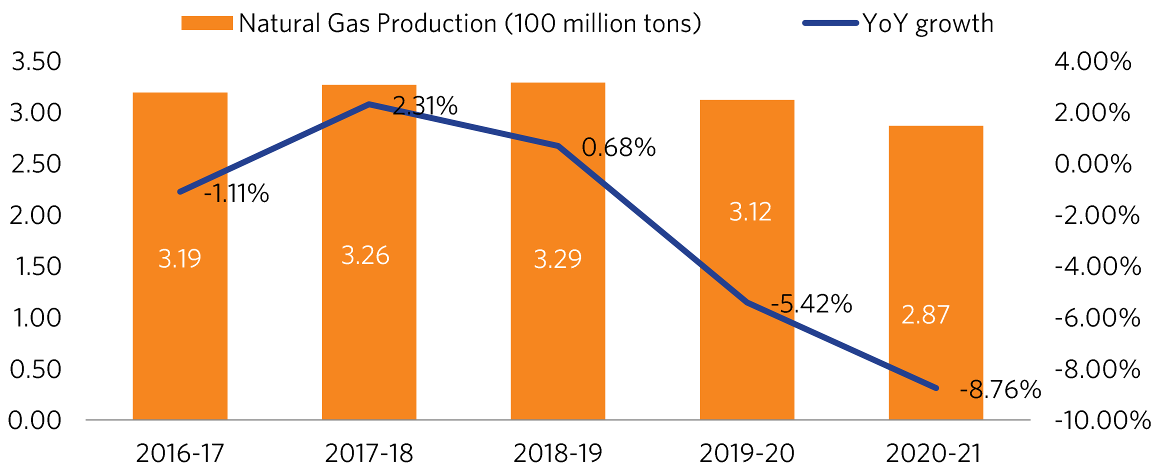
Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

India is also highly dependent on imports of crude oil to meet domestic consumption. Imports of crude oil have increased from 213.93 MTs during 2016-17to 226.95 MTs during 2019-20. But during FY: 2020-21 the same has been reduced to198.11 MTs, a reduction of 13% over the FY: 2019-20. The overall AAGR of Net imports of crude oil in the last ten years from 2016-17 to 2020-21(P) has seen to have a growth rate of 0.97%.

3. Natural Gas

Net production of Natural Gas for consumption decreased from to 30.26 Billion Cubic Meters (BCM) in 2019-20 to 27.78 BCM in 2020-21, registering a sharp decline of 8.17%. The Net-Production for sale has also experienced a decline over past 5 years.

Figure 3.1-11: Natural Gas Production from 2016-17 to 2020-21

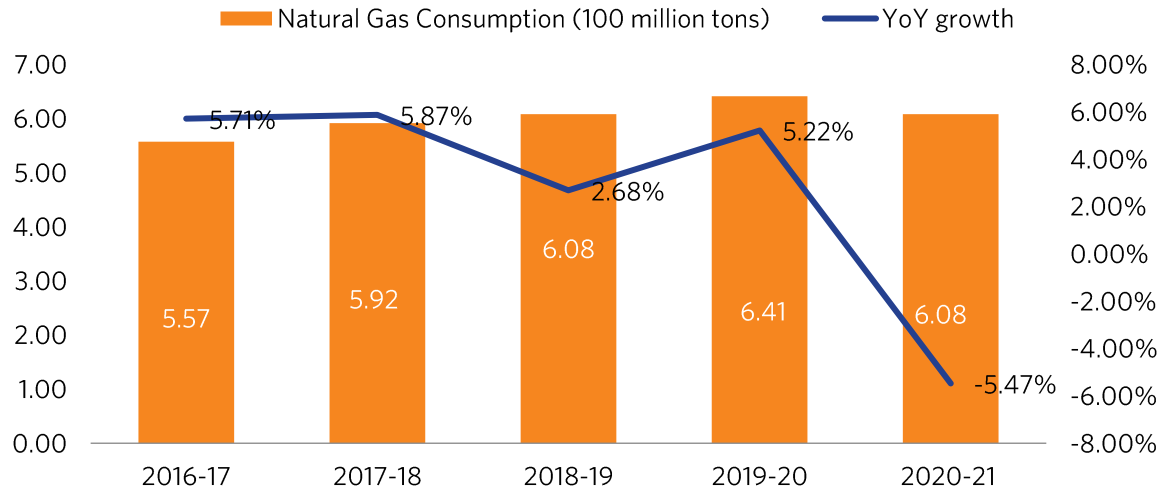


Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

The consumption of Natural Gas, both for energy and non-energy purpose, have experienced a fluctuation over time. Where the use against energy purposes have found to be dwindling during 2020-21, the uses against 'non-energy' purposes have shown positive growth during 2020-21.

The maximum use of Natural Gas is in the fertilizers industry (29.32%) followed by power generation (17.87%). The off-take of natural gas shows that, out of the Total Consumption (Availability Basis (Net Production + LNG Imports)), 57.08% of natural gas has been used for Energy purposes, 35.45% is used for nonenergy purposes.

Figure 3.1-12 Natural Gas Consumption from 2016-17 to 2020-21



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

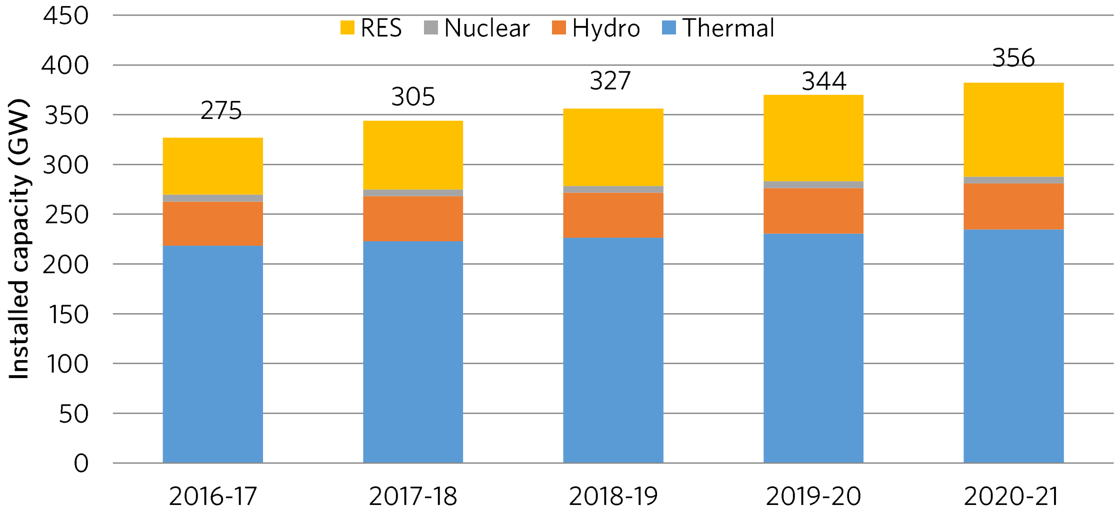
The Import of Natural Gas has experienced a steady increase over time. From a figure of 24.85 BCM (Billion Cubic Meter) during 2016-17 to 33.89 BCM during 2019-20i.e., an increase of over 36% in a span of 5 years. However, the same stood at 32.86BCM for the year 2020-21 as compared to 33.89 BCM.

4. Electric Power

Total all India installed electricity generating capacity as of 31.03.2021 is 382151.22 MW comprising Thermal 234728.22 MW, Hydro 46209.22 MW, Nuclear 6780.00 MW and 94433.79 MW from Renewable Energy Sources (RES).

India has experienced steady growth in gross electricity generation over time. Also, in terms of year-on-year growth, from 2019-20 to 2020-21, gross generation of electricity from Hydro, Nuclear declined by (-)3.51%, (-)7.41%, respectively, but for the Other Renewable Resources, it grew by 6.44%. Again, the gross generation of Electricity from Utility declined by (-0.74%) during 2020-21over 2019-20.

Figure 3.1-13 Installed Capacity from 2016-17 to 2020-21

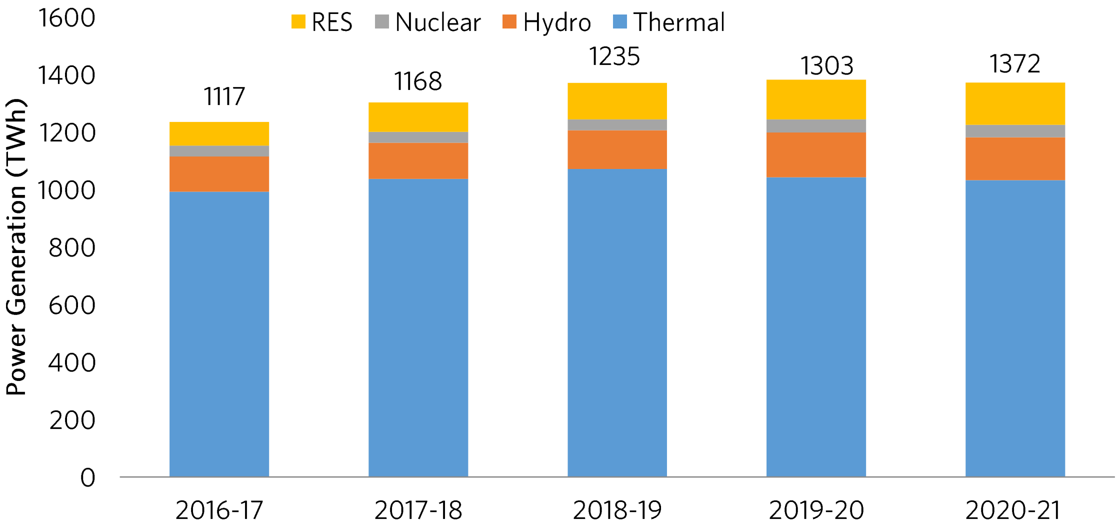


Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

Electricity available for supply has increased from 8,81,466GWh in 2011-12 to 13,09,187 GWh in 2020-21. However, there is a decrease of 1.05% in the availability of electricity (from 13,23,0148 GWh during 2019-20 to 13,09,187GWh) during 2020-21.

Out of the total consumption of electricity in 2020-21, the industry sector accounted for the largest share (41.09%), followed by domestic (25.67%), agriculture (17.52%) and commercial sectors (8.31%). The Domestic sector has experienced the highest growth.

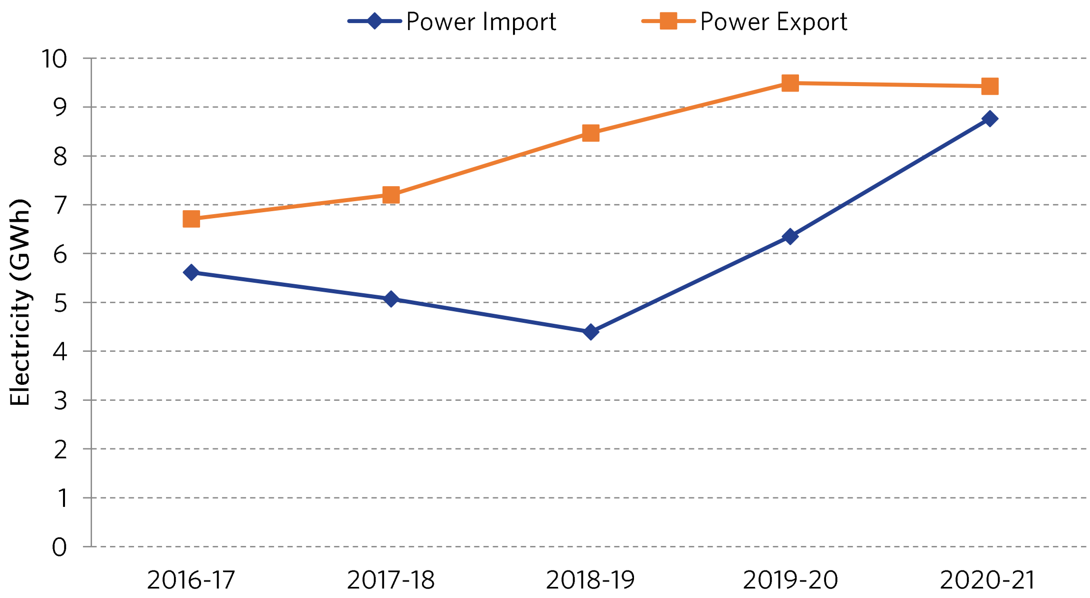
Figure 3.1-14 Electric Power Generation from 2016-17 to 2020-21



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

India's electricity exports started rising compared to gross imports in 2016-17. The export of electricity has increased from 135 GWh in 2011-12 to 9426 GWh in 2020-21.

Figure 3.1-15 Electric Power Import and Export from 2016-17 to 2020-21



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

However, the export of electricity has slightly declined from the year 2019-20, when 9491 GWh was available for exports.

5. Nuclear Power

For the past five years, the installed capacity for nuclear power has not changed (6.78 GW). In terms of year-on-year growth, from 2019-20 to 2020-21, the gross electricity generation from Nuclear declined by -7.41%.

Figure 3.1-16 **Installed Capacity of Nuclear Power from 2016-17 to 2020-21**

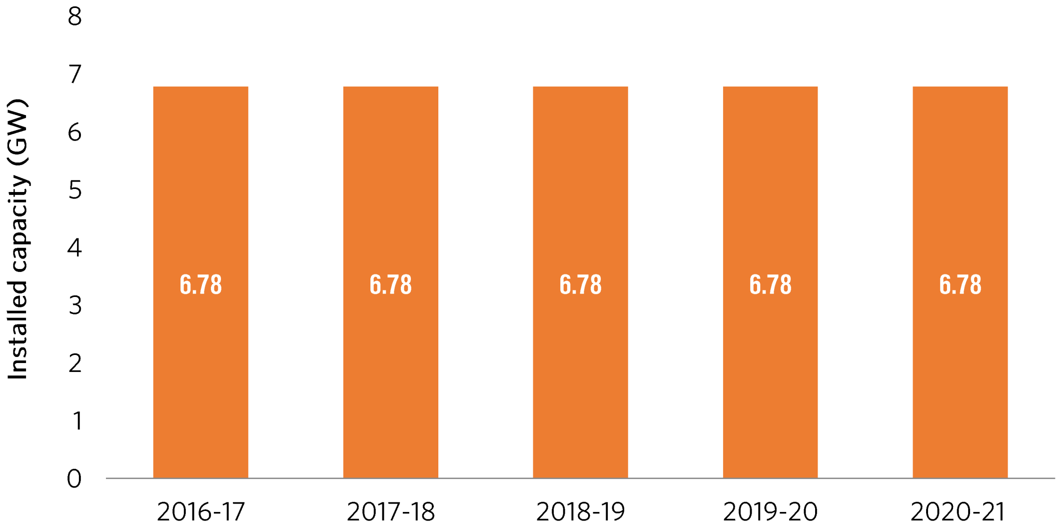
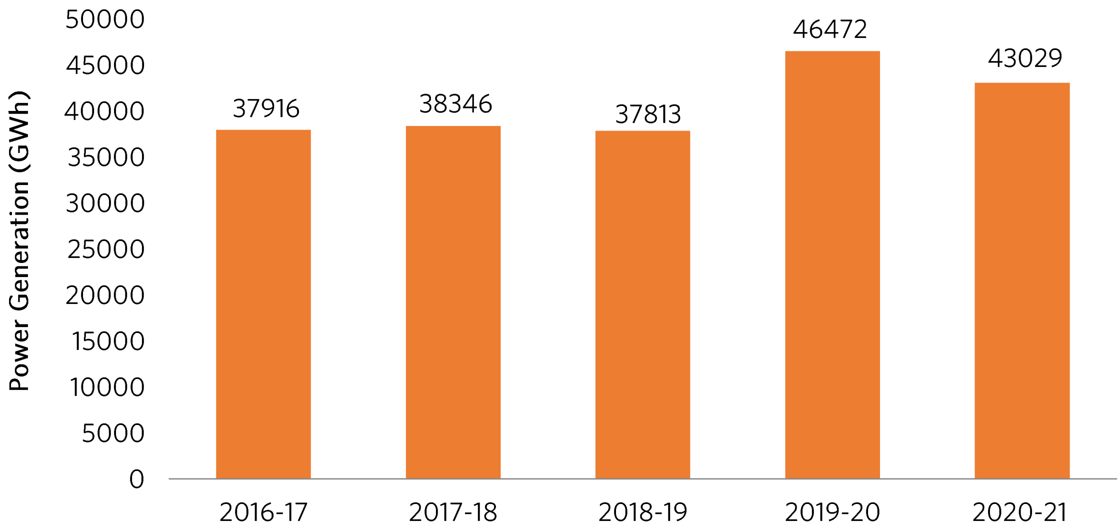


Figure 3.1-17 **Power Generation from Nuclear Power 2016-17 to 2020-21**



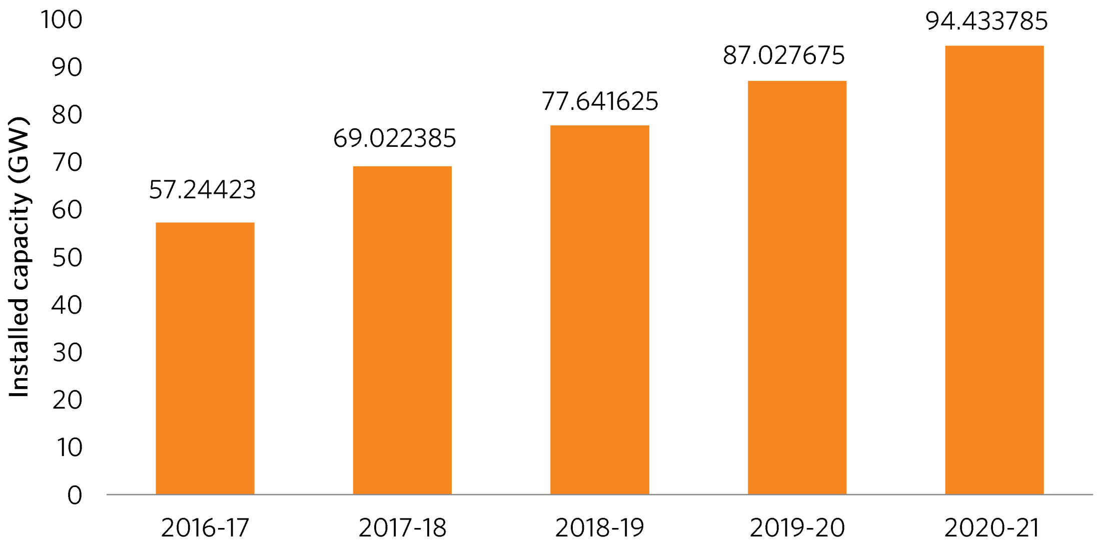
Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

6. Renewable Energy

The Government of India has set a target of achieving 500 GW of non-fossil fuel installed capacity by 2030. This would mean that 62% of our installed power generation capacity is expected to be from Non-Fossil fuel-based energy sources by 2030 while the share of fossil fuels in the installed capacity will decrease from 60% presently to 38% in 2030.

As on 31-03-2021, the total grid-connected installed capacity from renewable energy sources is 94433.79 MW.

Figure 3.1-18 Installed Capacity of Renewable Energy 2016-17 to 2020-21



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

The generation from the Other Renewable Resources has grown by 6.44%. The source wise break up of cumulative RE Generation for 2020-21 is:

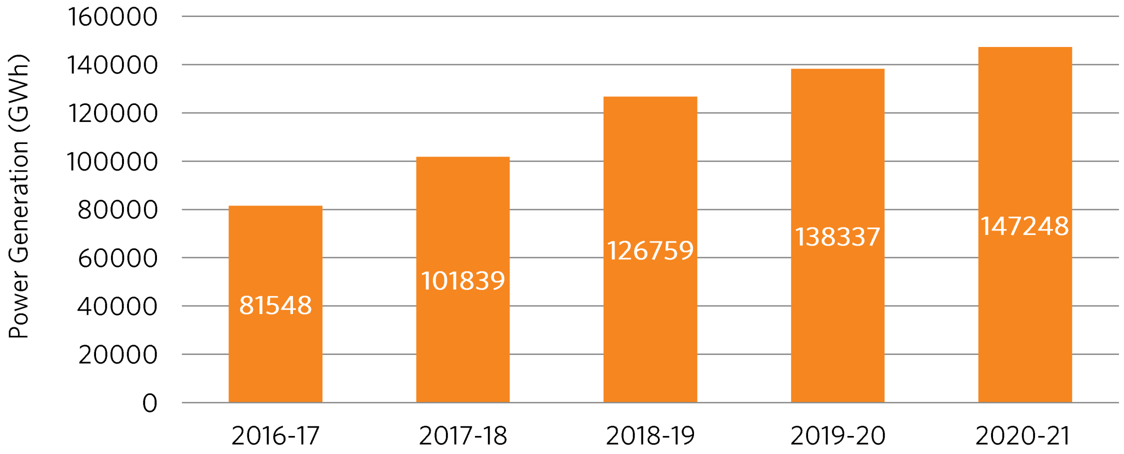
Table 3.1-3 Source wise break up of cumulative RE Generation for 2020-21

RE Generation Sources	Percentage
Solar	41.2%
Wind	40.85%
Small Hydro	6.97%
Biomass	2.39%
Biogasses	7.68%
Other	1.10%

Source: CEA Annual Report 2020-21, Central Electricity Authority, Ministry of Power, Government of India.

Generation from Renewable Energy sources from 2016-17 to 2020-21 is shown below:

Figure 3.1-19 Power Generation from Renewable Energy 2016-17 to 2020-21



Source: Energy Statistics 2022, Central Statistics Office Ministry of Statistics and Programme Implementation, Government of India.

III. SUSTAINABLE ENERGY DEVELOPMENT

1. Energy Access

The Government of India is committed to improving the quality of life of its citizens by ensuring adequacy of electricity availability. The aim is to provide each household access to electricity, round the clock. The 'Power for All' by 2022 program is a major step in this direction. India has achieved universal access and has added 28 million consumers in just about 18 months, which was the fastest expansion access anywhere in the world, and much of it is because of rapid increase in deployment og=f renewables in the past 7 years.

The government has also made considerable progress to expand the access to LPG through the PMUY scheme. 97.5% of households today can access LPG.

To bring clean fuel in rural areas the Pradhan Mantri Ujjawala Yojana, should be complemented by: Setting up of biomass pelletising units; and distribution of 'efficient biomass stoves'. On the agricultural front, solar irrigation pump distribution target must be stepped up and financed through credit support from NABARD and government subsidy.

2. Green and low-carbon transition

For sustainable development and economic growth, the focus of the Government of India is towards reducing the carbon footprint of the Indian Power Sector and increasing the share of non-fossil fuel based energy sources, which are cleaner, safer, environment friendly and more sustainable.

India has embarked upon clean energy transition by increasing energy efficiency and deployment of renewables while simultaneously ensuring access to affordable energy, which is inevitable for sustainable development and climate change mitigation. RE capacity has increased by more than 210% in last 7-8 years which has resulted in a version of about 1 Billion Tonnes CO_2 emission.

India is also in the process of retiring old and inefficient thermal units. A total of 250 units with capacity of 17526 MW have been retired till date with increased efforts towards modernizing the existing thermal power plant fleet, while ensuring energy security and system reliability.

However, since renewable energy is intermittent in nature, and therefore, till the time commercially viable storage technologies are developed, India will continue to be dependent on coal for the base load and for the stability of the grid.

India's Total Emissions from the Energy Sector have increased from 16,51,928 GgCO2 Equivalent in 2011 to 21,29,428 GgCO2 Equivalent in 2016 as per the latest estimates by MoEFCC in February 2021. The major sector contributing to total emissions remains Energy industry with its share increasing marginally from 55.95% in 2011 to 56.66 in 2016.

India has made important progress towards meeting the United Nations Sustainable Development Goals, notably Goal 7 on delivering energy access. **India's has achieved reduction of 24% in emission intensity of its GDP between 2005 and 2016** and the rate of reduction is aligned with the target reduction of 45% by 2030. This represents commendable progress even as total energy related carbon dioxide (CO2) emissions continue to rise. Today, India's per capita emissions are 1.6 tonnes of CO2, well below the global average of 4.4 tonnes, while its share of global total CO2 emissions is 6.4%.

The potential non-conventional energy sources must be explored and researched to make them technologically economical and accessible, like geothermal energy, tidal energy etc.

A key focus of the Government of India is on implementing the largest Renewable Energy

(RE) expansion programme in the world envisaging 500 GW of non-fossil fuel based power capacity in the country by 2030. India's total non-fossil fuel based installed capacity today stands at around 167 GW, which is about 41.5 % of the total installed power generation capacity. About 80 GW of renewable energy projects are already under various stages of implementation.

By 2030, 62% of India's installed power generation capacity is expected to be from Non-Fossil fuel-based energy sources while the share of fossil fuels in the installed capacity will decrease from 60% presently to 38% in 2030.

3. Energy security

One of the Targets identified by the Sustainable Development Goals focuses on universal affordable, reliable and modern energy accessible to all people.

India's electricity security has improved markedly by creating a single national power grid and significant thermal and renewable capacity investments. India's power system is currently experiencing a major shift to higher shares of variable renewable energy, making system integration and flexibility a priority issue. The Government of India has supported more significant interconnections across the country and now requires the existing coal fleet to operate more flexibly. The Indian Government through its various policy initiatives, The Government has also been exploring means to make alternative viable storage technologies to support RE integration.

International experience suggests that a diverse mix of flexibility investments is needed for the successful system integration of wind and solar PV. This flexibility is available not only from the coal fleet but also from natural gas capacity, variable renewables, energy storage, demand-side response and power grids. By 2030, India's target is to install 500 GW of non-fossil fuel capacity including about 280 GW of solar energy. As part of commitments to global climate goals, India has committed to enhancing the focus on renewable power over the next decades.

India is the world's third-largest consumer of oil, the fourth-largest oil refiner and a net exporter of refined products. To improve oil security, the government has prioritized reducing oil imports, increasing domestic upstream activities, diversifying its sources of supply and increasing Indian investments in overseas oil fields in the Middle East and Africa.

[IV]

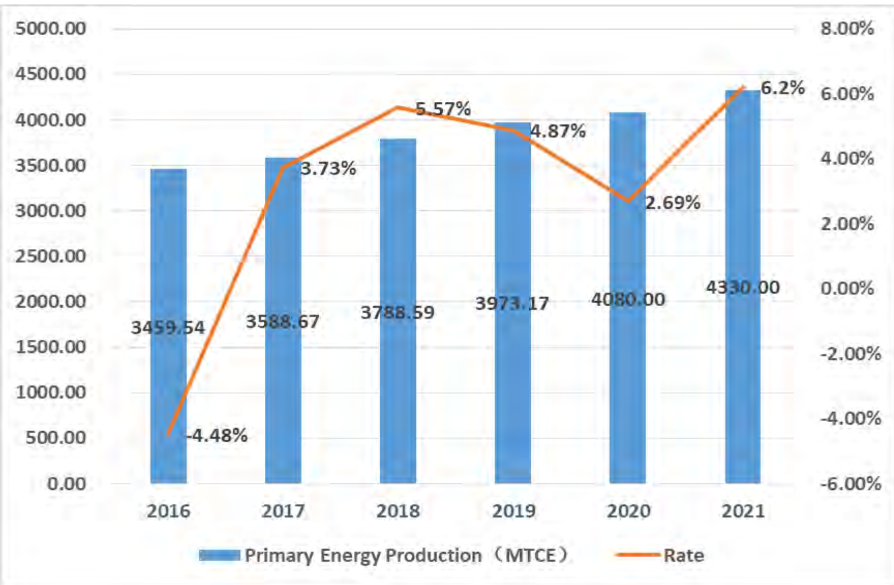
CHINA

I. OVERVIEW OF ENERGY DEVELOPMENT

1. Energy Production

Overall, energy production in China increases steadily. In 2020, the COVID-19 epidemic slowed down the growth rate of China's total primary energy production. In 2021, energy enterprises overcame the adverse impact of the epidemic and actively promoted the resumption of production, leading to a significant increase in energy production, which guaranteed energy supply and security. In 2021, China's total primary energy production reached 4.33 billion tons of standard coal, an increase of 6.2% year on year. The average annual growth rate from 2016 to 2021 was 4.6%.

Figure 4.1-1 Primary Energy Production（MTCE）

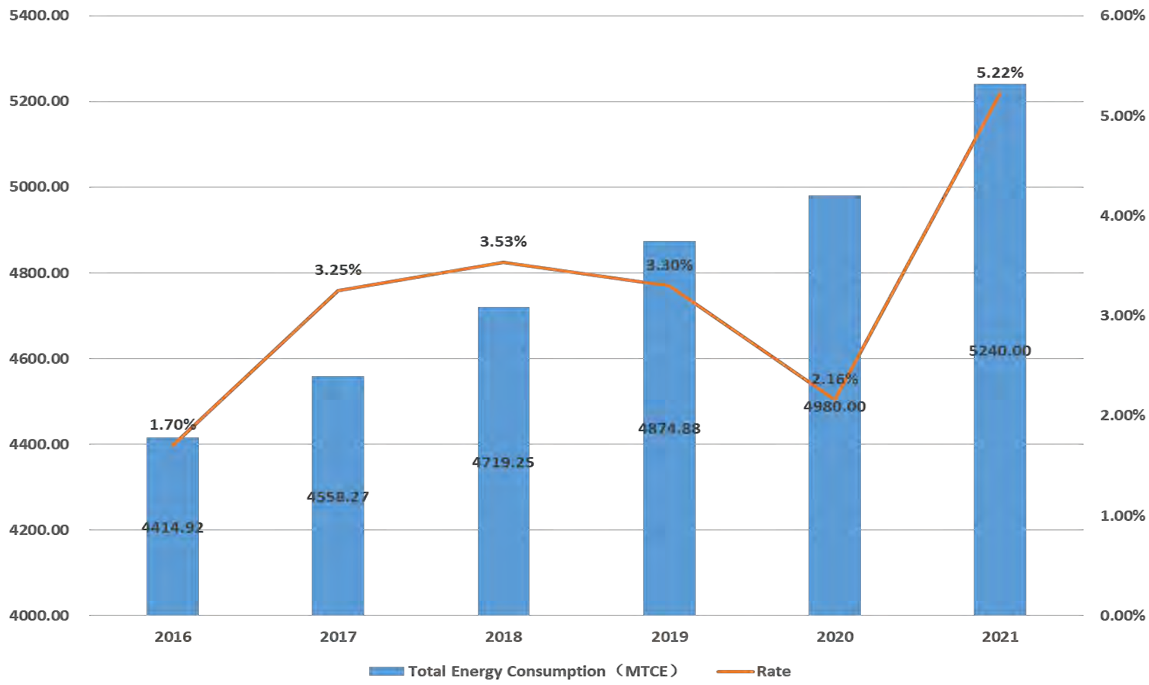


China is increasingly capable of ensuring energy supply security. Coal remains the basic energy source for securing energy supply, with raw coal production up 5.7% year on year. China’s ability to provide oil and gas has improved remarkably, with the production of crude oil up 2.1% year-on-year and the production of natural gas up 7.8% year-on-year. Electricity generation is up 9.7% year on year. The scale of renewable energy development and utilization is expanding rapidly, with the cumulative installed capacity of hydropower, wind power, and solar power all ranking first in the world.

2. Energy Consumption

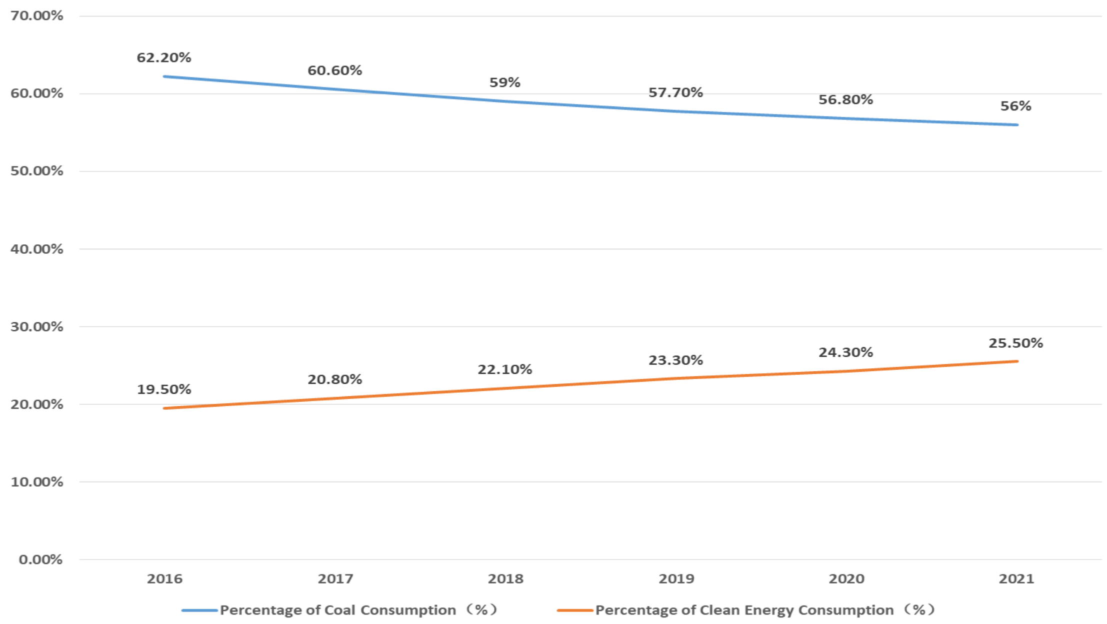
Energy consumption increases slightly. China strictly controls the total amount and intensity of energy consumption while ensuring healthy economic and social development with low energy consumption growth. With the epidemic raging, the growth rate of energy consumption in 2020 was 1.14 percentage points lower than the previous year. In 2021, recovering from the epidemic, China's energy consumption grew significantly, reaching a total of 5.24 billion tons of standard coal, an increase of 5.2% over the previous year. Among them, coal consumption grew by 4.6%, crude oil consumption by 4.1%, natural gas consumption by 13%, and electricity consumption by 10.3%. From 2016 to 2021, China's energy consumption grew at an average annual rate of 3.5%.

Figure 4.1-2 **Energy Consumption（MTCE）**



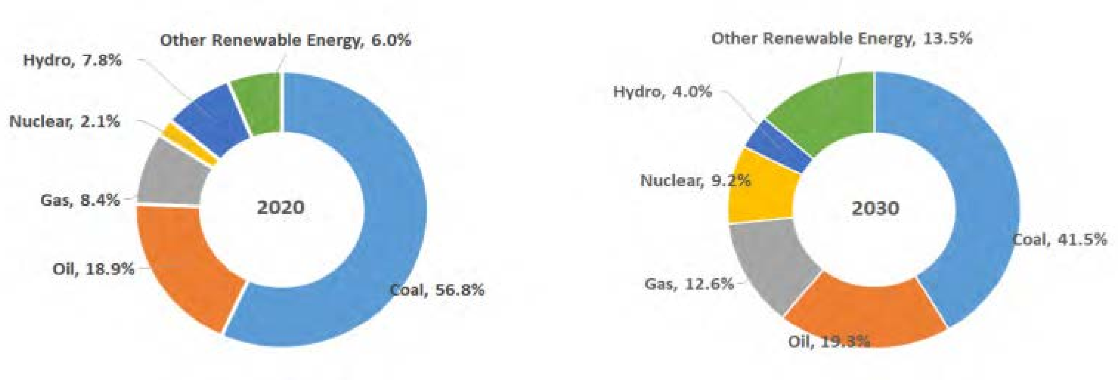
The energy consumption mix continues to be optimized. In 2021, coal consumption accounted for 56.0% of total energy consumption, down 6.2 percentage points compared to the 2016 level; clean energy consumption such as natural gas, hydropower, nuclear power, wind power, and solar power accounted for 25.5% of total energy consumption, up 6 percentage points compared to that of 2016.

Figure 4.1-3 Percentage of Energy Consumption



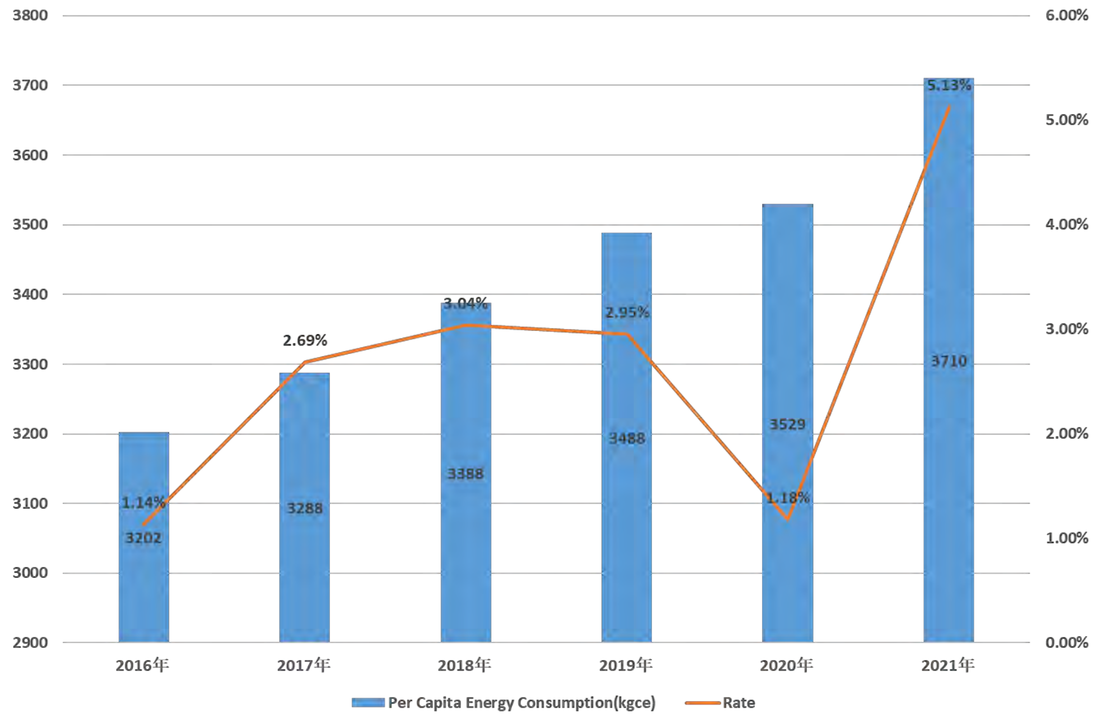
According to the prediction of International Energy Agency (IEA), compared with 2020, the proportion of coal in China's energy consumption mix will decrease significantly in 2030, from 56.8% to 41.5%. The proportion of non-aqueous renewable energy will increase significantly from 6.0% to 13.5%. In 2030, non fossil energy consumption will account for around 25%.

Figure 4.1-4 Energy Consumption Structure



Per capita energy consumption grows steadily. In 2021, China's per capita energy consumption was 3,710 kg of standard coal, an increase of 5.13% year-on-year. From 2016 to 2021, the average annual growth rate of per capita energy consumption was 3%.

Figure 4.1-5 Per Capita Energy Consumption



3. Energy Imports and Exports

In 2021, in light of the domestic energy supply and demand situation, China made flexible moves and benefited from the international market by actively importing energy as a supplement, especially oil and gas resources. The annual energy imports registered rapid growth. Crude oil imports increased from 380 million tons in 2016 to 510 million tons in 2021, with an average annual growth rate of 6.1%. Natural gas imports grew from 74.6 billion cubic meters in 2016 to 167.5 billion cubic meters in 2021, with an average annual growth rate of 17.6%. Coal imports grew from 260 million tons in 2016 to 320 million tons in 2021, with an average annual growth rate of 4.8%.

Table 4.1-1 Energy Imports and Exports

	Coal (10,000 tons)			Natural gas (100 million cubic meters)			Crude oil (10,000 tons)		
Indicator	Exports	Imports	Net Imports	Exports	Imports	Net Imports	Exports	Imports	Net Imports
2016	879	25543	24664	34	746	712	294	38101	37807
2017	817	27090	26273	35	946	911	486	41957	41471
2018	493	28189	27696	34	1246	1212	263	46189	45926
2019	603	29952	29349	36	1332	1296	81	50568	50487
2020	319	30331	30012	0	1413	1413	0	54201	54201
2021	260	32322	32062	0	1680	1680	0	51298	51298
Average annual growth rate from 2016-2021	-21.6%	4.8%	5.4%	-100%	17.7%	18.8%	-100%	6.1%	6.3%

4. Energy Technology Innovation

China's Achievements in Energy Technology Innovation

China continues to pursue technological innovation in the energy sector, with its energy technologies continuously improving and producing many historic achievements.

(1) There are complete industrial chains for the manufacturing of clean energy equipment for hydropower, nuclear power, wind power, and solar power. China has successfully developed and manufactured the world's largest hydropower unit, with a capacity of 1000 MW; it is able to manufacture a full range of wind turbines with a maximum single-unit capacity of 10 MW; and it continues to establish new world bests in the conversion efficiency of solar PV cells.

(2) China has built a number of nuclear power plants using advanced third-generation technologies, and made significant breakthroughs in a number of nuclear energy technologies such as new-generation nuclear power generation and small modular reactors (SMRs).

(3) Its technological capabilities in oil and gas exploration and development keep

improving. It leads the world in technologies such as the high-efficiency development of low-permeability crude oil and heavy oil, and a new generation of compound chemical flooding. The technology and equipment for shale oil and gas exploration and development have greatly improved, and successful natural gas hydrate production tests have been completed.

(4) China is developing green, efficient and intelligent coal mining technology. It has achieved mechanization in 98 percent of its large coal mines, and mastered the technology for producing oil and gas from coal.

(5) It has built a safe, reliable, and world-leading power grid which is the largest across the world, with reliability of supply at the forefront of the world.

(6) A large number of new energy technologies, new businesses, and new models such as "Internet +" smart energy, energy storage, block chain, and integrated energy services are booming.

China's Plan for the Development of Energy Technology

In April 2022, China issued *the Plan for Science and Technology Innovation in the Energy Sector During the 14th Five-Year Plan Period*, focusing on advanced renewable energy, new power systems, safe and efficient nuclear energy, green and efficient fossil energy development and utilization, as well as digital and smart energy. It identifies relevant tasks for focused research, demonstration tests, and application promotion, deploying relevant demonstration projects with technology roadmaps.

(1) In advanced renewable energy power generation and comprehensive utilization technology, 17 key tasks are laid out to focus on large-scale and high-proportion renewable energy development and utilization. Research and development on advanced power generation and comprehensive utilization of technology are needed to gain more efficient, economical, and reliable access to water, wind, solar, biomass, geothermal energy, and marine energy, supporting the high-quality development and utilization of renewable energy.

(2) In terms of new power systems and supporting technologies, 12 key technologies are proposed to speed up breakthroughs in strategic and forward-looking core grid technologies to support the construction of advanced power grids that can adapt to large-scale friendly grid integration of renewable energy

and distributed power sources, and coordination of power source-grid-load. The breakthroughs in energy-type, power-type, and other energy storage devices as well as in systemic integration of key technologies and core equipment will help meet the development needs of energy storage in different application scenarios of the energy system.

(3) Concerning safe and efficient nuclear energy technology, 11 key tasks are set out to improve the level of nuclear power technology, equipment, and project economics with more research on optimization of key technologies for third-generation nuclear power to be carried out, contributing to the establishment of standardized models and model spectrums; We will strengthen strategic and prospective nuclear energy technology innovation, and carry out R&D to secure breakthroughs in key core technologies of the advanced next-generation nuclear energy systems such as small modular reactors, (ultra) high-temperature gas-cooled reactors (HTGRs), molten salt reactors, etc.

(4) In terms of green and efficient technologies for the development and utilization of fossil fuels, 37 key technologies are planned to focus on enhancing the security of oil and gas, carrying out research and development on both conventional and unconventional oil and gas exploration, and securing breakthroughs in transportation and refining related key core technologies, so as to help effectively explore oil and gas resources and build an integrated system for the production, supply, and marketing of natural gas.

(5) With regard to digital and smart technology of energy system, 16 key tasks are listed to focus on next-generation information technologies and energy integration development, with planned research on common key technologies to make the energy sector digital and smart; We will promote the deep integration of coal, oil and gas, power plants, power grids and other traditional industries with digital and intelligent technologies, launch pilot demonstrations of energy plants and stations and regional smart energy system integration, and lead the transformation and upgrading of the energy industry.

5. Policies and Objectives

The Plan for A modern Energy System During the 14th Five-Year Plan Period and It's Objectives

In March 2022, China officially released *the Plan for A modern Energy System During the 14th Five-Year Plan Period*, which set out the main objectives for the construction of a modern energy system during the 14th five-year plan period.

Better energy security. By 2025, the comprehensive domestic energy production capacity will reach more than 4.6 billion tons of standard coal annually. The annual production of crude oil will rebound and stabilize at the level of 200 million tons; the annual production of natural gas will reach more than 230 billion cubic meters, and the total installed capacity of power generation will reach about 3000 GW.

Remarkable achievements in the low-carbon energy transition. The cumulative carbon dioxide emissions per unit of GDP in 5 years will drop by 18%. By 2025, the proportion of non-fossil energy consumption will increase to about 20%; the proportion of non-fossil energy generation will reach about 39%; the level of electrification will continue to rise, and the proportion of electrical energy to energy end use will reach about 30%.

Significantly higher efficiency of the energy system. Energy-saving and consumption reduction efforts are effective, and energy consumption per unit of GDP will decrease by 13.5% in five years. By 2025, the proportion of flexibly regulated power sources will reach about 24%, and the power response capability on the demand side will reach 3% to 5% of the maximum electricity consumption load.

Increased capacity for innovation-driven development. During the 14th five-year plan period, it's estimated that the average annual investment in energy research and development will increase by more than 7%, and new key technology breakthroughs will be made possible in 50 or so areas.

Constantly improved service for the general public. The per capita domestic electricity consumption will reach about 1,000 kWh, and the coverage of natural gas pipeline network will be further expanded.

"1+N" Policy Framework for Carbon Emissions Peaking and Carbon Neutrality and It's Objectives

In order to achieve carbon emissions peaking and carbon neutrality, China will issue relevant implementation plans and many supporting measures in key areas and industries and build a "1+N" policy framework for carbon peak and carbon neutrality.

"1" refers to The Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in

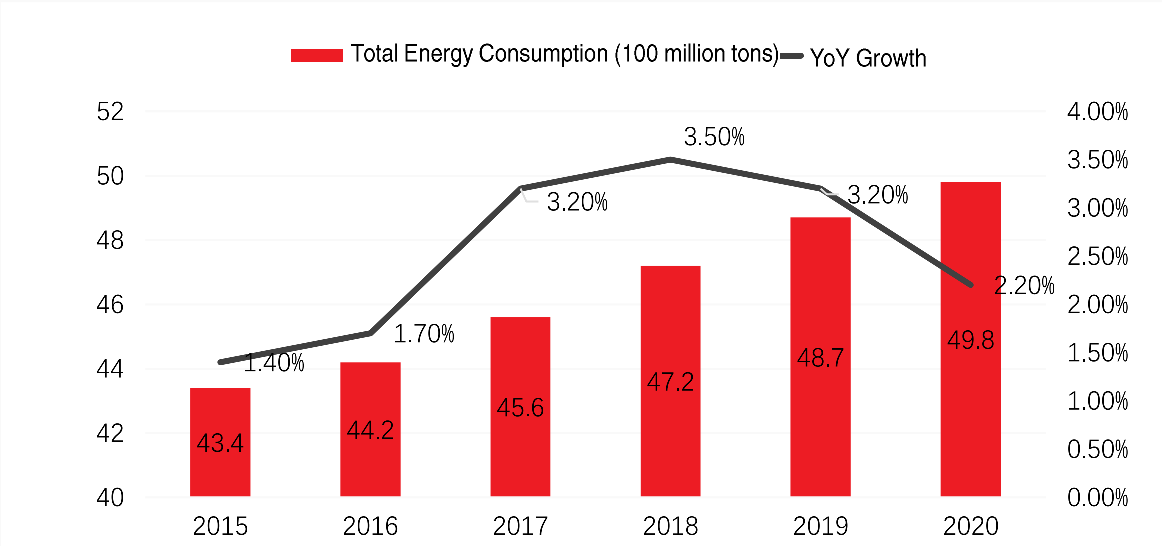
Full and Faithful Implementation of the New Development Philosophy(hereinafter the Guidance) issued by the CPC Central Committee and the State Council. The Guidance clearly pointed out that China aims to gradually increase the share of non-fossil energy consumption to around 20 percent by 2025, around 25 percent by 2030, and over 80 percent by 2060 so as to successfully achieve carbon neutrality.

“N” refers to Action Plan for Carbon Dioxide Peaking Before 2030 issued by the State Council and other solutions and actions in key areas and industries. The Action Plan for Carbon Dioxide Peaking Before 2030 reiterated the above goals and pointed out China's key tasks in green and low-carbon transformation of energy so as to realize carbon emissions peaking by 2030.

II. ENERGY SECTOR

From 2016 to 2020, China placed dual-control on total energy consumption and energy intensity to ensure sound economic and social development on the back of a slower growth in energy consumption. In 2020, China's total energy consumption was about 5 billion tons of standard coal. The average annual growth rate in the previous five years remained about 3%. Affected by the COVID-19 pandemic, the overall growth rate of energy production and consumption in 2020 was lower than previous years.

Figure 4.2-1 Energy Consumption in 2015-2020



1. Coal

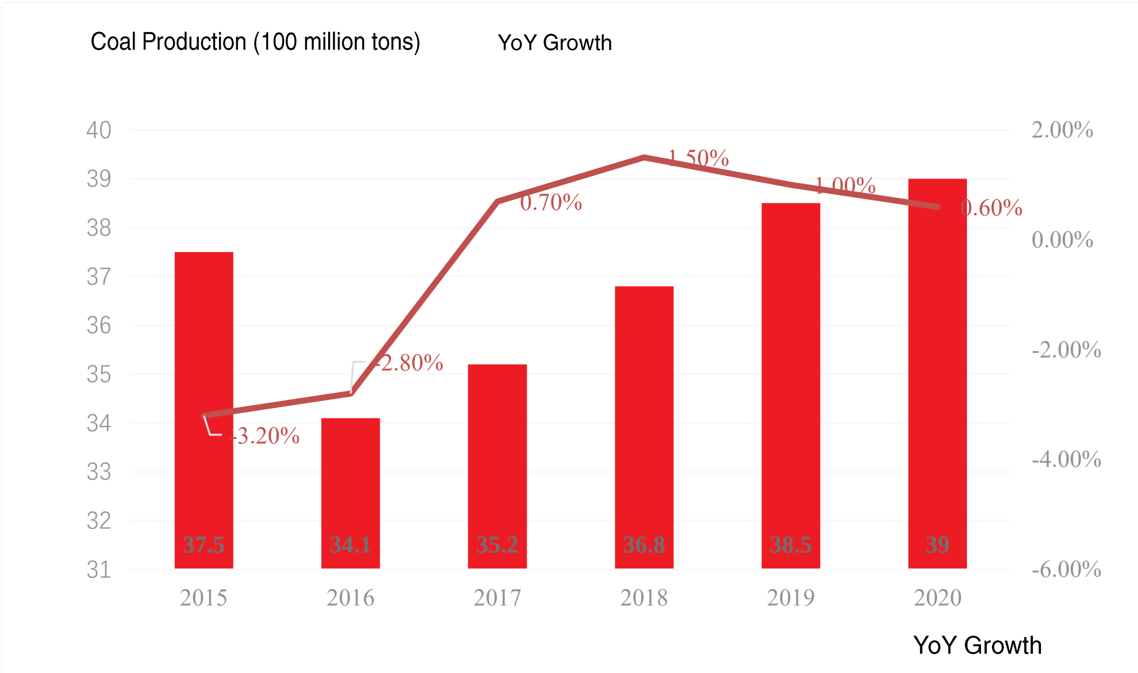
(1) Resource Endowment

By the end of 2020, China's proven coal reserves were about 160 billion tons. Shanxi Province, Shanxi Province and Inner Mongolia had larger coal reserves than other places.

(2) Production

In 2020, China's coal production was about 3.9 billion tons. From 2015 to 2020, China's coal production decreased before going up, with the total output within 3.9 billion tons.

Figure 4.2-2 China's Coal Production in 2015-2020

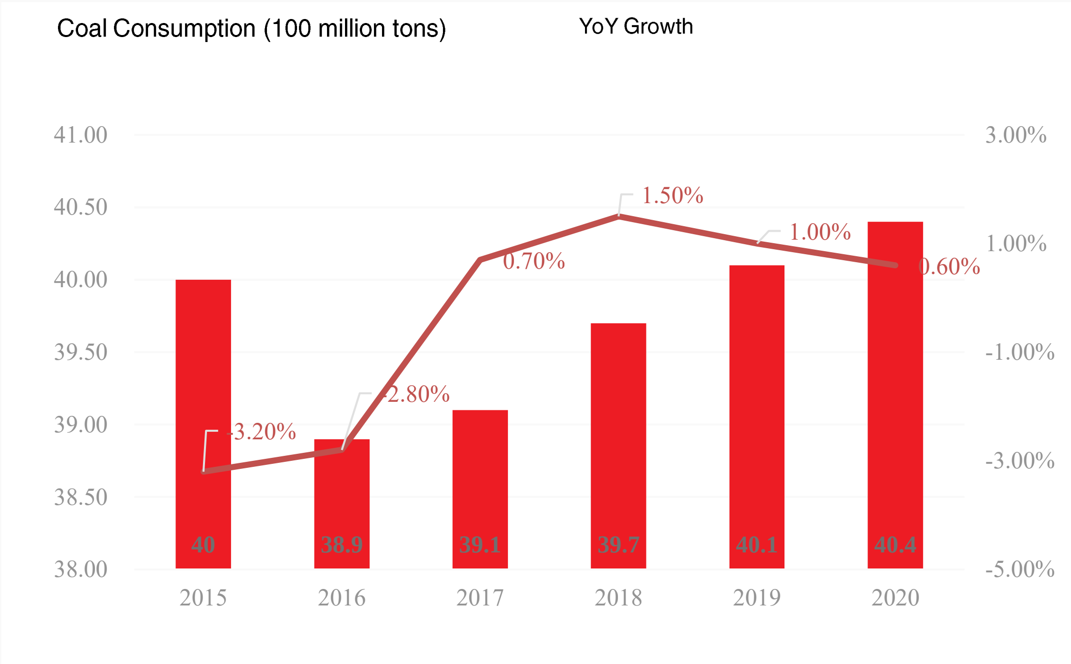


In 2016, China decided to effectively resolve the excess capacity of the coal industry in 3-5 years by phasing out about 500 million tons of capacity and reducing and restructuring about 500 million tons. By the end of 2020, more than 1 billion tons of outdated coal production capacity had been phased out in China and the coal industry achieved the goal of high-quality transition and development.

(3) Consumption

In 2020, China's annual coal consumption was about 4 billion tons, a 0.6% YoY increase. From 2015 to 2020, coal consumption dropped before going up, with the total amount at about 4 billion tons.

Figure 4.2-3 **China's Coal Consumption in 2015-2020**



(4) Import and Export

In 2020, China's coal import exceeded 200 million tons, a YoY increase of 3.5%, mainly from Indonesia, Australia, Russia and Mongolia.

2. Oil

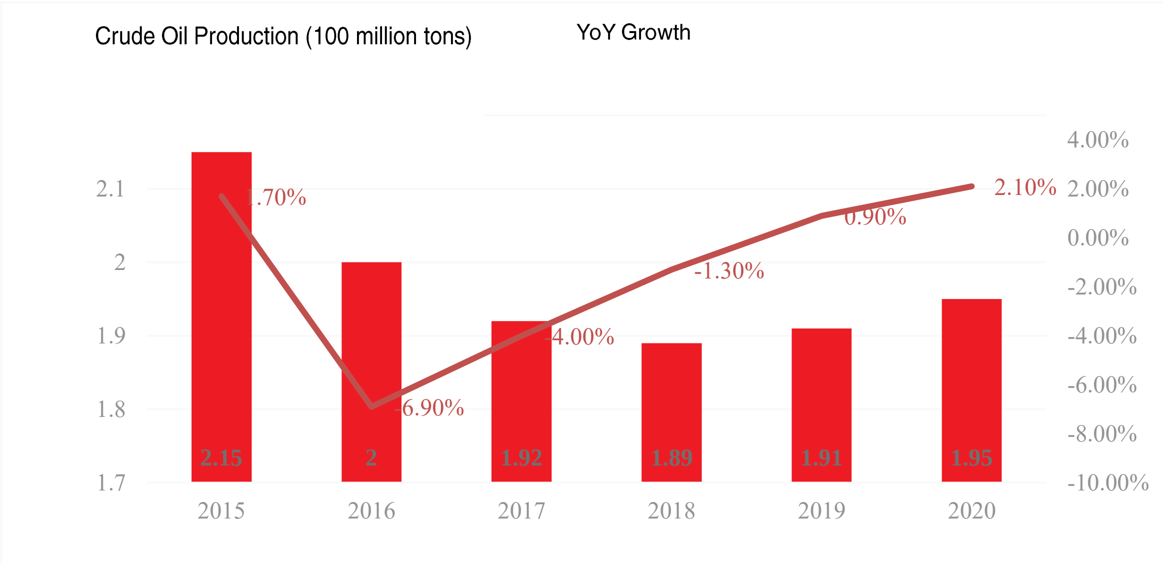
(1) Resource Endowment

In 2020, China's newly-proven geological reserves of oil exceeded 1.3 billion tons, a YoY increase of more than 17%. The cumulative proven reserves of oil were about 42.2 billion tons.

(2) Supply

In 2020, China's crude oil production was 195 million tons, a YoY increase of 1.6%. From 2015 to 2020, China's crude oil production showed a general trend of falling before rising. In 2015, the crude oil output registered 215 million tons. The year 2018 saw the lowest figure, 189 million tons. In 2019 and 2020, it rebounded slightly to 191 and 195 million tons respectively.

Figure 4.2-4 China's Crude Oil Production in 2015-2020

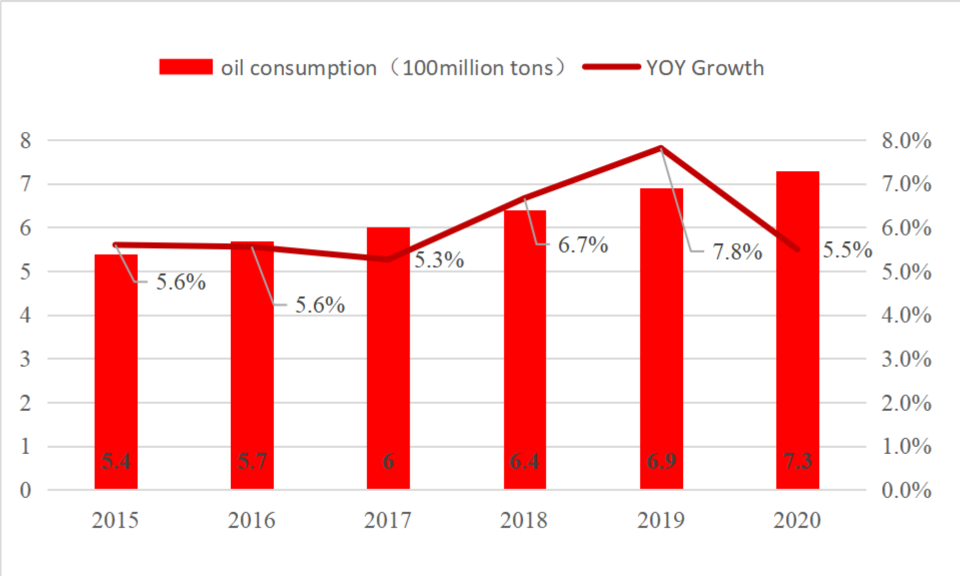


(3) Consumption

Related statistics indicate that the growth of China's oil consumption slowed down in 2020. The annual apparent oil consumption was about 730 million tons, a YoY increase of more than 5.5%.

From 2015 to 2020, oil consumption increased year by year, rising from 540 million tons in 2015 to 730 million tons in 2020, with an average annual growth rate of more than 5%.

Figure 4.2-5 **China's Oil Consumption in 2015-2020**



(4) Import and Export

Oil prices fell sharply in 2020. China was among the first to restart the economy and recover from the pandemic. It increased crude oil import, buying 540 million tons of foreign oil, a YoY increase of more than 7%. The largest sources of import were Saudi Arabia, Russia and Iraq.

3. Natural Gas

(1) Resource Endowment

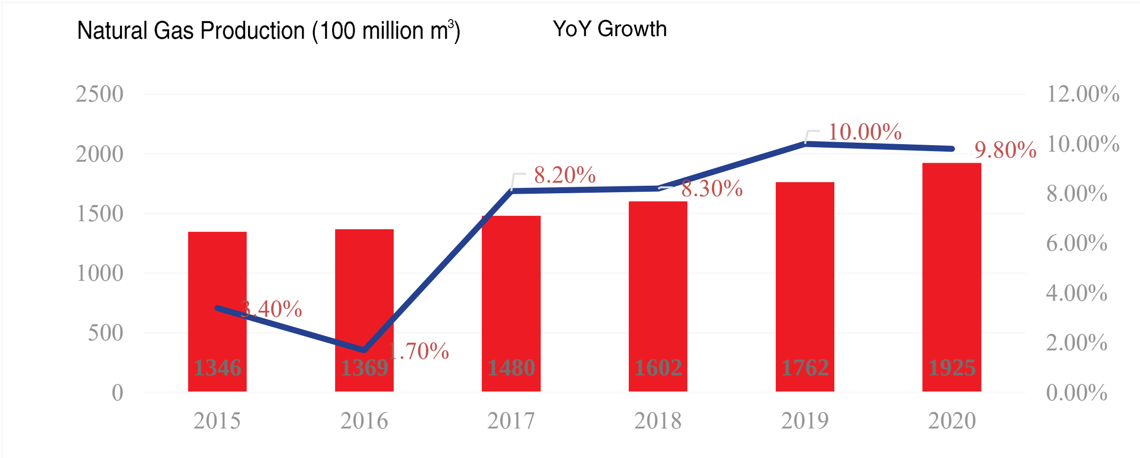
In 2020, China's newly-proven reserves of natural gas exceeded 1 trillion cubic meters, a YoY increase of 30.0%. The newly-proven reserves of shale gas hit about 1.98 billion cubic meters, and those of coalbed methane were about 67.3 billion cubic meters. The cumulative proven geological reserves of natural gas, shale gas and coalbed methane were about 16.9 trillion cubic meters, 2 trillion cubic meters and 700 billion cubic meters respectively.

(2) Supply

In 2020, China's natural gas output reached 192.5 billion cubic meters, a YoY increase of 9.8%. The output has increased by more than 10 billion cubic meters for four consecutive years.

From 2015 to 2020, China's conventional natural gas production increased steadily, with an average annual growth rate of over 7%.

Figure 4.2-6 China's Natural Gas Production from 2015 to 2020

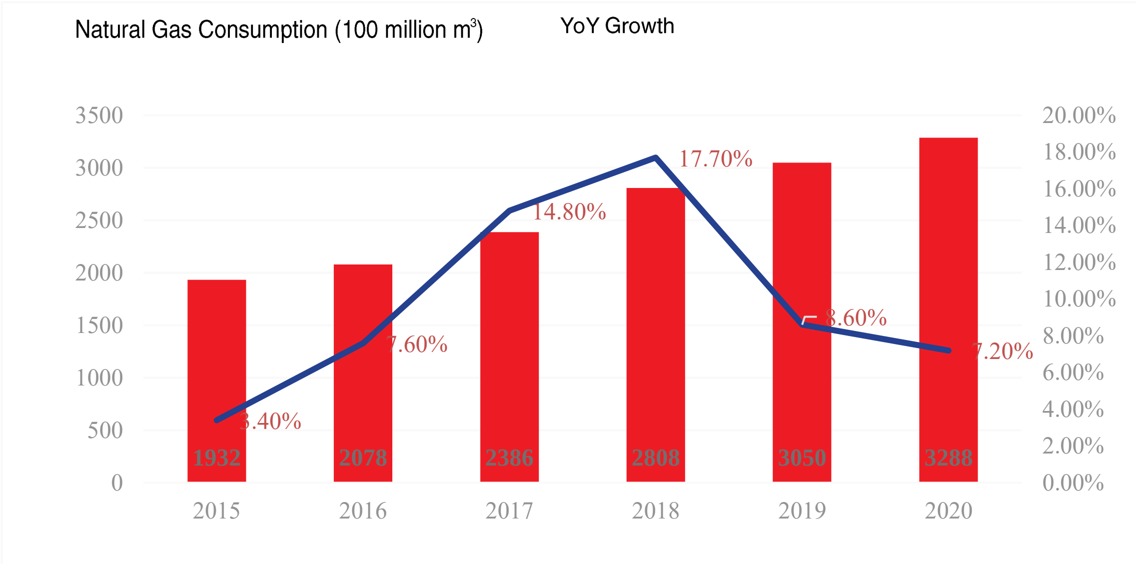


(3) Consumption

In 2020, China's natural gas consumption was about 328 billion cubic meters, a YoY increase of 7.2%, which was lower than in previous years. To break it down by users, the industrial sector and urban utilities users each accounted for more than 1/3 of the total consumption in 2020, while gas for power generation and the chemical industry jointly accounted for nearly 1/3. The industrial sector and urban utilities were the main drivers of the growth of natural gas consumption. The newly-added gas-powered vehicles in the transport sector were mainly commercial vehicles like LNG heavy-duty trucks.

Natural gas consumption increased year by year from 2015 to 2020, with the fastest growth in 2017 and 2018, exceeding 10%. Total natural gas consumption grew from 193.2 billion cubic meters in 2015 to 328 billion cubic meters in 2020.

Figure 4.2-7 China's Natural Gas Consumption in 2015-2020



(4) Import and Export

China is a major importer of natural gas. Related statistics indicate that China's natural gas imports in 2020 were about 135 billion cubic meters, a YoY increase of more than 5%. Yet the growth moderated by 1.2 percentage points from the previous year. Among them, the import of natural gas through pipeline was about 46 billion cubic meters, a YoY decrease of 6%. LNG import continued to grow, with an annual volume of 89 billion cubic meters, a YoY increase about 6%. China mainly imported natural gas from Australia, Turkmenistan, and Qatar, etc.

4. Electric Power

According to statistics from China Electricity Council (CEC), at the end of 2020, China's total installed power capacity was 2,200 GW, an increase of 190 GW compared with 2019. The installed capacity increased by 33% from 2016 to 2020, ranking first in the world. The total power generated in 2020 hit 7,623 TWh, a YoY increase of 4% and a 27% increase from 2016. Figures 8~9 indicate the growth of China's installed capacity and power generation from 2016 to 2020.

Figure 4.2-8 China's Installed Power Capacity in 2016-2020

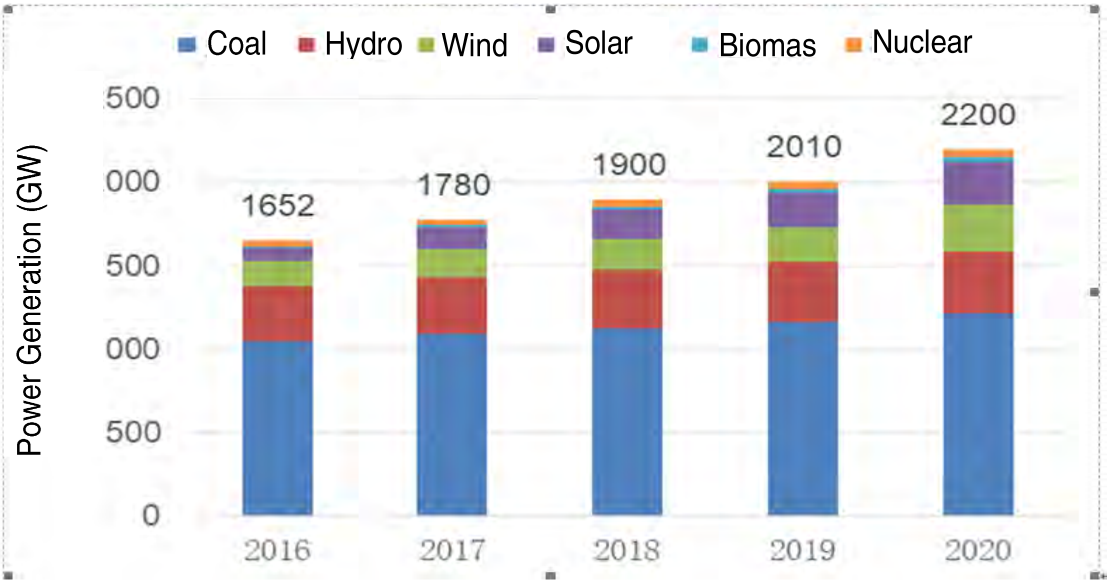
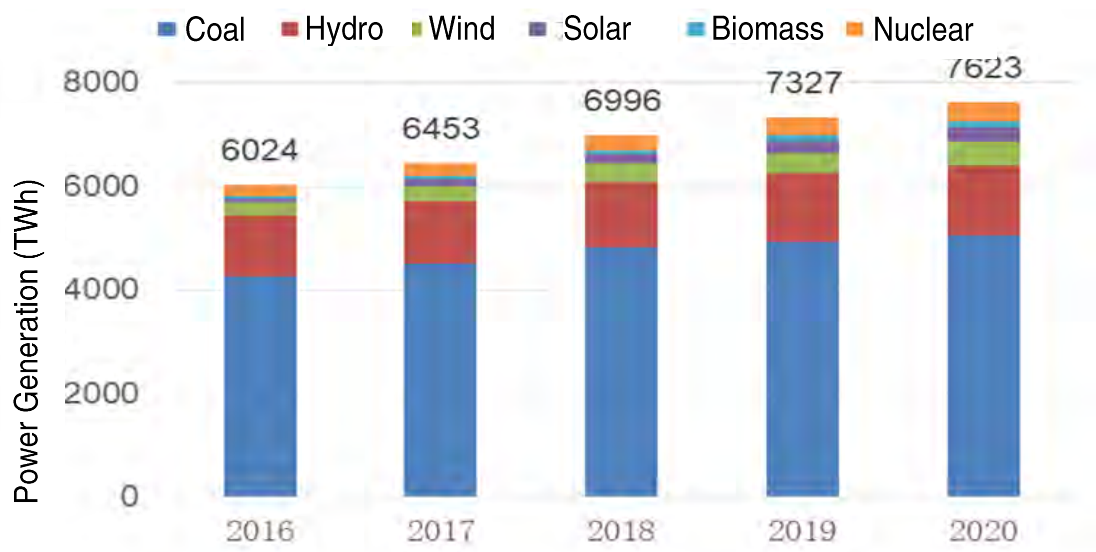


Figure 4.2-9 China's Power Generation Structure in 2016-2020

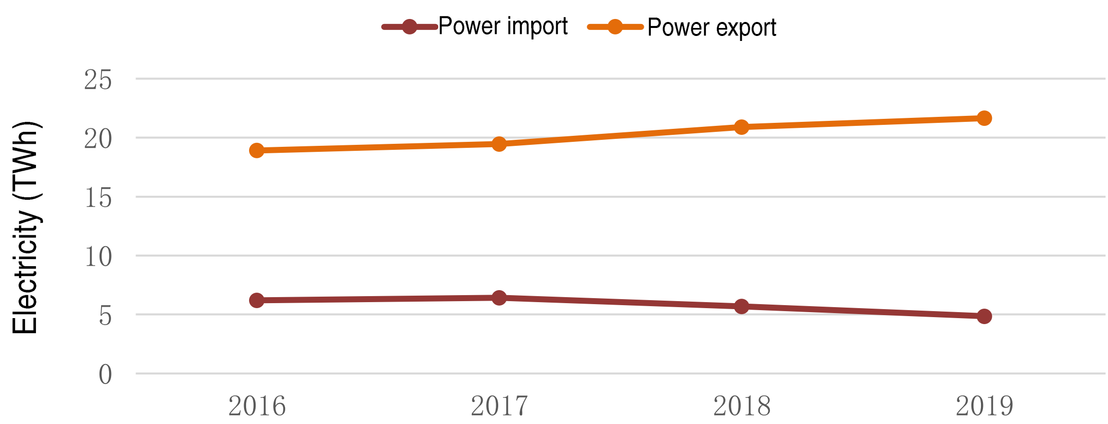


According to statistics from the CEC, at the end of 2020, China's installed coal power capacity was 1,080 GW, a YoY increase of 4%, accounting for 49% of the total installed capacity. Since 2016, the proportion of annual coal-fired power generation in China has gradually declined. In 2020, 4,632 TWh coal-fired power was generated, a YoY decrease of 2%. In recent years, China has launched a series of policies to promote the orderly development of coal-fired power generation. As coal remains its dominant energy source, China aims to build a modern and secure energy system on the premise of breaking away from coal after obtaining reliable alternatives and making strategic plans.

According to statistics from the CEC, at the end of 2020, China's total installed gas-fired power capacity was 98 GW, a YoY increase of 9%, accounting for 5% of China's total. In 2020, China's gas-fired power generation reached 248.5 billion kWh, a YoY increase of 5%, accounting for 3% of the total. Affected by factors such as gas source and price, the newly-commissioned projects in 2020 were still mainly concentrated in the developed regions of Southeast China.

In 2019, China imported 5 TWh of electric power and exported 22 TWh. In the past five years, the import and export of electric power has been stable on the whole, with a slight decrease in import and a slight increase in export. Russia, Mongolia, Myanmar, Vietnam, the Laos and other neighboring countries were China's main partners in electric power import and export.

Figure 4.2-10 China's Electric Power Import and Export in 2016-2019



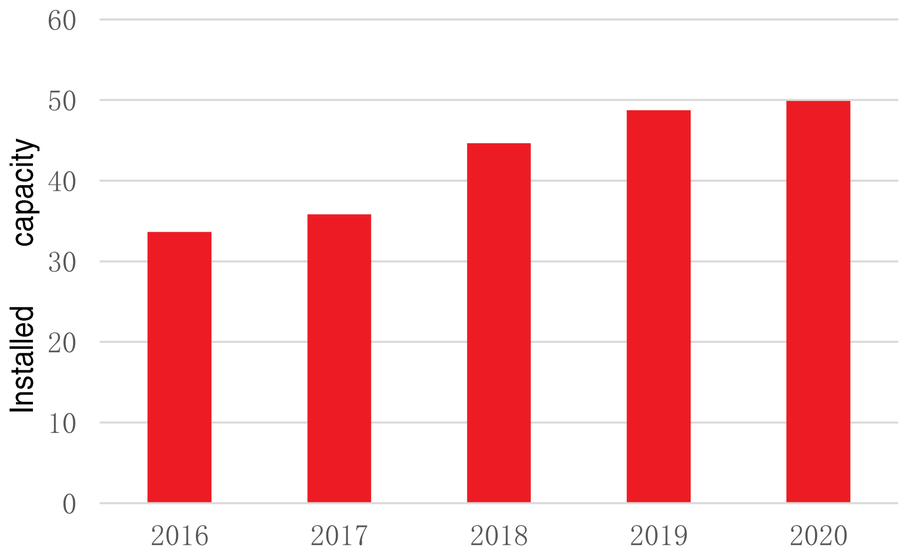
Guided by the strategic goals of carbon peaking and neutrality, China's electric power industry focused on transforming power sources, grids and consumption and building a new power system that can accommodate a bigger share of new energy on a larger scale. In 2020, the Chinese government issued a series of policies to promote the green and healthy development of the power sector. The *Notice on Matters Concerning the Construction of Wind Power and Photovoltaic Power Generation Projects in 2020*prioritizes affordable grid-connected wind power and photovoltaic projects. It is proposed in the *Guidance on Promoting the Integration of Power Sources, Grids, Load and Energy Storage and the Multi-energy Complementary Development* that measures such as "integration of wind power, solar energy, hydropower and energy storage" and "integration of power sources, grids, load, and energy storage" to comprehensively utilize various types of renewable energy, optimize the cleaner utilization of energy and improve the operational efficiency of the power sector.

In 2020, China made new progress in power technology innovation. The research and test platform for key technologies of supercritical carbon dioxide (S-CO2) high-efficiency thermal power generation units were built and the boiler hydraulic test was completed. The technology R&D, including hydrogen-added/pure hydrogen gas turbine and fuel cell power generation, entered a critical stage.

5. Nuclear Power

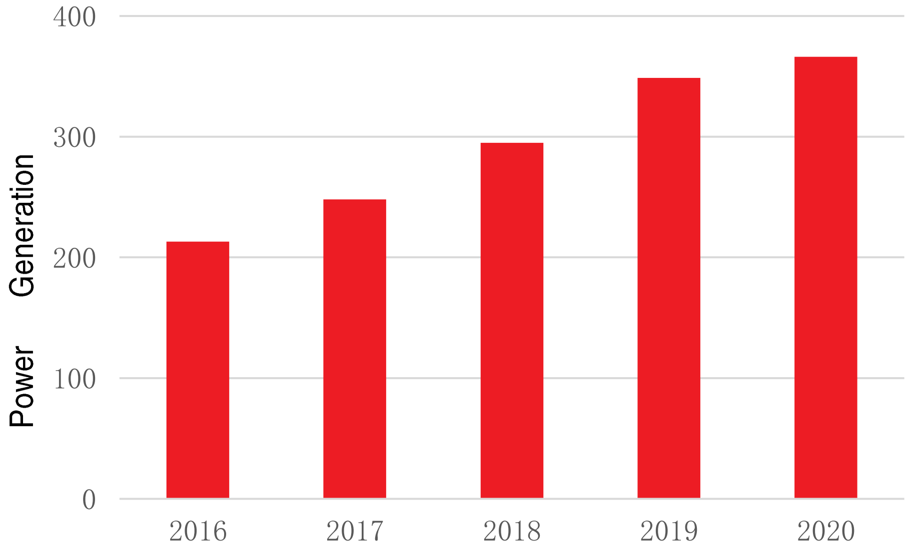
By the end of 2020, China had 48 nuclear power units in operation, with a total installed capacity of about 50 GW, accounting for 2.3% of the total and 5.2% of the installed non-fossil power capacity in China.

Figure 4.2-11 Changes in China's Installed Nuclear Power Capacity in 2016-2020



In 2020, China's nuclear power generation was 366 TWh, accounting for 5% of the total power generation and 15% of non-fossil power generation.

Figure 4.2-12 Changes in China's Nuclear Power Generation in 2016-2020



With the strategic goals of carbon peaking and neutrality, China has unleashed broad and systemic changes in economy and society. A clean, low-carbon, secure and efficient energy system is required to promote energy revolution and drive China's economic and social transformation and development. In the *Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy*, it is proposed to develop nuclear power in a safe and orderly manner. The *Action Plan for Carbon Dioxide Peaking Before 2030* also requires that the layout and development sequence of nuclear power plants be reasonable so that nuclear power can be exploited in an orderly manner and nuclear power plants can be built at a steady pace and in a safe way.

After more than 40 years of research, design, manufacturing, construction and operation, many breakthroughs have been made in China's nuclear power technology. Among them, the Hualong One is an important innovation of the third-generation pressurized water reactor technology with completely independent intellectual property. In November 2020, Unit 5 of Fuqing Nuclear Power Plant in Fujian, which was the world's first Hualong One reactor, was connected to the grid for the first time, setting a record for the shortest construction period for the first reactor of a third-generation nuclear power plant. In the same year, the first overseas Hualong One reactor, Unit 2 of Karachi Nuclear Power Plant in Pakistan, also completed its first fuel loading.

China always regards safety as the lifeline of nuclear power development, placing equal emphasis on safety and development. So far, the operation of nuclear power units on the Chinese mainland has been safe and stable with no operational incidents/accidents of level 2 or above according to the International Nuclear and Radiological Event Scale, and no adverse impact on the public or the environment. Meanwhile, China has been performing well in nuclear power operation, and the total number of annual operational incidents has been decreasing year by year, from 1.76 per reactor in 2013 to 0.39 per reactor in 2020. According to statistics of 12 indicators from the World Association for Nuclear Operators (WANO), 70% of China's nuclear power operation indicators have reached to the advanced level, and are moving upward on the scale.

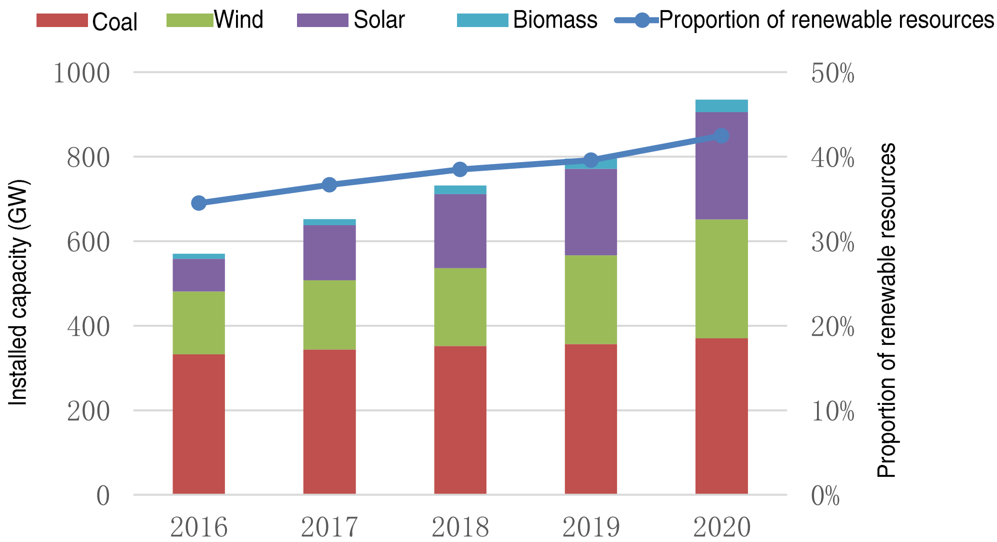
6. Renewable Energy

China has a vast territory and is rich in renewable energy resources. Hydro resources that are technically recoverable in China hits 687 GW, with a power generation potential of about 300 TWh, ranking first in the world. In terms of wind power, the onshore and offshore wind resources in China that are technically recoverable are more than 10 TW, mainly in the southeast coast and nearby islands, northeast, north, and northwest. In terms of solar energy, China's annual total solar irradiance on the horizontal land surface averages about 5,360 MJ/m^2. From northwest to southwest, the solar irradiance first increases, then decreases and then increases again. Taking into account factors such as regional distribution of solar resources, topography, technological development level and land conditions, China's photovoltaic (PV) power generation potential is 100-130 TW. In addition, China is rich in biomass resources, which mainly include agricultural waste, forestry waste, livestock and poultry manure, municipal solid waste, organic wastewater and waste residue. The total amount of biomass resources that can be used as energy every year is about 500 million TCE.

With outstanding renewable energy resource endowment and a number of key technological breakthroughs in nearly two decades, China's industrial chain has become mature and policies and systems have been gradually improved, laying a solid foundation for the development of renewable energy.

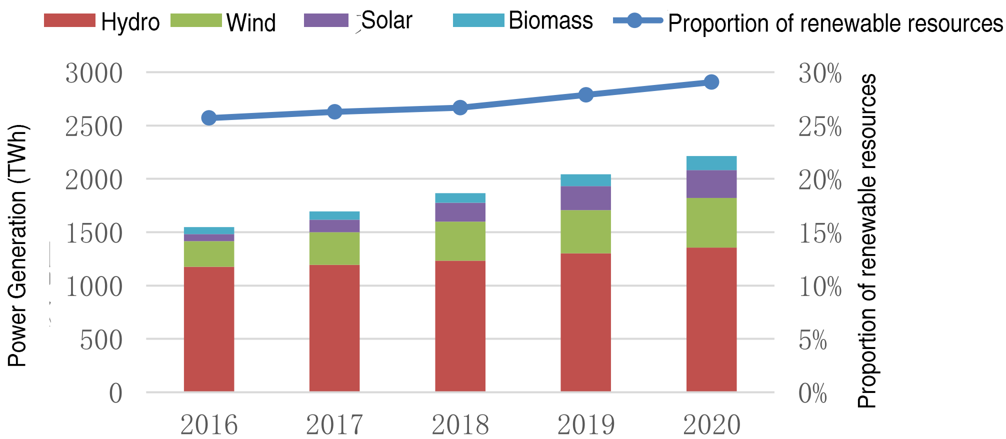
At the end of 2020, China's installed capacity of renewable energy was 934 GW, accounting for 43% of the total installed capacity, an increase of 8% from 2016. Specifically, the installed capacity of hydropower was 370 GW, those of wind power and solar energy were 281 GW and 253 GW respectively, and that of biomass was 30 GW. At the end of 2020, the cumulative installed capacity of renewable energy in China accounted for about one-third of the world's total. What's more, its newly installed capacities of wind power and solar PV accounted for more than half of the world's total.

Figure 4.2-13 The Installed Capacity and Proportion of Renewable Energy in China in 2016-2020



In terms of power generation, China's renewable energy power generation reached 2,215 TWh in 2020, accounting for 29% of its total power generation. And the proportion of renewable energy in the total power generation has been increasing year by year. Specifically, hydropower generation reached 1,355 TWh, accounting for 61% of the total of renewable energy. Wind power and solar power were 467 TWh and 261 TWh respectively, and biomass 133 TWh.

Figure 4.2-14 The Power Generation and Proportion of Renewable Energy in China in 2016-2020



At present, China's hydrogen industry is in the early stage of commercialization. China attaches great importance to the hydrogen industry and local governments have stepped up planning and investment. With gradual improvement in its industrial chain, the hydrogen sector has seen its upstream, mid-stream and downstream industrial clusters take shape.

Significant progress has been made in hydrogen energy and fuel cell related technologies and basic research, but there is room for improvement in key materials and core components. In 2020, China's hydrogen production capacity was about 25 million tons, a YoY increase of 9%. Hydrogen production from renewable energy has kept expanding.

In September 2020, China set the goal of peaking carbon dioxide emissions by 2030 and achieving carbon neutrality by 2060. By 2030, the proportion of non-fossil energy in primary energy consumption will reach around 25% and the total installed capacity of wind power and solar energy will exceed 1.2 billion kW. Guided by the goals of carbon peaking and neutrality, China will scale up the development of renewable energy with a higher proportion in the energy mix and through a market-based approach, promoting both large-scale development and high-level consumption while ensuring the stable and reliable supply of electricity. Renewable energy will be the priority in China's energy production and consumption revolution, playing a leading role in the clean and low-carbon energy transition and providing strong support for carbon peaking and neutrality.

China lays stress on enhancing the capabilities in renewable energy technology innovation and technical equipment self-reliance. In terms of hydropower, China boasts mature and internationally advanced technologies in the design and manufacturing of conventional hydropower units and energy storage units and in supporting equipment manufacturing and hydraulic metal structure equipment. In terms of wind power, the key components have been basically localized and China can manufacture a series of standardized and type spectrum-based wind turbine equipment. A number of technical routes for wind turbines have been formed to adapt to different environments. And technologies regarding low wind speed, high altitude, and typhoon resistance have reached the world-class level. Domestic wind turbines account for 90% of the installed capacity of wind power in China. With regard to solar PV, China has witnessed significant improvement in PV cell technology innovation. PERC, TopCon and heterojunction cells have set world records for cell conversion efficiency. Besides, the PV production line equipment is basically localized. For biomass, the domestic technology of biomass power generation boilers is mature with continuous improvement in efficiency. In addition, the upgrading of key technologies of bio-natural gas has sped up. The domestic biomass boiler boasts obvious advantages in multi-variety straw co-combustion. As it is highly adaptable to fuels, it is helpful for biomass power plants to expand their fuel sources and increase economic efficiency. For hydrogen, in 2020, domestic basic research on hydrogen approached the world's advanced level and the hydrogen production from renewable energy has entered the demonstration stage.

Preliminary progress was made in hydrogen storage technology, with active efforts being made in the follow-up research and development of low-temperature liquid hydrogen storage and transportation. In addition, the solid hydrogen storage technology has great potential for development. China has basically mastered the technologies regarding stacks and key materials, power systems and core components, and vehicle integration, and stepped up efforts in promoting self-reliance and localization of fuel cell core materials and key components.

7. Energy Efficiency

Since 2015, China's energy consumption per unit of GDP has been declining, with substantial progress in energy conservation of all sectors. The quality and efficiency of economic and social development have been on a steady rise.

In industry, China has strengthened the energy conservation and environmental protection sectors, and promoted the green and low-carbon transformation of key sectors. The energy efficiency of major high energy consumption products keeps growing, and the energy consumption per value-added of industrial enterprises above the designated size has dropped. In construction, great efforts have been made to develop green buildings and promote energy-saving renovation of existing buildings. For new residential buildings in severely cold and cold regions, the 75% energy-saving design standard has been fully implemented. Energy-saving buildings account for 63% in China and it has outperformed the target of constructing green buildings that account for 50% of newly constructed urban buildings. In transport, efforts are made to adjust the transport structure, with priority given to green and low-carbon vehicles. The development of efficient transport such as railways and water transport is accelerated. With the continuous advancement of urban public transit systems, the proportion of urban green commuting keeps rising and the efficiency of vehicles keeps growing. For public utilities, key energy-consuming public utilities are under intensified regulation, a campaign has been launched for building demonstration institutions. With the efforts to carry out energy-saving transformation of key public institutions, China has seen the energy consumption per unit floor area down by 10.07% and the per capita overall energy consumption down by 11.11%.

In order to improve the laws and regulations on energy conservation, the Chinese government promulgated the *Energy Conservation Law* and formulated a series of supporting regulations and rules on key energy consumers, energy conservation supervision, and energy efficiency labeling, and improved and implemented fiscal, tax, price and financial policies for energy conservation. China also created and enhanced energy-saving market-based mechanisms for energy rights trading and energy performance contracting (EPC). Meanwhile, the Chinese government has enhance dual control on total energy consumption and energy intensity, and has issued the *Comprehensive Work Plan for Energy Conservation and Emission Reduction*, in which overall arrangements for energy conservation and emission reduction are made.

Next, China will continue to vigorously promote energy conservation and improve energy efficiency, better implement dual-control, uplift energy utilization efficiency, speed up green and low-carbon economic and social transition, and continuously enhance the quality and benefits of economic and social development, laying the groundwork for peaking carbon dioxide emissions and achieving carbon neutrality.

III. SUSTAINABLE ENERGY DEVELOPMENT

1. Energy Access

Achievements in Energy Access

As the largest developing country, China is committed to improving energy access based on the people-centered development philosophy. Through continuous efforts, China made electricity accessible for 1.3 billion people in 2015, successfully solving the problem of no-electricity. In 2020, electricity was available for every village in China, which can not only meet villagers' electric demand in basic life activities but also in production. After making electricity accessible for people, China delivered its efforts to alleviate poverty through energy popularization. It has implemented nationwide poverty alleviation projects based on PV power generation and established photovoltaic power stations with an installed capacity of 26.36GW benefiting nearly 100,000 villages and 4.15 million poor households.

Concrete Actions to Achieve Energy Access

China is committed to solving the problem of no-electricity. By the end of 2012, there were still 2.73 million people not accessible to electricity, most of whom lived in remote ethnic minority areas in Xinjiang, Tibet, Sichuan, Qinghai and other provinces and regions. In 2013, the National Energy Administration formulated the Three-Year Action Plan for Bring Electricity to People without Electricity (2013-2015), which put forward the goal of ensuring 2.73 million people access to electricity and stated technical roadmaps, tasks and measures. As of 2014, additional 2.5 million people have been accessible to electricity, and people in Tibet, Xinjiang, Inner-Mongolia and Gansu provinces have achieved full access to electricity, with 237,800 people living in Sichuan and Qinghai failing to access electricity. The 2015 Government Work Report pointed out that we should redouble our efforts to bring electricity to the rest 200,000 people. As of June 2015, people in Sichuan Province were provided access to electricity, with only 39,800 people living in Qinghai without electricity. By taking many measures, the rest 39,800 people in Qinghai Province were successfully available for electricity in December 2015. China has achieved its goal of 100% access to electricity in 2015.

Table 4.3-1 Population without Electricity

Time	Population without electricity (10,000)	Distribution of the population without electricity
As of the end of 2012	273	Remote ethnic minority areas in Xinjiang, Tibet, Sichuan, Qinghai and other provinces and regions
As of the end of 2014	23.78	Sichuan and Qinghai
As of June 2015	3.98	Qinghai
December 2015	0	-

From 2013 to 2015, China invested 24.78 billion yuan, of which 14.55 billion yuan was from the central government, in implementing grid extension in areas without electricity and establishing renewable energy power generation projects. Among them, 20.68 billion yuan was provided for the power grid plan, which brought electricity to 1.545 million people; 4.1 billion yuan was invested in the development of photovoltaic independent power generation projects. As a result, over 670 photovoltaic independent power stations and more than 350,000 sets of photovoltaic household systems were built, making electricity accessible for 1.185 million people.

Successful Experience

China's achievements in energy access are the result of three measures. Firstly, an integrated mechanism in which central and local governments cooperated with each other was established. Through formulating practical and effective energy development plans in phases, China clarified implementation entities and supportive measure in energy access projects; secondly, some categorized measures which accord with local conditions were formulated. Based on different economic and demographic characteristics of the eastern and western regions, China adopted many ways including grid extension, countryside power grid upgrading and distributed renewable energy power generation; thirdly, a cooperative model between governmental and social funds was established. Energy enterprises took it as their social responsibility to solve the problem of no-electricity.

2. Green and Low-Carbon Transformation

Commitments and Goals for A Green and Low-Carbon Transition

On September 22, 2020, President Xi Jinping promised at the General Debate of the 75th Session of the United Nations General Assembly that China will scale up its Nationally Determined Contributions and adopt more vigorous policies and measures to achieve CO^2 emissions peaking by 2030 and carbon neutrality by 2060.

On December 12, 2020, President Xi Jinping further put forward at the Climate Ambition Summit that China's carbon dioxide emissions per unit of GDP will be reduced by over 65% compared with 2005; the proportion of non-fossil energy in primary energy consumption will stand around 25%; the forest stock will increase by 6 billion cubic meters compared with 2005; the total installed wind and solar energy capacity will reach more than 1200 GW.

On April 22, 2021, President Xi Jinping pointed out at the Leaders' Summit on Climate that the time China used to achieve carbon emissions peaking and carbon neutrality is far shorter than that of developed countries, which means China should make more efforts. By incorporating carbon emissions peaking and carbon neutrality into the overall layout of ecological civilization development, China now is formulating a carbon peaking action plan, profoundly carrying out carbon emissions peaking action plans and supporting qualified regions, key industries and key enterprises to take the lead in reaching the peak. China will strictly manage coal-powered electricity generation projects, limit the increase in coal consumption over the 14th Five-Year Plan period and phase it down in the 15th Five-Year Plan period.

On September 21, 2021, President Xi Jinping promised at the General Debate of the 76th Session of the United Nations General Assembly that China will strive to achieve carbon emissions peaking by 2030 and carbon neutrality by 2060. It will strongly support the green and low-carbon development of energy in developing countries and no longer carry out new overseas coal power projects.

A Roadmap for Green and Low-Carbon Transition

The Action Plan for Reaching Carbon Dioxide Peak Before 2030 issued in 2021 pointed out that the green and low-carbon transformation of energy should be committed to the principle of reducing carbon emission in a safe manner. Under the premise of ensuring energy security, China will implement alternative renewable energy plans so as to accelerate the establishment of a clean, low-carbon, safe and efficient energy system. The key tasks are as follows:

(1) Promote the coal substitution and upgrading. China will pick up the pace in cutting coal consumption, strictly and rationally limit the increase in coal consumption over the 14th Five-Year Plan period and phase it down in the 15th Five-Year Plan period.

(2) Vigorously develop new energy resources. China will spur the large-scale, high-quality development of wind and solar power generation across the board, continue to promote both concentrated and distributed systems to establish wind and photovoltaic power generation bases. By 2030, total installed capacity of wind and solar power will reach above 1200 GW.

(3) Develop hydropower according to local conditions. China will actively advance the construction of hydropower bases. This includes pushing for work to begin on the construction of hydropower projects that have already been incorporated into the plan and meet environmental protection requirements, pushing the development of hydropower on the lower Yarlung Zangpo River, and promoting the green development of small hydropower plants. Approximately 40 GW of additional hydropower capacity will be installed during both the 14th and 15th Five-Year Plan periods, respectively, while a renewable energy system based largely on hydropower will be generally established in southwestern China.

(4) Actively develop nuclear power through a safe and orderly approach. China will set a reasonable layout and timetable for the construction of nuclear power stations, and maintain a steady pace of construction. We will develop nuclear power in an orderly manner under the premise of ensuring safety and maintain a steady pace of construction.

(5) Rationally regulate oil and gas consumption. China will keep oil consumption within a reasonable range, gradually adjust the scale of gasoline consumption, vigorously promote alternatives like advanced liquid biofuels and sustainable aviation fuel in substitution for traditional fuel oils, and make end-user fueled by oil more efficient.

(6) Speed up the development of the new electric power system. China will build

a new electric power system that the share of new energy resources keep increasing, and work toward an optimized distribution of clean electricity generation on a broad scale. By 2025, installed capacity of new types of energy storage will reach 30 GW or more. By 2030, installed pumped-storage hydropower capacity will reach approximately 120 GW, and provincial-level power grids will be equipped with peak load response capacity of 5% or more.

3. Energy Security

The General Situation of Energy Security

At present, it remains a difficult task to ensure energy security in China. After years of development, a diversified energy supply infrastructure consisting of coal, oil, natural gas, electricity, nuclear energy, new energy, and renewable energy is in place, which has effectively ensured economic and social development and people's demand for energy. Meanwhile, however, China is troubled by a combination of old and new risks to energy security where regional and temporal energy supply and demand tensions occur now and then and non-traditional security risks such as network security are becoming increasingly prominent. This being the case, it is particularly important to do better in ensuring energy security.

Measures To Be Taken for Energy Security

To enhance the capacity of ensuring energy security in all aspects, we should focus on strengthening the building of “Two Capacities and One System” to improve the stability and security of the energy supply chain. We should enhance the capacity of strategic energy security. Multiple measures need to be taken to enhance the capacity of oil and gas supply security, such as expanding domestic oil and gas exploration, enhancing reserve capacity, and strengthening international cooperation in energy, etc. We will improve capacity for the smooth operation of the energy system, allowing coal and coal-fired power generation to play a critical role in safeguarding the bottom line of security and resolving regional and temporal conflicts between energy supply and demand. We will build a sound risk control system for energy security by strengthening power security in mega-cities, core areas, and among important users, laying out a number of strong local power grids, and preventing and resolving non-traditional security risks.

How to Coordinate Energy Security and Low-Carbon Transition

As the clean and low-carbon energy transition advances, China will gradually get rid of its dependence on fossil fuels. However, in this process, some regions are also facing the challenge that the supply of electricity and coal is not able to meet the demand at times. Meanwhile, large-scale development of new energy will put pressure on the safe and stable operation of the power system. Therefore, the gradual withdrawal of traditional energy sources is based on the safe and reliable substitution of new energy sources.

In the context of an increasingly complex landscape of energy security, how can China accelerate its clean and low-carbon transition while safeguarding energy security. The answers are as follows: Making good use of China's energy resource endowment, we need to consolidate the foundation of domestic energy production, ensure the security of coal supply, and maintain the stable growth of crude oil and natural gas production capacity; we should strengthen the gas and oil reserve capacity, and promote the large-scale application of advanced energy storage technology, particularly taking the basic national reality that coal still accounts for a lion's share of the energy mix into account. The focus is on the clean and efficient use of coal with close attention paid to R&D on green and low-carbon technologies.

We should put the promotion of new and clean energy development higher on the agenda while actively and orderly developing light energy, silicon energy, hydrogen energy, and renewable energy; we should increase the capacity of accommodating power generated from renewable energy, promote the optimal combination of coal and new energy, and increase our efforts to plan and build a new energy supply and accommodation system that is based on large scenic power bases, supported by clean, efficient and advanced energy-saving coal power in their vicinity, and with stable and safe ultra-high voltage transmission and substation lines as carriers.

We should promote the deep integration of energy technology with modern information, new materials, and advanced manufacturing technology, and explore new modes of energy production and consumption; we should coordinate hydropower development and ecological protection, and actively develop nuclear power in a safe and orderly manner.

[V]

SOUTH AFRICA

I. OVERVIEW OF ENERGY DEVELOPMENT

ENERGY SUPPLY

The South African energy supply is dominated by coal which made up 65% of the primary energy supply in 2018, followed by crude oil with 18% and renewables with 11%. Natural gas contributed 3% while nuclear contributed 2% to the total primary supply during the same period. The primary energy supply in this case includes indigenous production and imported sources less exported quantities.

ENERGY DEMAND

Energy is the lifeblood of the South African economy and is an important sector of the economy that creates jobs and value by extracting, transforming and distributing energy goods and services throughout the economy. The five sectors identified in this report are industrial (51%), transport (26%), agriculture (2%), residential (7%), commerce and public services (11%) and non-specified (3%). The sector “non-specified” refers to unaccounted energy (energy that has not been classified into a specific sector).

INDUSTRIAL SECTOR

Chemical and petrochemical at 28% followed by iron and steel at 13% and mining and quarrying at 10%, respectively, are the largest consumers of energy in the industrial sector. Non-ferrous metals account for 7% while non-metallic minerals account for 3%. The remaining sub-sectors had minor energy consumption of 1% or less. The industrial sector consumed 51% of the final energy supplied in 2018.

COMMERCE AND PUBLIC SERVICES SECTOR

The commercial sector comprises of financial services, information technology, retail, tourism and services industry. Public services sector comprises of government and quasi government institutions which provides goods and services to the public, mainly for free. The total energy used by this sector is approximately 391 822TJ. The sector consumed electricity at 34% of the total energy consumed in the sector while petroleum products accounted for 63% and coal's contribution accounted for 3%.

AGRICULTURAL SECTOR

The agricultural sector consumed 47 920TJ of liquid fuels which amounted to 68% of the energy consumed in the sector in 2018. This is as a result of transportation of agricultural raw materials, feeds, intermediary and finished products from farms to various market areas. Electricity accounted for 31% of energy demanded in the same year amounting to 21 485TJ in consumption.

TRANSPORT SECTOR

As the largest user of liquid fuels, the transport sector consumed 726 306TJ in 2018. Most of the liquid fuels (78%) were used on the road followed by international civil aviation and domestic air transport both consuming 10%. The transport sector accounted for 63% of the total petroleum products consumed in the country.

RESIDENTIAL SECTOR

The residential sector accounted for 7% of the total energy consumption in 2018. The consumption of electricity amounted to 76% of the total energy consumed in the sector. Renewables accounted for 12% while geothermal and coal accounted for 7% and 5%, respectively. In total the sector consumed 230 064TJ of energy.

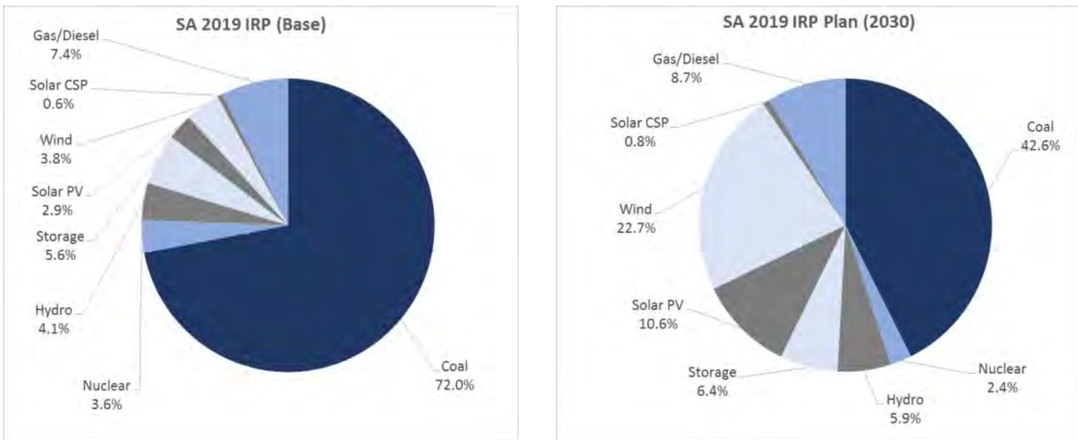
II. ENERGY SECTOR

IRP2019 ENERGY MIX

Overall generation capacity in 2019 is 51,605 MW and in 2030 it grows to 78,284 MW. Coals contribution reduces by 29%, with a concomitant increase in renewable power, which includes hydro, storage, solar PV, concentrated solar and wind power.

Since the publication of the IRP 2019, SA government has decided to extend the use of the Koeberg nuclear power station and additional IPP determinations have been mooted for inclusion in the IPP programme. The country also supplies several international customers, including electricity utilities in the Southern African Development Community (SADC) region.

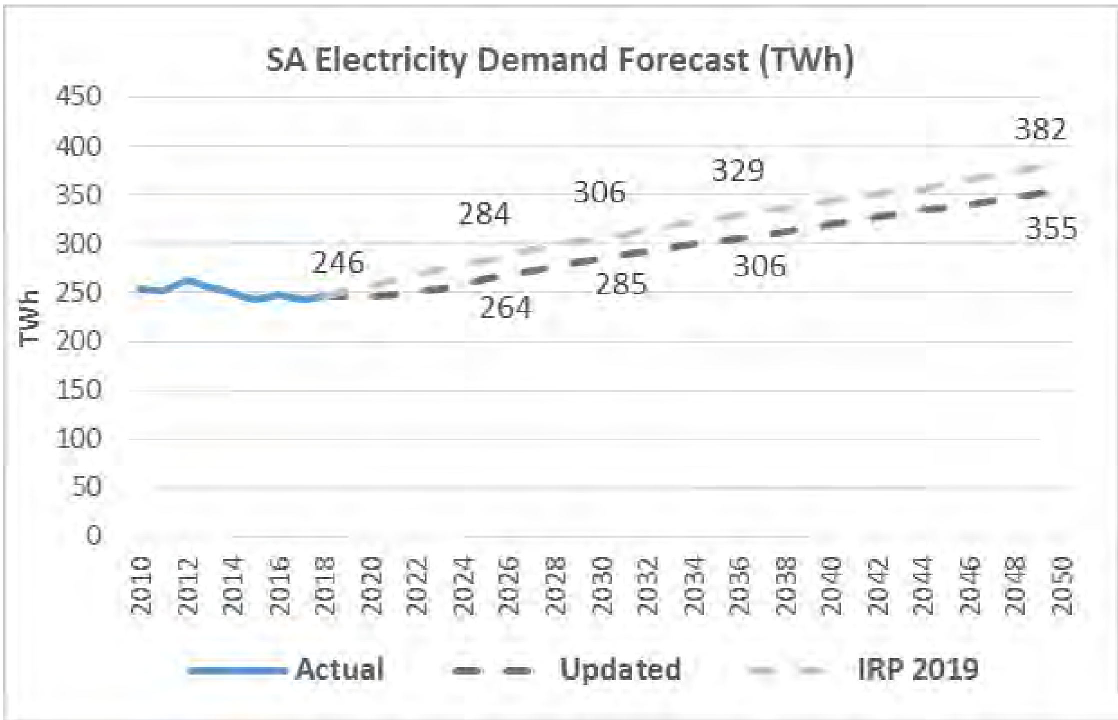
Figure5.1-1 **SA Current (base) and Planned Energy Mix as per IRP2019 (2030)**



Electricity Demand Forecast

CSIR developed a SA electricity demand forecast up to 2050. Demand shows a compound annual growth (CAGR) of 1.15% rising to 355 TWh in 2050. The updated forecast shows energy demand of approximately 7% to 8 % less than the 2019 IRP baseline.

Figure 5.1-2 **SA Electricity Demand Forecast (CSIR)**



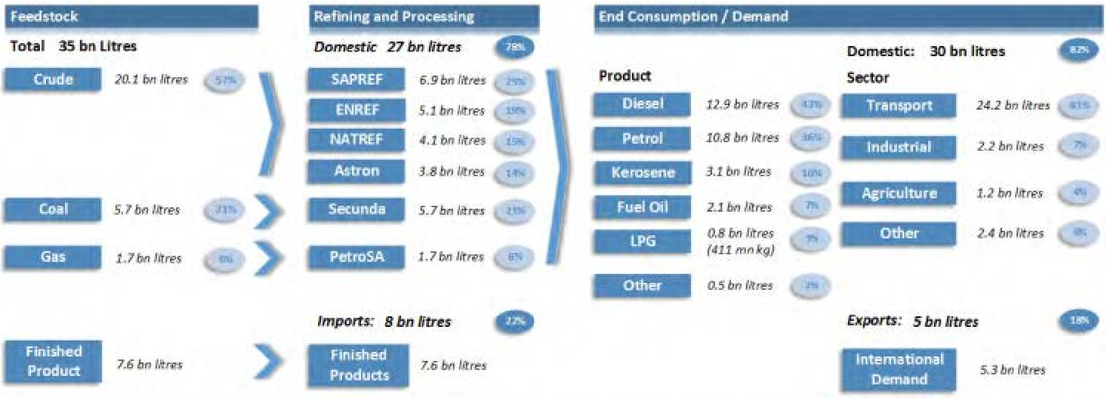
Source: CSIR

Petroleum Products Supply and Demand

Owing to the lack of reserves, the country imports almost 90% of its crude oil from Saudi Arabia, Nigeria and Angola. During the transformation stage, the country produced approximately 3.2% of its fuel requirements from gas (GTL), 42.3% from coal (CTL), and 54.4% from crude oil (DoE, Energy Balance 2018). Majority of petroleum products are refined in the country, however, some petroleum products are imported to supplement the production shortfall.

South Africa imported approximately 7.6 billion litres of liquid fuels in 2019, while the balance of the local and regional demand was produced by South Africa crude oil refineries (20.1 billion litres crude oil) and from coal and gas at Sasol's synthetic fuels plant. The transport sector consumes the bulk of liquid fuel products.

Figure 5.1-3 Oil Industry Supply and Demand 2019



Source: SAPIA

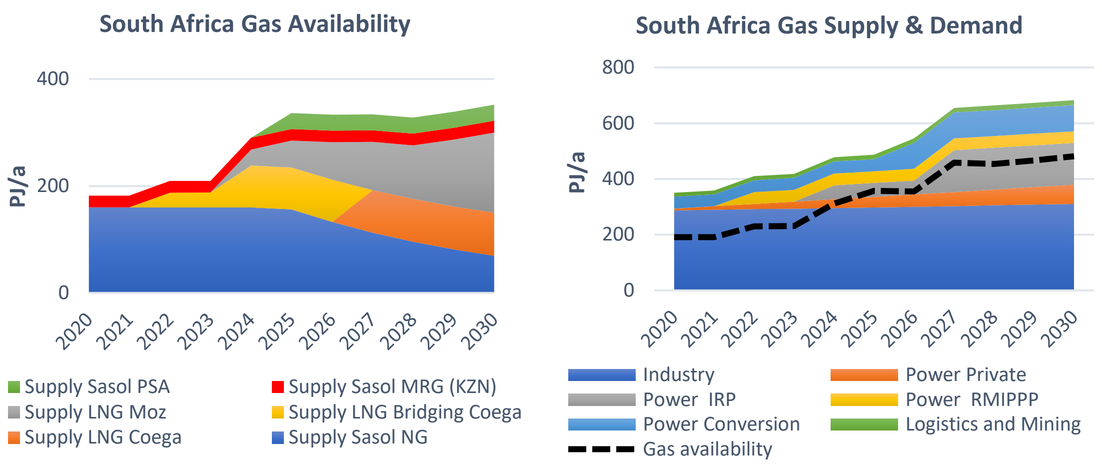
South Africa has the second largest refining capacity in Africa amounting to 718 000 barrels per day following Egypt. There are six refineries in the country; four of the refineries are on the coast and two are inland. Two of the refineries are synthetic fuels production facilities that produce liquid fuels from coal and gas, which are owned by Sasol and PetroSA respectively. Sasol uses both the Coal-To-Liquids (CTL) and Gas-To-Liquids (GTL) technologies. The Petroleum Oil and Gas Corporation of South Africa (PetroSA) produce synthetic products using GTL technology. Major refineries include Sapref and Enref in Durban, Chevron in Cape Town, and Natref at Sasolburg.

SA Natural Gas Supply and Demand

Currently natural gas is imported into South Africa by Sasol Gas via a 865 km pipeline from the Temane and Pande gas fields in Mozambique. Reserves in the Temane and Pande are estimated around 2.6 trillion cubic feet (TCF). The pipeline has a capacity of 240 million gigajoules (GJ) per annum. Approximately 120 million GJ is used annually by Sasol in the GTL and chemicals plant in Secunda, while the balance is distributed to commercial and industrial customers via a pipeline network covering more than 2 000km in the Free State, Gauteng, Mpumalanga and KwaZulu-Natal. In 2018, natural gas made up 3% of the total primary energy supply in South Africa. Natural gas domestic production amounted to 12% in 2018 whilst imports amounted to 88% during the same period.

The figures below depict the Industrial Gas Users Association of Southern Africa's (IGUA-SA) view on gas supply and demand until 2030. There is a significant gap between the supply of gas and the demand resulting in a market shortfall. The IGUA-SA estimated the total demand for 2020 (including latent demand) to be 350 PJ p.a. whilst supply was limited to 191 PJ p.a

Figure5.1-4 SA Gas Supply and Demand



Source: IGUA-SA

[VI]

PROSPECTS FOR BRICS ENERGY COOPERATION

The year 2022 is bound to be eventful. The COVID-19 pandemic is still continuing. Countries around the world are faced with challenges in economic recovery and hindrances in global mobility. Soaring energy prices have led to higher global inflation and an energy crisis is imminent. In the face of multiple challenges, BRICS cooperation will serve as a powerful force driving global economic recovery and sustainable development. Amid the complexities and challenges, BRICS has always been committed to building consensus and promoting development. BRICS should join hands and take measures to ensure the energy security of the BRICS and facilitate economic recovery.

After years of development, the BRICS mechanism has become an important platform for the five countries to strengthen cooperation for mutual benefits. This year, under the theme "foster high-quality partnership, usher in a new era for global development", BRICS members will make efforts to enhance a deeper, substantial and sustained BRICS energy cooperation.

To carry forward the sound tradition of BRICS energy cooperation, make full use of the BRICS Energy Research Cooperation Platform (ERCP), explore the way forward for future BRICS energy cooperation, we have made a detailed review of energy cooperation among the BRICS members in the past. When Russia held the rotating presidency of the BRICS in 2020, the "Road Map for BRICS Energy Cooperation up to 2025" was adopted. We all agree to update the items of the roadmap during the successive years and support stronger cooperation among member countries along the roadmap, particularly direct contacts using the energy research directory, experience sharing and technological exchange among energy think tanks, research centers and relevant institutions so as to promote research and cooperation in renewable energy trade, investment, technology, industry and supply chain and advance the interests of BRICS members under the umbrella of the BRICS ERCP.